

Carbohydrate Counting vs. Sliding Scale for Insulin Dosage Estimation

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A B S T R A C T

OBJECTIVE

To determine if there is a difference in outcome in patients with type 1 diabetes who use different methods to estimate insulin dosage: sliding scale or carbohydrate counting.

METHODS

This study assessed patients who initiated continuous subcutaneous insulin infusion (CSII) and used either sliding scale (n=81) or carbohydrate counting (n=44) methodology to determine bolus insulin dosages. Groups were compared in terms of glycosylated hemoglobin (A1C), weight, frequency of hypoglycemia and insulin requirement at CSII initiation and follow-up. Within-person changes in a subgroup that started out using the sliding scale method and then crossed over to carbohydrate counting (n=21) were also evaluated.

RESULTS

At baseline, only A1C differed significantly ($p < 0.05$), with the sliding scale group having a higher A1C. At follow-up, the sliding scale and carbohydrate counting groups did not differ significantly in any parameter. No significant changes in A1C, weight, frequency of hypoglycemia or insulin requirement were observed in patients switching from the sliding scale method to carbohydrate counting.

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R É S U M É

OBJECTIF

Déterminer si le résultat varie chez les patients atteints de diabète de type 1 selon la méthode d'évaluation de la dose d'insuline qu'ils utilisent : échelle mobile ou comptage des glucides.

MÉTHODES

Cette étude a porté sur des patients qui ont amorcé la perfusion sous-cutanée continue d'insuline (PSCI) et se sont servi de l'échelle mobile (n = 81) ou du comptage des glucides (n = 44) pour déterminer les doses d'insuline. Les groupes ont été comparés pour ce qui est de l'hémoglobine glycosylée (HbA_{1c}), du poids, de la fréquence des hypoglycémies et des besoins d'insuline au début de la PSCI et au moment du suivi. On a aussi évalué les changements chez chaque personne dans un sous-groupe ayant commencé par utiliser l'échelle mobile et étant passé au comptage des glucides (n = 21).

RÉSULTATS

Au départ, seule l'HbA_{1c} variait significativement ($p < 0,05$), étant plus élevée dans le groupe utilisant l'échelle mobile. Au moment du suivi, la différence n'était pas significative pour aucun des paramètres entre le groupe utilisant l'échelle mobile et celui utilisant le comptage des glucides. Il n'y a pas eu de changements significatifs de l'HbA_{1c}, du poids, de la fréquence des hypoglycémies ni des besoins d'insuline chez les patients qui étaient passés de l'échelle mobile au comptage des glucides.

CONCLUSIONS

Puisque seule l'utilisation de l'échelle mobile a produit une baisse significative de l'HbA_{1c}, le comptage des glucides ne semble pas être une meilleure méthode pour estimer la dose d'insuline chez les patients utilisant la PSCI.

CONCLUSION

With only the sliding scale method showing a significant decrease in A1C, carbohydrate counting does not appear to be superior for insulin dosage estimation in patients using CSII.

KEYWORDS

Carbohydrate counting, continuous subcutaneous insulin infusion, insulin dosage estimation, insulin pump, sliding scale

MOTS CLÉS

comptage des glucides, estimation des doses d'insuline, pompe à insuline, perfusion sous-cutanée continue d'insuline, échelle

INTRODUCTION

In 1993, the Diabetes Control and Complications Trial illustrated that, for people with type 1 diabetes, stringent control of glycosylated hemoglobin (A1C) levels may prevent or prolong the onset of diabetes-related microvascular complications (1). Results of the trial also showed that intensive therapy, consisting of either multiple daily injections or continuous subcutaneous insulin infusion (CSII), is preferable to conventional therapy for lowering A1C levels, with CSII therapy resulting in particularly favourable outcomes (2). Subsequent research has found that CSII is effective in controlling A1C levels and may limit hypoglycemia, insulin dosage requirements and weight gain (3-9).

Although the insulin pump continuously delivers basal insulin to the subcutaneous tissue, patients using CSII are responsible for administering an additional insulin bolus prior to each meal (10). Two common methods of bolus insulin dosage estimation are sliding scale and carbohydrate counting. The sliding scale method requires that patients titrate their bolus dosages using an insulin dose scale that varies according to their preprandial ambient blood glucose (BG) level while keeping the carbohydrate content of meals consistent. On the other hand, patients using carbohydrate counting base their bolus insulin dosage on both a correction factor (determined by a preprandial BG measurement) and a carbohydrate factor. The latter quantitatively takes into account the carbohydrate content of the patient's upcoming meal, which may be variable (11). Patients who use carbohydrate counting not only make use of an insulin dose scale that varies according to their preprandial BG values, they also base their dosage titration on insulin/carbohydrate ratios. These ratios allow them to vary their carbohydrate quantity within meals and from day to day, as long as there is adequate insulin to account for the carbohydrate content.

Each method of insulin dosage estimation has its own hypothetical advantages and limitations. Theoretically, the carbohydrate counting method is both flexible and precise, as it enables patients to refine their bolus dosage in response to the amount of carbohydrate they consume (4,11). Additionally, patient feedback suggests that carbohydrate counting has a positive impact on quality of life (12,13). Thus, carbohydrate counting appears to be the technique most often used for dosage estimation in recent studies and reviews involving CSII (3,4,10).

However, it is important to recognize that patients using carbohydrate counting must have an understanding of the relationship between carbohydrate consumption and appropriate insulin dosage. They must also be able to accurately estimate how much carbohydrate is in all of their meals. Consequently, this approach takes considerable time to teach. It requires mathematical aptitude, motivation to learn and perseverance to apply the method at every meal. Rizer and Richards suggest that although carbohydrate counting patients initially adhere to this method quite fastidiously, many eventually find it to be overly complicated and time consuming. As a result, the accuracy of carbohydrate content estimates begins to decline, which can cause extreme postprandial BG excursions (14).

Unlike carbohydrate counting, the sliding scale leaves little room for patient error and requires minimal teaching and little commitment, indicating that it might be an effective insulin dosage estimation technique over the long term. However, the use of the sliding scale on inpatients with diabetes has been highly criticized (15-19). Arguments against this method could also be extended to outpatient treatment. The sliding scale has been criticized for contributing to sub-optimal BG control because it manages hyperglycemia after an episode occurs rather than placing emphasis on its prevention; because it permits doctors to write a "stock" prescription and then leaves patients and nurses to interpret BG levels and adjust insulin dosages; and because it does not promote an understanding by the patient of the numerous factors that influence glycemic control (16,18,19). Empirically, studies of the sliding scale in inpatient care have drawn conflicting conclusions about its efficacy (15,20,21). There is a paucity of data regarding sliding scale use in outpatients, but it has been criticized for its inflexibility and its propensity to overcompensate for hyperglycemia in such patients (22).

Despite the fact that both the sliding scale and carbohydrate counting methods of insulin dosage titration have numerous theoretical benefits and drawbacks, empirical data are scarce. To our knowledge, 1 study has compared bolus dosage titration methods. Kalergis and colleagues followed 15 patients with type 1 diabetes who were taking multiple daily insulin injections. These patients tested 3 different strategies, one of which was similar to the sliding scale approach we describe here: patients used a sliding scale to determine correction factors and attempted to keep their

day-to-day diet consistent. The other 2 approaches used a sliding scale as well, but also incorporated a correction factor for varying carbohydrate consumption. One of these strategies corrected qualitatively for changes in carbohydrate consumption, while the other corrected quantitatively with insulin/carbohydrate ratios, much like the carbohydrate counting method. Results showed no difference in metabolic outcomes between the 3 strategies, but patients seemed to prefer the approach that corrected qualitatively for changes in diet, as it incorporated both flexibility and simplicity (23).

Because clinical data are so limited, the goal of the present study was to compare A1C, weight, frequency of hypoglycemic episodes and daily insulin requirements of CSII patients using a sliding scale alone and those practising carbohydrate counting. We sought to determine whether these clinical parameters were influenced by the method used to determine insulin dosage.

METHODS

This study reviewed patients with type 1 diabetes who initiated CSII therapy at our diabetes education and treatment centre between 1987 and 2005, and then returned to the centre within 3 to 24 months for follow-up. The centre offers a 4-day outpatient program for patients that provides consultations with endocrinologists, registered dietitians and nurses on a one-on-one basis, in addition to structured group education.

Patients taking multiple daily injections who were recommended to commence CSII therapy attended this 4-day program. They also worked closely with a CSII-specialized nurse who taught them how to operate their new pump and instructed them in insulin dosage estimation. Until 1998, it was recommended that patients on CSII use Humulin-R insulin; subsequent to that, analogue insulin was recommended (24). Prior to August 2002, patients initiating CSII were instructed to use a sliding scale to determine their bolus dosages. After August 2002, patients commencing CSII were taught the carbohydrate counting method. All patients after 2002 were made aware of their options for insulin bolus adjustment and were able to choose either method.

In addition to one-on-one training with a nurse, patients had several hours of teaching sessions with a registered dietitian during the 4-day education program. Patients participated in 7 1/2 hours of group classes focusing on how to calculate the carbohydrate content of meals and how to adjust for meals with high protein and lipid content by decreasing bolus insulin accordingly. Each patient also had a 45-minute meeting with a registered dietitian, at which time the dietitian assessed the patient's dietary knowledge, and a personal nutrition plan was formulated. In addition, those patients who started with carbohydrate counting received 3 hours of one-on-one teaching of this method. Although nutritional strategies have evolved between 1987 and 2006, dietitian contact has remained consistent for those switching from multiple daily injections to CSII during this time frame. Patients who used the sliding scale

method used meal plans, which enabled them to keep the carbohydrate content of their meals consistent from day to day. These patients were taught to follow the Canadian Diabetes Association's *Good Health Eating Guide* (25) to keep the carbohydrate content of their meals consistent. Patients who exercised were given standardized instructions on how to adjust for exercise by either increasing their carbohydrate intake or decreasing their basal insulin rate accordingly.

Follow-up at a 1-day education and treatment program was offered at 3, 6, 12 and 24 months after CSII initiation, and annually thereafter. Patients were asked to attend each of these follow-up sessions, but some elected to return to only 1 or 2 sessions in the first 3 to 24 months of follow-up. At each visit (to either the 4-day or 1-day program), clinical parameters including A1C and weight were measured, and the frequency of hypoglycemic episodes per month and total required daily insulin dose (bolus and basal insulin) were obtained by self-report and recorded. All information was entered into the centre's clinical database.

Prior to 1990, A1C levels were measured using a cation-exchange resin in a disposable column (HbA_{1c} Microcolumn test, Bio-Rad Laboratories, Hercules, California, United States). From 1990 onward, A1C measurement has been done using ion-exchange high-performance liquid chromatography (Diamet analyzer, Bio-Rad Laboratories). Vacutainer tubes containing ethylenediamine tetraacetic acid were used to collect the blood specimens. Although 2 different methods of A1C measurement were employed during this study, values recorded prior to 1990 were adjusted to accurately represent values obtained with the more recent liquid chromatography methodology. We developed a conversion factor to adjust pre-1990 A1C values (26).

A hypoglycemic episode was defined as an instance in which a patient experienced low BG, as indicated by a BG measurement or evidence of appropriate symptoms. While at the centre, patients were asked to report the number of hypoglycemic episodes they had experienced in the month prior to their visit.

Identification and classification of subjects

We searched our clinical database to identify patients with type 1 diabetes who had initiated CSII at our centre between 1987 and 2005 and had returned for at least 1 follow-up visit in the subsequent 3- to 24-month period. Depending on when they initiated CSII, each of these patients was placed into 1 of 2 groups. The sliding scale group consisted of patients who had commenced CSII prior to August 2002 (n=81), and the carbohydrate counting group consisted of those who had commenced CSII after August 2002 (n=44). Medical charts were reviewed to confirm that patients had been correctly grouped. Although carbohydrate counting was recommended to all patients who commenced CSII after 2002, a very small number of patients elected to use the sliding scale method instead. These patients were excluded from analysis. Additionally, a

subgroup of patients from the sliding scale group was identified as a crossover group. These patients had initiated CSII prior to August 2002 and were taught to use a sliding scale, but they returned to the centre's 4-day program again after August 2002, at which time they switched their insulin dosage estimation technique from the sliding scale method to carbohydrate counting and then returned again to the centre between 3 and 24 months after the crossover (n=21).

We assessed clinical parameters (A1C, weight, monthly frequency of hypoglycemia and daily insulin requirement) at the time of CSII initiation (baseline) and again at 3 to 24 months' follow-up. For the crossover subgroup, we assessed these parameters at the time of crossover and again after 3 to 24 months. If patients had more than 1 visit within the 3- to 24-month follow-up period, we took the average mean of all recorded values.

Statistical analysis

A 2-group t-test was performed to compare the sliding scale and carbohydrate counting groups at baseline and follow-up in terms of A1C, weight, frequency of hypoglycemia and daily insulin dosage. Within each group, a paired t-test was used to

determine whether any of these parameters varied between CSII initiation and follow-up. Mean change in A1C, weight, frequency of hypoglycemia and insulin requirements from baseline to follow-up were compared for the sliding scale and carbohydrate counting groups using a 2-group t-test. Additionally, a paired t-test was used on the crossover group to assess whether any changes in A1C, weight, frequency of hypoglycemia and daily insulin dosage occurred as a result of crossing over from the sliding scale method to carbohydrate counting. All t-tests were 2-tailed, and statistical significance was established at $p < 0.05$. Because the follow-up intervals in the sliding scale and carbohydrate counting groups were so dissimilar, we also used a repeated measures analysis of variance to analyze and compare the A1C change over time for the follow-up data. Both methods of data analysis confirmed the same result, which is summarized in Table 2.

RESULTS

A comparison of the sliding scale and carbohydrate counting groups at the time of CSII initiation (baseline) and after 3 to 24 months (follow-up) is presented in Table 1. At baseline, the 2 groups were comparable in terms of duration of dia-

Table 1. Baseline and follow-up comparison of the sliding scale and carbohydrate counting groups			
Parameter	Sliding scale	Carbohydrate counting	p value
Demographics			
n	81	44	NA
Females/males, n	53/28	30/14	NA
Age, years	37.4±11.9	42.0±13.0	0.05
Duration of diabetes, years	18.3±11.5	20.9±12.2	NS
Baseline			
A1C, %	8.56±1.64	7.73±1.51	<0.05
Weight, kg	73.9±12.5	75.0±18.7	NS
Hypoglycemia, episodes/month	12.2±12.6	14.7±13.9	NS
Insulin dosage, units/day	49.6±24.3	56.5±21.3	NS
Follow-up			
A1C, %	7.98±1.30	7.70±1.12	NS
Weight, kg	74.5±12.3	77.5±16.2	NS
Hypoglycemia, episodes/month	8.5±6.9	8.08±8.01	NS
Insulin dosage, units/day	40.5±14.9	44.6±18.9	NS

Except for the first two parameters (N, females/males), all data are presented as mean±SD

A1C = glycosylated hemoglobin

NA = not applicable

NS = not significant

SD = standard deviation

Table 2. Within-person changes in clinical parameters

Parameter	Sliding scale		Carbohydrate counting	
	Change	p value	Change	p value
A1C, %	-0.0059±0.013	<0.0005	-0.0007±0.0122	NS
Weight, kg	0.58±5.3	NS	1.73±14.7	NS
Hypoglycemia, episodes/month	-3.7±12.0	<0.05	-6.1±9.1	<0.05
Insulin dosage, units/day	-9.4±21.8	<0.05	-13.8±18.8	<0.05

All data are presented as mean±SD

A1C = glycosylated hemoglobin

NS = not significant

SD = standard deviation

betes, but the sliding scale group was slightly younger than the carbohydrate counting group ($p=0.05$). Baseline clinical parameters were not significantly different between the 2 groups, with the exception of A1C; the sliding scale group had significantly higher A1C levels than the carbohydrate counting group at baseline ($p<0.05$). At follow-up, there was no significant difference in A1C, weight, frequency of hypoglycemia or insulin dosage between those who were estimating their bolus insulin dosage with a sliding scale and those who were using carbohydrate counting.

Within-group changes in clinical parameters were also assessed for patients who initiated CSII using the sliding scale method and those who initiated CSII using carbohydrate counting. These results are presented in Table 2. Within the sliding scale group, A1C decreased significantly following CSII initiation ($p<0.0005$), as did hypoglycemia ($p<0.05$) and daily insulin dosage ($p<0.05$). There was no significant variation in weight. Within the carbohydrate counting group, neither A1C nor weight changed significantly following the initiation of CSII. However, a marked decrease in frequency of hypoglycemic events ($p<0.05$) and required insulin dosage ($p<0.05$) was observed. The mean change in each parameter for both the sliding scale and carbohydrate counting groups was compared using a 2-group t-test to indicate whether any of these changes were significantly different for the 2 groups. Only the mean change in A1C was significantly different between the sliding scale and carbohydrate counting groups ($p<0.05$), with the sliding scale group having a greater mean decrease in A1C levels. This result was confirmed using a repeated measures analysis of variance ($p<0.05$), comparing the mean A1C change over time between the sliding scale and carbohydrate counting groups.

Clinical parameters measured for the crossover group are presented in Table 3. No significant changes in A1C, weight, frequency of hypoglycemia or insulin dosage were observed

for this subgroup after switching from the sliding scale method to carbohydrate counting.

DISCUSSION

The present study is a retrospective comparison of 2 different methods of bolus insulin dosage estimation used by CSII patients. Two groups of patients were followed as they switched from multiple daily insulin injections to CSII therapy, both groups using different bolus dosage estimation tactics. The groups were compared after 3 to 24 months on CSII, in order to determine whether the sliding scale and carbohydrate counting methods of insulin dosage adjustment produced different results in terms of the following clinical parameters: A1C, weight, frequency of hypoglycemia and required insulin dosage.

Comparison of the sliding scale and carbohydrate counting groups at 3 to 24 months follow-up found no difference between the 2 groups. This indicates that, ultimately, CSII therapy results in similar A1C, weight, frequency of hypoglycemia and required insulin dosage at follow-up regardless of which technique is used to estimate insulin bolus dosage. Further support for this conclusion is the observation that no change in A1C, weight, frequency of hypoglycemia or daily insulin requirement was observed in the subgroup of 21 patients who switched dosage estimation techniques from the sliding scale to carbohydrate counting.

The present study also assessed the within-person changes that occurred in each group before and after CSII initiation. That is, we attempted to determine whether the method of bolus estimation influenced the mean change in clinical parameters that occurred between CSII initiation and follow-up. Results indicate that patients who initiated CSII using the sliding scale for dosage estimation exhibited significant drops in A1C, frequency of hypoglycemia and insulin requirements. Conversely, while patients who initiated CSII and used the carbohydrate counting technique exhibited a signif-

Table 3. Changes in clinical parameters of crossover group (n=21)			
Parameter	Before crossover (sliding scale)	After crossover (carbohydrate counting)	p value
A1C, %	8.00±0.97	8.19±0.82	NS
Weight, kg	73.6±11.2	73.8±11.7	NS
Hypoglycemia, episodes/month	10.4±9.7	8.2±6.4	NS
Insulin dosage, units/day	36.4±7.6	36.8±11.8	NS

All data are presented as mean±SD

A1C = glycosylated hemoglobin

NS = not significant

SD = standard deviation

icant drop in frequency of hypoglycemia and insulin requirements, this group did not show a significant decrease in A1C levels. Neither group had a significant fluctuation in weight. Previous studies of CSII therapy show that it significantly decreases A1C and hypoglycemia when compared to multiple daily injections, although methods of bolus dosage estimation are often not considered in analysis (3,27). Similar to both groups in the present study, CSII has also been found to limit weight gain and decrease insulin requirements (4,7).

When the mean changes in clinical parameters are compared for the sliding scale and carbohydrate counting groups, the sliding scale group had a significantly higher drop in A1C, but mean change in all other parameters were no different. Based on this data, it appears that the patients using the sliding scale benefited from a more significant decrease in A1C than the patients using carbohydrate counting. Furthermore, at baseline 17% of the sliding scale group and 32% of the carbohydrate counting group had A1C values within the Canadian Diabetes Association's recommendation of $\leq 7.0\%$ (28), and at follow-up, this proportion had risen to 27% in the sliding scale group and dropped to 23% in the carbohydrate counting group.

Our findings indicate that the method used for insulin dosage estimation while on CSII is irrelevant to clinical outcome. To our knowledge, no randomized, controlled trials exist comparing the sliding scale and carbohydrate counting methods of insulin estimation, so it is difficult to assess whether the data obtained from our centre regarding these methods is indicative of a larger-scale phenomenon. However, making use of sliding scale formulas has been shown to reduce A1C levels in outpatients with type 1 diabetes who take multiple daily insulin injections (19). Evidence also indicates that the carbohydrate counting method is difficult to master, even for the healthcare providers who teach the method to patients. A study that had healthcare professionals attempt to identify the carbohydrate content of several meals, for which ingredient lists were provided, reported that they were only able to

correctly identify the carbohydrate content of 44% of the meals within a 5 g margin of error (29). When Kalergis and colleagues compared 3 strategies for insulin dosage titration in patients using multiple daily insulin injections, they found that clinical outcomes were not influenced by the method of dosage estimation used, but patient preference favoured a strategy that combined simplicity and flexibility (23).

Theoretically, carbohydrate counting can offer more precise and accurate control of BG than a sliding scale; however, our results found no difference between the 2 methods. It may be that carbohydrate counting offers some patients improved flexibility and tighter control of BG, but it may be too difficult for others to properly learn and practice. Furthermore, although simple, the sliding scale method may actually serve to maintain adequate control of diabetes in some patients.

Limitations

It is important to note that the present study was not randomized. Additionally, data collected for the sliding scale group reflected visits to our centre between 1987 and 2002, whereas data for the carbohydrate counting patients reflects a more recent time frame (2002 to 2006). Therefore, although demographic characteristics and most clinical parameters indicate that the groups were quite comparable at baseline, there may have been some factors that influenced the amount by which clinical parameters varied after CSII initiation. For instance, the quality of insulin pumps has increased considerably since 1987, and patients in the sliding scale group would not have had access to the newest models. Also, as pump technology improves, the latest models are equipped with computer programs that are capable of calculating correction factors and carbohydrate factors. It is conceivable that patients with such pumps may find carbohydrate counting less complex, and this technology may precipitate better outcomes than the present study reflects.

Additionally, the ambient baseline A1C values of the carbohydrate counting group were significantly lower than those

of the sliding scale group, and this may have affected the mean change in A1C that was observed for each group. In a meta-analysis of 3 different CSII efficacy studies, Retnakaran and colleagues noted that the decrement in A1C precipitated by CSII therapy is dependent upon the baseline A1C level. In his analysis, higher baseline A1C levels promoted a greater absolute reduction after CSII initiation (27). Thus, it is possible that the significantly lower reduction in A1C seen in the sliding scale group in comparison with the carbohydrate counting group may be due to the higher baseline A1C levels in this group. However, although the carbohydrate counting group had a significantly lower baseline A1C and was smaller than the sliding scale group, we might still have expected to see a significant decrement in A1C. A study of the effects of CSII therapy on 34 patients over the age of 50 who had a mean baseline A1C of only 7.64% found that A1C levels decreased significantly in the year following CSII initiation (9).

Additionally, it is important to note that patients using the sliding scale approach were given a guideline for dosage titration and instructed to keep daily carbohydrate consumption constant. However, it is likely that some of these patients did qualitatively vary their insulin dosages beyond the recommendations of the sliding scale to compensate for variation in carbohydrate consumption and unplanned exercise.

Finally, although the present study did not compare the quality of life of patients using the sliding scale with those using carbohydrate counting, we recognize that quality of life is an important factor. In future studies, an analysis of quality of life in conjunction with comparison of clinical parameters may help to better elucidate the merits of each method and possibly determine which types of patients might be better suited to either method.

CONCLUSION

Advanced carbohydrate counting using insulin/carbohydrate ratios is often recommended by clinicians and in the literature for bolus dosage estimation (3,4,10), although empirical evidence to support these recommendations is lacking. In a retrospective review of our patients on CSII therapy, we found that the sliding scale method for bolus dosage estimation was not inferior to carbohydrate counting, the sliding scale group being the only group to demonstrate a significant improvement in A1C. If both the sliding scale and carbohydrate counting methods result in comparable clinical outcomes, then perhaps these recommendations should be revised. From our observations, tailoring bolus estimation techniques to the requirements of individual patients or developing methods that combine the simplicity of the sliding scale and flexibility of carbohydrate counting may help to maximize glycemic control in CSII patients.

AUTHOR DISCLOSURES

No dualities of interest declared.

AUTHOR CONTRIBUTIONS

HDT contributed to research concept, data review and manuscript writing. EB contributed to patient interviews, data acquisition and manuscript writing. TF contributed to data review, literature review and manuscript revisions. AT contributed to patient interviews, data acquisition and manuscript revision. All authors approved the final version of this paper for publication.

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