

# Basal Insulin Requirement Is ~30% of the Total Daily Insulin Dose in Type 1 Diabetic Patients Who Use the Insulin Pump

AKIO KURODA, MD<sup>1</sup>  
HIDEAKI KANETO, MD<sup>1</sup>  
TETSUYUKI YASUDA, MD<sup>1</sup>  
MUNEHIDE MATSUHISA, MD<sup>2</sup>  
KAZUYUKI MIYASHITA, MD<sup>1</sup>  
NORITAKA FUJIKI, MD<sup>1</sup>

KEIKO FUJISAWA, MD<sup>1</sup>  
TSUNEHICO YAMAMOTO, MD<sup>1</sup>  
MITSUYOSHI TAKAHARA, MD<sup>1</sup>  
FUMIE SAKAMOTO, MD<sup>1</sup>  
TAKA-AKI MATSUOKA, MD<sup>1</sup>  
ICHIRO SHIMOMURA, MD<sup>1</sup>

**OBJECTIVE**—To investigate the basal insulin requirement in total daily insulin dose in Japanese type 1 diabetic patients who use the insulin pump.

**RESEARCH DESIGN AND METHODS**—The basal insulin requirement in 35 type 1 diabetic patients without detectable C-peptide using the insulin pump (Paradigm 712) was investigated during 2–3 weeks of hospitalization. The patients were served diabetic diets of 25–30 kcal/kg ideal body weight. Each meal omission was done to confirm stable blood glucose levels within 30 mg/dL variance until the next meal. Target blood glucose level was set at 100 mg/dL before each meal and 150 mg/dL at 2 h after each meal.

**RESULTS**—Total daily insulin dose was  $31.6 \pm 8.5$  units, and total basal insulin requirement was  $8.7 \pm 2.9$  units, which was  $27.7 \pm 6.9\%$  of the total daily dose.

**CONCLUSIONS**—Basal insulin requirement is ~30% of the total daily dose in Japanese type 1 diabetic patients who use the insulin pump.

*Diabetes Care* 34:1089–1090, 2011

Insulin therapy consists of basal insulin to keep blood glucose level stable and bolus insulin to control postprandial hyperglycemia and to correct hyperglycemia if necessary. Type 1 diabetic patients who run out of their own insulin secretion are recommended to set proper amounts of basal insulin. According to the textbook, total basal insulin dose (TBD) is ~50% of the total daily insulin dose (TDD) (1–3).

The purpose of this study was to assess basal insulin requirement in type 1 diabetic patients, who are on insulin pump therapy, without detectable C-peptide (<0.1 ng/mL). This study was done during 2–3 weeks of hospitalization in patients on diabetic diets.

## RESEARCH DESIGN AND METHODS

Among 42 Japanese patients treated with the insulin pump, 35 were consecutively selected who met the inclusion and exclusion criteria and who signed an informed consent. We used a Paradigm 712 pump (Medtronic, Northridge, CA) with which we program basal insulin infusion hourly every 0.05 units. All patients used rapid-acting insulin in their pumps and were asked to monitor blood glucose four times daily. To exclude factors that could modify insulin dose requirements (2), the patients were hospitalized in Osaka University Medical Hospital from July 2007 to July 2010 to adjust the insulin pump. We excluded individuals with eating disorders, concomitant

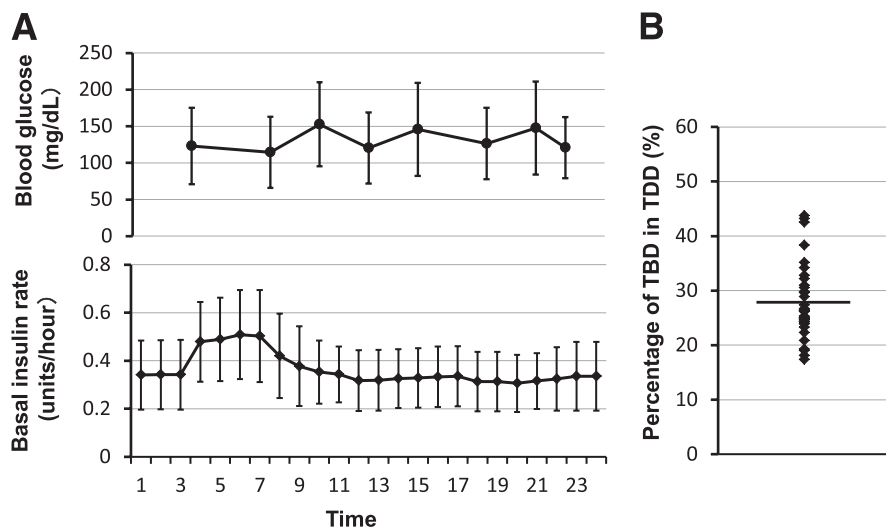
dietary restrictions, unstable retinopathy, renal failure, or pregnancy or who were using other antidiabetic agents or steroids. During the 2–3 weeks of hospitalization, an eight-point glucose testing (before and 2 h after each meal [2200 and 0300 h]) was performed to allow optimization of basal insulin rates according to the previous report (4). The diabetic meals in all studies were 25–30 kcal/kg ideal body weight, consisting of 50–60% carbohydrate, 15–20% protein, and 20–25% fat and were prepared by dietitians. Overnight basal insulin rates were evaluated with the blood glucose readings at 2200, 0300, and 0700 h and set using the same method (4). Upon verification of the basal rates, bolus insulin was determined by physicians using carbohydrate counting. All meals were consumed within 20 min; no additional food or drink was consumed unless required to treat hypoglycemia. The target fasting glucose and 2-h postprandial glucose values were set at 100 and 150 mg/dL in each participant. TDD, TBD, and percentage of TBD to TDD (%TBD) were collected after achieving the target glucose level at least for 3 days. The average of the eight-point glucose testing for the final 3 days of the study period was collected. HbA<sub>1c</sub>, TDD, and %TBD at 6 months after the study period in 26 patients were collected. Demographic data are presented as means  $\pm$  SD.

**RESULTS**—Characteristics of the study subjects were as follows: sex, 11 males/24 females; age,  $39.7 \pm 10.9$  years (20–69) [mean  $\pm$  SD (range)]; body weight,  $56.5 \pm 10.0$  kg (36–80); BMI,  $22.0 \pm 3.0$  kg/m<sup>2</sup> (14.6–28.7); duration of diabetes,  $22.1 \pm 11.4$  years (2–44); HbA<sub>1c</sub>,  $7.26 \pm 1.40\%$  (5.0–11.5).

The average of the eight-point blood glucose was shown in Fig. 1A (upper panel). According to the meal omission, basal insulin dose was adjusted in each patient. Basal insulin rate was shown in Fig. 1A (lower panel). TBD was  $8.7 \pm 2.9$  units (3.3–15.3), TDD was  $31.6 \pm 8.5$  units (18–50), and TDD/kg was  $0.56 \pm 0.13$

From the <sup>1</sup>Department of Metabolic Medicine, Osaka University Graduate School of Medicine, Osaka, Japan; and the <sup>2</sup>Diabetes Clinical Research and Development Center, Tokushima University, Tokushima, Japan. Corresponding author: Akio Kuroda, kurodaakio@gmail.com. Received 15 November 2010 and accepted 14 February 2011. DOI: 10.2337/dc10-2149

© 2011 by the American Diabetes Association. Readers may use this article as long as the work is properly cited, the use is educational and not for profit, and the work is not altered. See <http://creativecommons.org/licenses/by-nc-nd/3.0/> for details.



**Figure 1**—A: Eight-point blood glucose profile during the final 3 days of hospitalization in type 1 diabetic patients using the insulin pump (upper panel). Basal insulin requirement (units/h) (lower panel) is shown. Data are expressed as means  $\pm$  SD. B: Percentage of basal insulin requirement in TDD. TBD was  $27.7 \pm 6.9\%$  TDD ( $n = 35$ ).

units/kg (0.32–0.84). As shown in Fig. 1B, %TBD was  $27.7 \pm 6.9\%$  (16.6–43.8). No patients required 50% TDD. In addition, there was no relationship between BMI, age, HbA<sub>1c</sub>, and %TBD (data not shown).

HbA<sub>1c</sub> changed from  $7.42 \pm 1.32$  to  $6.95 \pm 1.46\%$  ( $P < 0.01$ ), TDD changed from  $32.0 \pm 7.8$  to  $33.9 \pm 12.0$  units/day ( $P = 0.21$ ), and %TBD changed from  $28.9 \pm 5.1$  to  $29.7 \pm 6.2\%$  ( $P = 0.54$ ) at 6 months after the study period.

**CONCLUSIONS**—We investigated here the basal insulin requirement in C-peptide-negative type 1 diabetic patients. Our results show that basal insulin requirement is  $\sim 30\%$  TDD in the inpatients on diabetic diets prepared by a dietitian (Fig. 1B). In addition, the maximal basal insulin requirement in all patients was 43.8% TDD, and no patients required 50% TDD. These results indicate the currently widely published formula ( $TBD = 0.5 \times TDD$ ) (1–3) overestimates the TBD. King (5) also recently suggested that this should be revised to  $TBD = 0.4 \times TDD$  to prevent excess basal insulin treatment. In our results, TBD was  $\sim 30\%$  TDD, which was less than King's estimation. We assume that this is the result of the strict diabetic diet in the hospital setting. Diabetic meals are served to all patients. These meals are close to the macronutrient content as the meals recommended by the American Diabetes Association (6).

We consider that previous estimation ( $TBD = 0.5 \times TDD$ ) might have been

influenced by several factors as follows. One is diet failure, i.e., increased fat intake. Fat ingestion may cause delay of gastric emptying, leading to late glucose excursion (7). When eating fat-rich pizza, it was recommended to give dual-wave bolus insulin for 8 h, which means giving bolus insulin for 8 h after normal bolus insulin to suppress late glucose excursion induced by fat (8). The basal insulin requirement in the daily life after discharge might be more than in the hospital if patients eat more fat than recommended. However, %TBD stayed at the same level without deteriorating glucose control 6 months after the study period. The other factor is the misunderstanding of blood glucose monitoring data in well controlled patients. There are some patients who set their basal insulin higher than required to lower their blood glucose. In these patients, although the peak glucose value is high, HbA<sub>1c</sub> is seemingly well controlled, which leads to the misunderstanding about their basal requirement.

We did not use a continuous glucose monitoring system (CGMS) in our study. Although there is a report showing that eight-point glucose testing a day is comparable to a continuous glucose monitoring system, eight-point glucose testing has the possibility of missing midnight hypoglycemia (9). In such a case, it might be better to further reduce the TBD. Furthermore, this study is of small size and is not designed to be a randomized study

comparing different percentages of basal and bolus.

In conclusion, basal insulin requirement is  $\sim 30\%$  TDD in Japanese type 1 diabetic patients who use the insulin pump.

**Acknowledgments**—No potential conflicts of interest relevant to this article were reported.

A.K. and H.K. researched data and wrote the manuscript. T.Y., M.M., and K.M. reviewed and edited the manuscript. N.F., K.F., and T.Y. researched data. M.T., F.S., and T.M. edited the manuscript. I.S. researched data and contributed to discussion.

## References

- Davidson PC, Hebblewhite HR, Steed RD, Bode BW. Analysis of guidelines for basal-bolus insulin dosing: basal insulin, correction factor, and carbohydrate-to-insulin ratio. *Endocr Pract* 2008;14:1095–1101
- Sherr J, Tamborlane W, Bode B. *Insulin Pump Therapy in Therapy for Diabetes Mellitus and Related Disorders*. 5th ed. Lebovitz H, Ed. Alexandria, VA, American Diabetes Association, 2009, p. 322–331
- Wolpert H. *Smart Pumping for People with Diabetes*. Wolpert H, Ed. Alexandria, VA, American Diabetes Association, 2002
- Scheiner G, Boyer BA. Characteristics of basal insulin requirements by age and gender in type-1 diabetes patients using insulin pump therapy. *Diabetes Res Clin Pract* 2005;69:14–21
- King AB. How much do I give? Reevaluation of insulin dosing estimation formulas using continuous glucose monitoring. *Endocr Pract* 2010;16:428–432
- Warshaw H, Bolderman K. *Practical Carbohydrate Counting: A How-to-Teach Guide for Health Professionals*. 2nd ed. American Diabetes Association, 2008
- Welch IM, Bruce C, Hill SE, Read NW. Duodenal and ileal lipid suppresses postprandial blood glucose and insulin responses in man: possible implications for the dietary management of diabetes mellitus. *Clin Sci (Lond)* 1987;72:209–216
- Jones SM, Quarry JL, Caldwell-McMillan M, Mauer DT, Gabbay RA. Optimal insulin pump dosing and postprandial glycemia following a pizza meal using the continuous glucose monitoring system. *Diabetes Technol Ther* 2005;7:233–240
- Fiallo-Scharer R; Diabetes Research in Children Network Study Group. Eight-point glucose testing versus the continuous glucose monitoring system in evaluation of glycemic control in type 1 diabetes. *J Clin Endocrinol Metab* 2005;90:3387–3391