

## Inpatient Glycemic Control With Sliding Scale Insulin in Noncritical Patients With Type 2 Diabetes: Who Can Slide?

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**OBJECTIVE:** Despite clinical guideline recommendations, sliding scale insulin (SSI) is widely used for the hospital management of patients with type 2 diabetes (T2D). We aimed to determine which patients with T2D can be appropriately managed with SSI in non-critical care settings.

**METHODS:** We used electronic health records to assess inpatient glycemic control in medicine and surgical patients treated with SSI according to admission blood glucose (BG) concentration between June 2010 and June 2018. Primary outcome was the percentage of patients with T2D achieving target glycemic control, defined as mean hospital BG 70 to 180 mg/dL without hypoglycemia <70 mg/dL during SSI therapy.

**RESULTS:** Among 25,813 adult patients with T2D, 8,095 patients (31.4%) were treated with SSI. Among patients with admission BG <140 mg/dL and BG 140 to 180 mg/dL, 86% and 83%, respectively, achieved target control without

hypoglycemia, as compared with only 18% of those with admission BG  $\geq$ 250 mg/dL ( $P < .001$ ). After adjusting for age, gender, body mass index (BMI), race, Charlson Comorbidity Index score, and setting, the odds of poor glycemic control increased with higher admission BG (BG 140-180 mg/dL: odds ratio [OR], 1.8; 95% CI, 1.5-2.2; BG 181-250 mg/dL: OR, 3.7; 95% CI, 3.1-4.4; BG >250 mg/dL: OR, 7.2; 95% CI, 5.8-9.0), as compared with patients with BG <140 mg/dL. A total of 1,192 patients (15%) treated with SSI required additional basal insulin during hospitalization.

**CONCLUSION:** Most non-intensive care unit patients with admission BG <180 mg/dL treated with SSI alone achieve target glycemic control during hospitalization, suggesting that cautious use of SSI may be a viable option for certain patients with mild hyperglycemia. *Journal of Hospital Medicine* 2021;16:462-468. © 2021 Society of Hospital Medicine

Sliding scale insulin (SSI) for inpatient glycemic control was first proposed by Elliott P Joslin in 1934 when he recommended titration of insulin based on urine glucose levels.<sup>1</sup> As bedside glucose meters became widely available, physicians transitioned to dosing SSI based on capillary blood glucose (BG) levels,<sup>2,3</sup> and SSI became widely used for the management of inpatient hyperglycemia.<sup>1</sup> However, during the past decade, there has been strong opposition to the use of SSI in hospitals. Many authors oppose its use, highlighting the retrospective rather than prospective nature of SSI therapy and concerns about inadequate glycemic control.<sup>4-6</sup> In 2004, the American College of Endocrinology first released a position statement discouraging the use of SSI alone and recommended basal-bolus insulin as the preferred method of glycemic control for inpatients with type 2 diabetes (T2D).<sup>7</sup> The American Diabetes Association (ADA) inpatient guidelines in

2005<sup>8</sup> and the Endocrine Society guidelines in 2012<sup>9</sup> also opposed SSI monotherapy and reaffirmed that a basal-bolus insulin regimen should be used for most non-critically ill patients with diabetes. Those guidelines remain in place currently.

Several randomized controlled trials (RCTs) and meta-analyses have shown that basal-bolus insulin regimens provide superior glycemic control in non-critical inpatients when compared with SSI alone.<sup>10-14</sup> In addition, the RABBIT 2 (Randomized Study of Basal-Bolus Insulin Therapy in the Inpatient Management of Patients With Type 2 Diabetes) trial showed a significant reduction in perioperative complications<sup>10</sup> among surgical patients when treated with basal-bolus insulin therapy. Despite these studies and strong recommendations against its use, SSI continues to be widely used in the United States. According to a 2007 survey of 44 US hospitals, 41% of noncritical patients with hyperglycemia were treated with SSI alone.<sup>15</sup> In addition, SSI remains one of the most commonly prescribed insulin regimens in many countries around the world.<sup>16-19</sup> The persistence of SSI use raises questions as to why clinicians continue to use a therapy that has been strongly criticized. Some authors point to convenience and fear of hypoglycemia with a basal-bolus insulin regimen.<sup>20,21</sup> Alternatively, it is possible that SSI usage remains so pervasive because it is effective in a subset of patients. In fact, a 2018 Cochrane review concluded that existing evidence is not sufficiently robust to definitively recommend

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basal-bolus insulin over SSI for inpatient diabetes management of non-critically ill patients despite existing guidelines.<sup>22</sup>

Owing to the ongoing controversy and widespread use of SSI, we designed an exploratory analysis to understand the rationale for such therapy by investigating whether a certain subpopulation of hospitalized patients with T2D may achieve target glycemic control with SSI alone. We hypothesized that noncritical patients with mild hyperglycemia and admission BG <180 mg/dL would do well with SSI alone and may not require intensive treatment with basal-bolus insulin regimens. To address this question, we used electronic health records with individual-level patient data to assess inpatient glycemic control of non-critically ill patients with T2D treated with SSI alone.

## METHODS

### Participants

Data from 25,813 adult noncritical inpatients with T2D, with an index admission between June 1, 2010, and June 30, 2018, were obtained through the Emory Healthcare Clinical Data Warehouse infrastructure program. All patients were admitted to Emory Healthcare hospitals, including Emory University Hospital, Emory University Hospital Midtown, and Emory Saint Joseph's Hospital, in Atlanta, Georgia. Data were extracted for each patient during the index hospitalization, including demographics, anthropometrics, and admission and inpatient laboratory values. Information was collected on daily point-of-care glucose values, hemoglobin A1c (HbA1c), hypoglycemic events, insulin doses, hospital complications, comorbidities, and hospital setting (medical vs surgical admission). *International Classification of Diseases, 9th and 10th Revisions (ICD-9/10)* codes were used to determine diagnosis of T2D, comorbidities, and complications.

From our initial dataset, we identified 16,366 patients who were treated with SSI during hospitalization. We excluded patients who were admitted to the intensive care unit (ICU) or placed on intravenous insulin, patients with missing admission BG values, and patients with a length of stay less than 1 day. To prevent inclusion of patients presenting in diabetic ketoacidosis or hyperosmolar hyperglycemic syndrome, we excluded patients with an admission BG >500 mg/dL. We then excluded 6,739 patients who received basal insulin within the first 2 days of hospitalization, as well as 943 patients who were treated with noninsulin (oral or injectable) antidiabetic agents. Our final dataset included 8,095 patients (Appendix Figure).

Patients in the SSI cohort included all patients who were treated with short-acting insulin only (regular insulin or rapid-acting [lispro, aspart, glulisine] insulin analogs) during the first 2 days of hospitalization. Patients who remained on only short-acting insulin during the entire hospitalization were defined as continuous SSI patients. Patients who subsequently received basal insulin after day 2 of hospitalization were defined as patients who transitioned to basal. Patients were stratified according to admission BG levels (first BG available on day of admission) and HbA1c (when available during index admission). We compared the baseline characteristics and clinical outcomes of patients who remained on SSI alone throughout the entirety of

hospitalization with those of patients who required transition to basal insulin. The mean hospital BG was calculated by taking the average of all BG measurements during the hospital stay. We defined hypoglycemia as a BG <70 mg/dL and severe hypoglycemia as BG <40 mg/dL. Repeated hypoglycemia values were excluded if they occurred within a period of 2 hours.

### Outcome Measures

The primary outcome was the percentage of patients with T2D achieving target glycemic control with SSI therapy, defined as mean hospital BG between 70 and 180 mg/dL without hypoglycemia <70 mg/dL during hospital stay. This threshold was determined based on 2019 ADA recommendations targeting hospital BG <180 mg/dL and avoidance of hypoglycemia.<sup>23</sup>

### Statistical Analysis

Patients were stratified according to continuous SSI versus transitioned to basal treatment. Patients who remained on continuous SSI were further categorized into four categories based on admission BG: <140 mg/dL, 140 to 180 mg/dL, 180 to 250 mg/dL, and ≥250 mg/dL. Clinical characteristics were compared using Wilcoxon rank-sum tests (if continuous) and chi-square tests or Fisher exact tests (if categorical). We then compared the clinical outcomes among continuous SSI patients with different admission BG levels (<140 mg/dL, 140-180 mg/dL, 180-250 mg/dL, and ≥250 mg/dL) and with different HbA1c levels (<7%, 7%-8%, 8%-9%, ≥9%). Within each scenario, logistic regression for the outcome of poor glycemic control, defined as mean hospital BG >180 mg/dL, was performed to evaluate the HbA1c levels and admission BG levels controlling for other factors (age, gender, body mass index [BMI], race, setting [medicine versus surgery] and Charlson Comorbidity Index score). A *P* value < .05 was regarded as statistically significant. All analyses were performed based on available cases and conducted in SAS version 9.4 (SAS Institute Inc.).

## RESULTS

Among 25,813 adult patients with T2D, 8,095 patients (31.4%) were treated with SSI alone during the first 2 days of hospitalization. Of those patients treated with SSI, 6,903 (85%) remained on continuous SSI alone during the entire hospitalization, and 1,192 (15%) were transitioned to basal insulin. The clinical characteristics of these patients on continuous SSI and those who transitioned to basal insulin are shown in Table 1. Patients who transitioned to basal insulin had significantly higher mean (SD) admission BG (191.8 [88.2] mg/dL vs 156.4 [65.4] mg/dL, *P* < .001) and higher mean (SD) HbA1c (8.1% [2.0%] vs 7.01% [1.5%], *P* < .001), compared with those who remained on continuous SSI. Patients who transitioned to basal insulin were also younger and more likely to have chronic kidney disease (CKD), but less likely to have congestive heart failure, coronary artery disease, or chronic obstructive pulmonary disease (COPD). The Charlson Comorbidity Index score was significantly higher for patients who transitioned to basal (4.4 [2.5]) than for those who remained on continuous SSI (4.1 [2.5], *P* < .001). There were no significant differences among sex, BMI, or glomerular filtration

TABLE 1. Clinical Characteristics of Hospitalized Patients With Type 2 Diabetes Treated With SSI by Continuous SSI vs Transitioned to Basal Insulin

| Variable                              | All patients<br>(N = 8,095) | Continuous SSI<br>(n = 6,903) | Transitioned to basal<br>(n = 1,192) | P value <sup>a</sup> |
|---------------------------------------|-----------------------------|-------------------------------|--------------------------------------|----------------------|
| Age, mean (SD), y                     | 65.3 (13.3)                 | 65.8 (13.1)                   | 62.9 (14.0)                          | <.001                |
| Sex, No. (%)                          |                             |                               |                                      | .61                  |
| Female                                | 4,176 (52)                  | 3,553 (51)                    | 623 (52)                             |                      |
| Male                                  | 3,919 (48)                  | 3,350 (49)                    | 569 (48)                             |                      |
| Race, No. (%)                         |                             |                               |                                      | .047                 |
| Black                                 | 4,398 (56)                  | 3,726 (56)                    | 672 (59)                             |                      |
| White                                 | 3,168 (41)                  | 2,737 (41)                    | 431 (38)                             |                      |
| Other                                 | 247 (3)                     | 203 (3)                       | 44 (4)                               |                      |
| BMI, mean (SD), kg/m <sup>2</sup>     | 31.6 (8.4)                  | 31.6 (8.3)                    | 31.4 (8.7)                           | .21                  |
| Admission setting, No. (%)            |                             |                               |                                      | .020                 |
| Medicine                              | 5,514 (68)                  | 4,721 (68)                    | 793 (67)                             |                      |
| Surgery                               | 2,581 (32)                  | 2,182 (32)                    | 399 (33)                             |                      |
| Admission BG, mean (SD), mg/dL        | 161.6 (70.3)                | 156.4 (65.4)                  | 191.8 (88.2)                         | <.001                |
| Admission HbA1c, mean (SD), %         | 7.3 (1.7)                   | 7.0 (1.5)                     | 8.1 (2.0)                            | <.001                |
| Admission eGFR, mean (SD), mL/min     | 64.3 (37.8)                 | 64.2 (37.1)                   | 64.7 (41.4)                          | .62                  |
| Comorbidities, No. (%)                |                             |                               |                                      |                      |
| Dyslipidemia                          | 4,160 (51)                  | 3,566 (52)                    | 594 (50)                             | .24                  |
| Congestive heart failure              | 2,632 (33)                  | 2,283 (33)                    | 349 (29)                             | .010                 |
| Coronary artery disease               | 2,956 (37)                  | 2,563 (37)                    | 393 (33)                             | .006                 |
| COPD                                  | 2,194 (27)                  | 1,913 (28)                    | 281 (24)                             | .003                 |
| Chronic kidney disease                | 1,430 (18)                  | 1,171 (17)                    | 259 (22)                             | <.001                |
| Stroke                                | 1,558 (19)                  | 1,322 (19)                    | 236 (20)                             | .60                  |
| Charlson Comorbidity Index, mean (SD) | 4.1 (2.5)                   | 4.1 (2.5)                     | 4.4 (2.5)                            | <.001                |

<sup>a</sup>P value is for comparison between continuous SSI and transitioned to basal insulin.

Abbreviations: BG, blood glucose; BMI, body mass index; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; HbA1c, hemoglobin A1c; SSI, sliding scale insulin.

rate (GFR) on admission. Of those transitioned to basal insulin, 53% achieved a mean hospitalization BG <180 mg/dL, compared with 82% of those on continuous SSI. The overall rate of hypoglycemia in the continuous SSI group was 8% compared with 18% in those transitioned to basal insulin.

Of the patients who remained on continuous SSI throughout the hospitalization, 3,319 patients (48%) had admission BG <140 mg/dL, 1,671 patients (24%) had admission BG 140 to 180 mg/dL, and 1,913 patients (28%) had admission BG >180 mg/dL. Only 9% of patients who remained on continuous SSI had admission BG ≥250 mg/dL. Patients with admission BG <140 mg/dL were older, had lower BMI and HbA1c, had higher rates of COPD and CKD, and were more likely to be admitted to a surgical service compared with patients with admission BG >140 mg/dL ( $P < .05$  for all; Table 2).

Hospital glycemic control for patients on continuous SSI according to admission BG is displayed in Table 3. Among patients who remained on continuous SSI, 96% of patients with admission BG <140 mg/dL had a mean hospital BG <180 mg/dL; of them, 86% achieved target control without hypoglycemia. Similar rates of target control were achieved in patients with admis-

sion BG 140 to 180 mg/dL (83%), in contrast to patients with admission BG ≥250 mg/dL, of whom only 18% achieved target control ( $P < .001$ ). These findings parallel those seen in patients transitioned to basal insulin. Of patients in the transition group admitted with BG <140 mg/dL and <180 mg/dL, 88.5% and 84.6% had mean hospital BG <180 mg/dL, respectively, while 69.1% and 68.9% had mean BG between 70 and 180 mg/dL without hypoglycemia. The overall frequency of hypoglycemia <70 mg/dL among patients on continuous SSI was 8% and was more common in patients with admission BG <140 mg/dL (10%) compared with patients with higher admission glucose levels (BG 140-180 mg/dL [4%], 180-250 mg/dL [4%], or ≥250 mg/dL [6%],  $P < .001$ ). There was no difference in rates of severe hypoglycemia <40 mg/dL among groups.

HbA1c data were available for 2,560 of the patients on continuous SSI (Table 3). Mean hospital BG increased significantly with increasing HbA1c values. Patients admitted with HbA1c <7% had lower mean (SD) hospital BG (132.2 [28.2] mg/dL) and were more likely to achieve target glucose control during hospitalization (85%) compared with those with HbA1c 7% to 8% (mean BG, 148.7 [30.8] mg/dL; 80% target control), HbA1c 8%

TABLE 2. Clinical Characteristics of Patients Who Remained on Continuous SSI by Admission Blood Glucose Concentration

| Variable                              | Admission BG, mg/dL |                        |                        |                   | P value |
|---------------------------------------|---------------------|------------------------|------------------------|-------------------|---------|
|                                       | <140<br>(n = 3,319) | 140-180<br>(n = 1,671) | 180-250<br>(n = 1,323) | ≥250<br>(n = 590) |         |
| Age, mean (SD), y                     | 65.7 (12.5)         | 66.5 (12.9)            | 66.2 (13.4)            | 63.1 (15.2)       | <.001   |
| Sex, No. (%)                          |                     |                        |                        |                   | .07     |
| Female                                | 1,748 (53)          | 857 (51)               | 640 (48)               | 308 (52)          |         |
| Male                                  | 1,571 (47)          | 814 (49)               | 683 (52)               | 282 (48)          |         |
| Race, No. (%)                         |                     |                        |                        |                   | .001    |
| Black                                 | 1,839 (58)          | 891 (55)               | 653 (51)               | 343 (59)          |         |
| White                                 | 1,257 (39)          | 671 (41)               | 590 (46)               | 219 (38)          |         |
| Other                                 | 98 (3)              | 55 (3)                 | 35 (3)                 | 15 (3)            |         |
| BMI, mean (SD), kg/m <sup>2</sup>     | 31.7 (8.4)          | 31.8 (8.5)             | 31.6 (8.0)             | 30.6 (7.7)        | .04     |
| Admission setting, No. (%)            |                     |                        |                        |                   | <.001   |
| Medicine                              | 2,130 (64)          | 1,182 (71)             | 958 (72)               | 450 (76)          |         |
| Surgery                               | 1,189 (36)          | 489 (29)               | 364 (28)               | 140 (24)          |         |
| Admission BG, mean (SD), mg/dL        | 107.9 (20.6)        | 157.9 (11.4)           | 207.4 (19.5)           | 311.3 (57.5)      | <.001   |
| Admission HbA1c, mean (SD), %         | 6.6 (1.1)           | 7.0 (1.2)              | 7.5 (1.3)              | 9.0 (2.2)         | <.001   |
| Admission eGFR, mean (SD), mL/min     | 63.7 (38.6)         | 65.1 (36.5)            | 64.8 (35.4)            | 62.9 (34.1)       | .37     |
| Comorbidities, No. (%)                |                     |                        |                        |                   |         |
| Dyslipidemia                          | 1,704 (51)          | 873 (52)               | 689 (52)               | 300 (51)          | .89     |
| Congestive heart failure              | 1,123 (34)          | 550 (33)               | 423 (32)               | 187 (32)          | .55     |
| Coronary artery disease               | 1,226 (37)          | 619 (37)               | 491 (37)               | 227 (38)          | .92     |
| COPD                                  | 988 (30)            | 447 (27)               | 332 (25)               | 146 (25)          | .002    |
| Chronic kidney disease                | 639 (19)            | 271 (16)               | 180 (14)               | 81 (14)           | <.001   |
| Stroke                                | 650 (20)            | 322 (19)               | 259 (20)               | 91 (15)           | .12     |
| Charlson Comorbidity Index, mean (SD) | 4.2 (2.5)           | 4.1 (2.5)              | 4.0 (2.5)              | 3.8 (2.3)         | .04     |

Abbreviations: BG, blood glucose; BMI, body mass index; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; HbA1c, hemoglobin A1c; SSI, sliding scale insulin.

to 9% (mean BG, 169.1 [37.9] mg/dL; 61% target control), or HbA1c ≥9% (mean BG, 194.9 [53.4] mg/dL; 38% target control) ( $P < .001$ ).

In a logistic regression analysis adjusted for age, gender, BMI, race, setting (medicine vs surgery), and Charlson Comorbidity Index score, the odds of poor glycemic control increased with higher admission BG (admission BG 140-180 mg/dL: odds ratio [OR], 1.8; 95% CI, 1.5-2.2; admission BG 180-250 mg/dL: OR, 3.7; 95% CI, 3.1-4.4; admission BG ≥250 mg/dL: OR, 7.2; 95% CI, 5.8-9.0; reference admission BG <140 mg/dL; Figure). Similarly, the logistic regression analysis showed greater odds of poor in-hospital glycemic control with increasing HbA1c (OR, 6.1; 95% CI, 4.3-8.8 for HbA1c >9% compared with HbA1c <7%).

## DISCUSSION

This large retrospective cohort study examined the effectiveness of SSI for glycemic control in noncritical inpatients with T2D. Our results indicate that SSI is still widely used in our hospital sys-

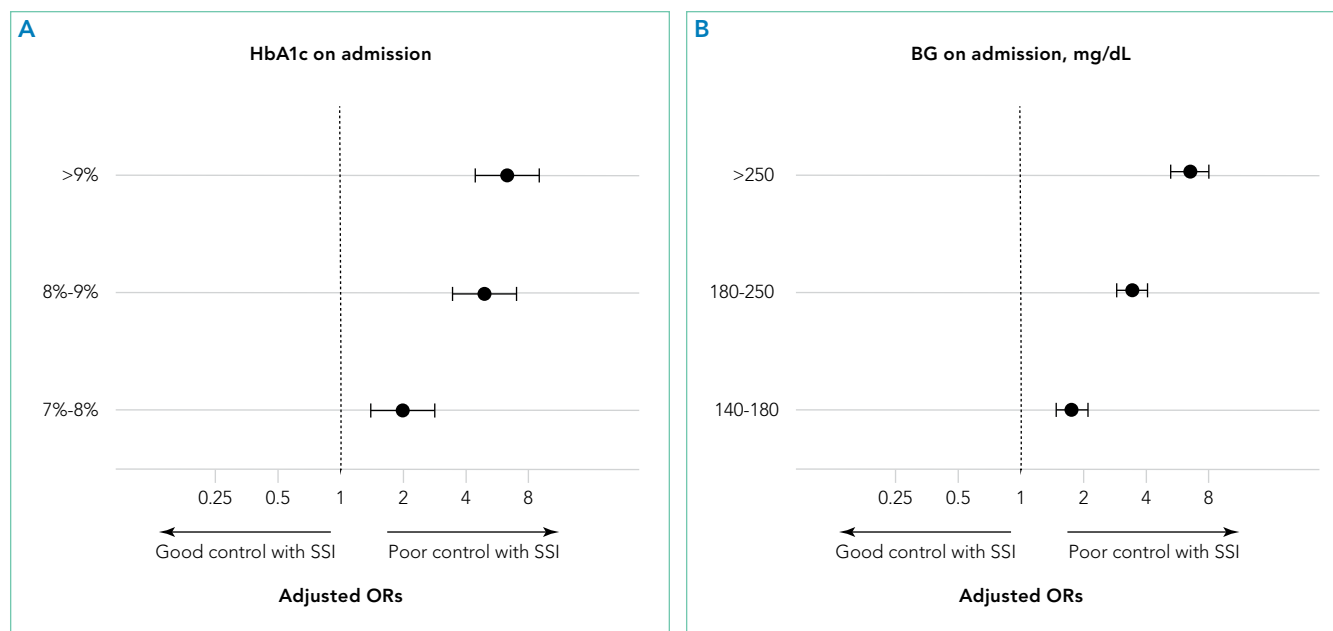
tem, with 31.4% of our initial cohort managed with SSI alone. We found that 86% of patients with BG <140 mg/dL and 83% of patients with BG 140 to 180 mg/dL achieved glycemic control without hypoglycemia when managed with SSI alone, compared with 53% of those admitted with BG 180 to 250 mg/dL and only 18% of those with admission BG ≥250 mg/dL. This high success rate of achieving optimal BG control with SSI alone is comparable to that seen with transition to basal insulin and may explain the prevalent use of SSI for the management of patients with T2D and mild to moderate hyperglycemia.

Published clinical guideline recommendations promoting the use of basal-bolus insulin treatment algorithms are based on the results of a few RCTs that compared the efficacy of SSI vs a basal-bolus insulin regimen. These studies reported significantly lower mean daily BG concentration with basal or basal-bolus insulin therapy compared with SSI.<sup>10,11,24</sup> However, it is interesting to note that the mean admission BG of patients treated with SSI in these RCTs ranged from 184 to 225 mg/dL. Patients in these trials

TABLE 3. Glycemic Data of Patients on Continuous SSI by Admission Blood Glucose Concentration and Admission HbA1c

| Variable   | Admission BG, mg/dL (N = 8,095) |              |              |              | P value |
|--|---------------------------------|--------------|--------------|--------------|---------|
|  | <140                            | 140-180      | 180-250      | ≥250         |         |
| Hospital blood glucose, mean (SD), mg/dL                       | 128.0 (26.9)                    | 151.2 (25.9) | 175.9 (33.0) | 223.8 (53.2) | <.001   |
| Patients with mean BG <180 mg/dL, No. (%)                      | 3,173 (96)                      | 1,450 (87)   | 752 (57)     | 120 (20)     | <.001   |
| Patients with mean BG <180 mg/dL without hypoglycemia, No. (%) | 2,851 (86)                      | 1,390 (83)   | 702 (53)     | 104 (18)     | <.001   |
| Patients with BG <70 mg/dL, No. (%)                            | 335 (10)                        | 60 (4)       | 53 (4)       | 35 (6)       | <.001   |
| Patients with BG <40 mg/dL, No. (%)                            | 24 (1)                          | 5 (0)        | 7 (1)        | 3 (1)        | .30     |
| Variable   | Admission HbA1c, % (n = 2,560)  |              |              |              | P value |
|  | <7                              | 7-8          | 8-9          | ≥9           |         |
| Hospital blood glucose, mean (SD) mg/dL                        | 132.2 (28.2)                    | 148.7 (30.8) | 169.1 (37.9) | 194.9 (53.4) | <.001   |
| Patients with mean BG <180 mg/dL, No. (%)                      | 970 (94)                        | 676 (85)     | 264 (67)     | 144 (44)     | <.001   |
| Patients with mean BG <180 mg/dL without hypoglycemia, No. (%) | 879 (85)                        | 639 (80)     | 241 (61)     | 126 (38)     | <.001   |
| Patients with BG <70 mg/dL, No. (%)                            | 95 (9)                          | 38 (5)       | 27 (7)       | 27 (8)       | .004    |
| Patients with BG <40 mg/dL, No. (%)                            | 6 (1)                           | 5 (1)        | 1 (0)        | 2 (1)        | .86     |

Abbreviations: BG, blood glucose; HbA1c, hemoglobin A1c; SSI, sliding scale insulin.



**FIG.** Results of Logistic Regression Analysis. Odds of poor glycemic control (mean hospital blood glucose [BG] >180 mg/dL) with sliding scale insulin (SSI) alone according to (A) hemoglobin A1c (HbA1c) on admission (reference group: HbA1c <7%) and (B) BG on admission (reference group: BG <140 mg/dL). Models adjusted by age, gender, body mass index, race, hospital setting (medicine or surgery), and Charlson Comorbidity Index.

were excluded if admission BG was <140 mg/dL.<sup>10,11,24</sup> This is in contrast to our study evaluating real-world data in non-critically ill settings in which we found that 48% of patients treated with SSI had admission BG <140 mg/dL, and nearly 75% had admission BG <180 mg/dL. This suggests that by nature of study design,

most RCTs excluded the population of patients who do achieve good glycemic control with SSI and may have contributed to the perception that basal insulin is preferable in all populations.

Our analysis indicates that healthcare professionals should consider admission BG when selecting the type of insulin reg-

imen to manage patients with T2D in the hospital. Our results suggest that SSI may be appropriate for many patients with admission BG <180 mg/dL and should be avoided as monotherapy in patients with admission BG  $\geq$ 180 mg/dL, as the proportion of patients achieving target control decreased with increasing admission BG. More importantly, if a patient is not controlled with SSI alone, intensification of therapy with the addition of basal insulin is indicated to achieve glycemic control. In addition, we found that the admission HbA1c is an appropriate marker to consider as well, with hospital glycemic control deteriorating with increasing HbA1c values, paralleling the admission BG. The main limitation to widespread use of HbA1c for therapeutic decision-making is access to values at time of patient admission; in our population, only 37% of patients had an HbA1c value available during the index hospitalization.

Previous publications have reported that hypoglycemia carries significant safety concerns, especially among a hospitalized population.<sup>25-27</sup> As such, we included hypoglycemia as an important metric in our definition of target glycemic control rather than simply using mean hospital BG or number of hyperglycemic events to define treatment effectiveness. We did find a higher rate of hypoglycemia in patients with moderate admission BG treated with SSI compared with those with higher admission BG; however, few patients overall experienced clinically significant (<54 mg/dL) or severe (<40 mg/dL) hypoglycemia.

In our population, only 15% of patients started on SSI received additional basal insulin during hospitalization. This finding is similar to data reported in the Rabbit 2 trial, in which 14% of patients failed SSI alone, with a higher failure rate among those with higher BG on admission.<sup>10</sup> Given the observational nature of this study, we cannot definitively state why certain patients in our population required additional basal insulin, but we can hypothesize that these patients admitted with BG  $\geq$ 180 mg/dL had higher treatment failure rates and greater rates of hyperglycemia, therefore receiving intensified insulin therapy as clinically indicated at the discretion of the treating physician. Patients who transitioned from SSI to basal insulin had significantly higher admission BG and HbA1c compared with patients who remained on SSI alone. We noted that the rates of hypoglycemia were higher in the group that transitioned to basal (18% vs 8%) and similar to rates reported in previous RCTs.<sup>11,24</sup>

This observational study takes advantage of a large, diverse study population and a combination of medicine and surgery patients in a real-world setting. We acknowledge several limitations in our study. Our primary data were observational in nature, and as such, some baseline patient characteristics were notably different between groups, suggesting selection bias for treatment allocation to SSI. We do not know which patients were managed by primary teams compared with specialized diabetes consult services, which may also influence treatment regimens. We did not have access to information about patients' at-home diabetes medication regimens or duration of diabetes, both of which have been shown in prior publications to affect an individual's overall hospital glycemic control. Data on HbA1c values were available for only approximately one-third of patients. In addition, our study did not include patients without a history of

diabetes who developed stress-induced hyperglycemia, a population that may benefit from conservative therapy such as SSI.<sup>28</sup> A diagnosis of CKD was defined based on ICD 9/10 codes and not on admission estimated GFR. More specific data regarding stage of CKD or changes in renal function over the duration of hospitalization are not available, which could influence insulin prescribing practice. In addition, we defined the basal group as patients prescribed any form of basal insulin (NPH, glargine, detemir or degludec), and we do not have information on the use of prandial versus correction doses of rapid-acting insulin in the basal insulin-treated group.

## CONCLUSION

In conclusion, our observational study indicates that the use of SSI results in appropriate target glycemic control for most noncritical medicine and surgery patients with admission BG <180 mg/dL. In agreement with previous RCTs, our study confirms that SSI as monotherapy is frequently inadequate in patients with significant hyperglycemia >180 mg/dL.<sup>10,11,24,29</sup> We propose that an individualized approach to inpatient glycemic management is imperative, and cautious use of SSI may be a viable option for certain patients with mild hyperglycemia and admission BG <180 mg/dL. Further observational and randomized studies are needed to confirm the efficacy of SSI therapy in T2D patients with mild hyperglycemia. By identifying which subset of patients can be safely managed with SSI alone, we can better understand which patients will require escalation of therapy with intensive glucose management.

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