Incidence and Clinical Features of Diabetic Ketoacidosis After Bariatric and Metabolic Surgery

DOI: 10.2337/dc15-2647

Bariatric surgery is considered an effective (1,2) and relatively safe (3) option for the treatment of obesity and its comorbidities, including type 1 and type 2 diabetes. Diabetic ketoacidosis (DKA) is a life-threatening complication of diabetes, which mainly occurs in patients with type 1 diabetes but can present in patients with type 2 diabetes under stressful conditions (4,5). The characteristics of early postoperative DKA following bariatric surgery are largely unknown. The objective of this study is to determine the incidence and clinical circumstances underlying DKA after bariatric surgery.

From January 2005 to December 2015, a total of 12 patients who developed DKA within 90 days following bariatric surgery at an academic center were identified in a database approved by an institutional review board. All patients met the American Diabetes Association criteria for the diagnosis of DKA (4,5). Two endocrinologists independently verified the diagnosis of DKA in the included patients. Baseline characteristics, intraoperative data, and postoperative outcomes were assessed.

Of the 12 patients who developed early postoperative DKA, 8 had type 1 diabetes and 4 had type 2 diabetes (Table 1), which corresponded to the early postoperative incidence of 25% and 0.2% in type 1 and type 2 diabetes, respectively.

Patients had a female-to-male ratio of 5:1, a mean age of 49.1 ± 11.0 years, and a mean preoperative BMI of 43.1 ± 5.6 kg/m². Three patients (25%) had a past history of DKA. Eleven of the 12 patients (92%) were taking insulin before surgery. All had poor preoperative glycemic control with median glycated hemoglobin (A1C) of 9.3% (78 mmol/mol) (range 7.8–11.4% [62–101 mmol/mol]). Bariatric procedures included laparoscopic Roux-en-Y gastric bypass (n = 6), laparoscopic sleeve gastrectomy (n = 4), and laparoscopic adjustable gastric banding (n = 2). The median interval between bariatric surgery and DKA development was 12 days (range 0–61). One patient developed two episodes of postoperative DKA.

Inadequate insulin therapy or non-compliance was observed in eight (67%) patients. Three of these developed DKA in the immediate postoperative period before hospital discharge, which could be explained by the combination of under-treatment with insulin and surgical stress. Infection was a precipitating factor for the development of DKA in four (33%) patients. Poor oral intake (for several days) could be a contributing factor in three (25%) patients.

All patients were medically managed per established DKA management protocols with insulin infusion. Two patients with respiratory insufficiency needed intubation and mechanical ventilation. Other observed adverse events during the treatment of DKA included acute kidney injury (n = 2), deep vein thrombosis (n = 1), aspiration pneumonia (n = 1), and iatrogenic pneumothorax (n = 1). No mortality occurred.

Given the findings of this observational study, which is the largest case series of this kind to date, and the available literature (4,5), the following conclusions and suggestions can be drawn.

1. Postoperative DKA following bariatric surgery in patients with poorly controlled type 1 diabetes is not uncommon. Postbariatric surgery DKA can occur in patients with insulin-deficient type 2 diabetes but is uncommon and usually mild. High-risk patients should be informed about warning symptoms, signs, and predisposing factors of postoperative DKA.

2. Anesthesia and surgical stress, abrupt discontinuation of insulin or inadequate treatment in the perioperative period, postoperative infection, prolonged poor oral intake, and severe dehydration can be precipitating causes for postoperative DKA.

3. Optimizing glycemic control before surgery, not withholding basal insulin on the morning of surgery, and keeping the patients on insulin
| Patient no. | Sex | Age (years) | BMI (kg/m²) | Prior DKA | Drugs before Surgery | Preoperative A1C (%) | Surgery | Interval (days)* | Presenting symptoms | Severity of DKA* | Precipitating factors for DKA | Adverse events during treatment of DKA |
|------------|-----|-------------|-------------|-----------|----------------------|----------------------|---------|-----------------|-------------------|-----------------|-------------------------------|-------------------------------------|
| 1          | F   | 48          | 40          | Yes       | Insulin              | 10.8                 | LRYGB   | 9               | Fever and chills, Nausea, Abdominal pain, Dyspnea | Severe | Infection: severe wound infection at the site of the gastrostomy tube | Deep vein thrombosis |
| 2          | F   | 41          | 38          | Yes       | Insulin              | 9                    | LRYGB   | 45              | Nausea and vomiting | Severe | Poor oral intake and dehydration, Noncompliance with insulin, Developed DKA twice, 4 weeks apart | Acute kidney injury (during first episode), Respiratory failure needing intubation (during second episode) |
| 3          | F   | 43          | 46          | No        | Insulin              | 7.8                  | LSG     | 49              | Nausea and vomiting | Severe | Poor oral intake for 6 days | Respiratory insufficiency requiring mechanical ventilation, Aspiration pneumonia during intubation |
| 4          | F   | 40          | 54          | No        | Insulin              | 9.6                  | LRYGB   | 8               | Nausea and vomiting | Moderate | Inadequate insulin treatment: noncompliance with basal insulin after hospital discharge | Iatrogenic pneumothorax during central line insertion requiring chest tube placement |
| 5          | F   | 33          | 43          | Yes       | Insulin              | 8.7                  | LSG     | 3               | Nausea and vomiting, Abdominal pain | Moderate | DKA 3 days after surgery: Inadequate insulin treatment: not taking basal insulin since the day before surgery; not on insulin intravenous infusion in perioperative period, Surgical stress | None |
| 6          | F   | 45          | 48          | No        | Insulin, metformin   | 8.9                  | LRYGB   | 61              | Nausea and vomiting, Chest pain, Dyspnea | Mild | Inadequate insulin treatment: recent reduction in insulin dosage | None |

*Continued on p. e3*
| Patient no. | Sex | Age (years) | BMI (kg/m²) | Prior DKA | Drugs before Surgery | Preoperative A1C (%) | Surgery | Interval (days)^ | Presenting symptoms | Severity of DKA* | Precipitating factors for DKA | Adverse events during treatment of DKA |
|------------|-----|-------------|-------------|-----------|----------------------|----------------------|---------|----------------|---------------------|----------------|--------------------------|----------------------------------|
| 7          | M   | 63          | 40          | No        | Insulin              | 9.2                  | LSG     | 0              | Immediate postoperative | Mild            | DKA in postsurgery recovery room: | None |
|            |     |             |             |           |                      |                      |         |                | Inadequate insulin treatment: not taking basal insulin since the day before surgery, which only 20% of usual dosage was taken; not on insulin intravenous infusion in perioperative period | |
|            |     |             |             |           |                      |                      |         |                | Surgical stress |                | DKA 1 day after surgery: | None |
|            |     |             |             |           |                      |                      |         |                | Inadequate insulin treatment: not taking basal insulin since the day of surgery; not on insulin intravenous infusion in perioperative period | |
|            |     |             |             |           |                      |                      |         |                | Surgical stress |                |                          | |
| 8          | M   | 65          | 40          | No        | Insulin              | 7.8                  | LAGB    | 1              | Immediate postoperative | Mild            | DKA 1 day after surgery: | None |
|            |     |             |             |           |                      |                      |         |                | Inadequate insulin treatment: not taking basal insulin since the day of surgery; not on insulin intravenous infusion in perioperative period | |
|            |     |             |             |           |                      |                      |         |                | Surgical stress |                |                          | |
| 9          | F   | 53          | 35          | No        | Insulin, metformin   | 11.4                 | LRYGB   | 8              | Fever and chills | Moderate       | Infection: abdominal wall (laparoscopic port site) and intra-abdominal abscesses | None |
| 10         | F   | 53          | 51          | No        | Insulin              | 9.5                  | LRYGB   | 17             | Nausea and vomiting | Mild           | Omission of insulin: on insulin for many years, discharged home on no insulin | None |
|            |     |             |             |           |                      |                      |         |                | Abdominal pain |                |                          | |
| 11         | F   | 39          | 42          | No        | Insulin              | 9.4                  | LSG     | 15             | Nausea and vomiting | Mild           | Omission of insulin: on insulin for many years, discharged home on no insulin | None |
|            |     |             |             |           |                      |                      |         |                | Abdominal pain |                | Septicemia secondary to urinary tract infection with *Klebsiella pneumoniae* | |
| 12         | F   | 66          | 40          | No        | Diet control         | 10.5                 | LAGB    | 24             | Fever and chills | Mild           | Infection: septicemia with β-hemolytic group A (unknown source) | None |
|            |     |             |             |           |                      |                      |         |                | Nausea and vomiting |                | Poor oral intake for 5 days | |

F, Female; LAGB, laparoscopic adjustable gastric banding; LRYGB, laparoscopic Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy; M, male. ^ Interval between bariatric surgery and DKA (days). *Severity of DKA based on American Diabetes Association criteria (4,5).
intravenous infusion protocols in the perioperative period are necessary to prevent postoperative DKA in patients with severe diabetes.

4. A low-calorie diet (before and after surgery) and rerouting the gastrointestinal tract decrease the need for insulin. Adjustment of basal insulin dosage before surgery when the patient is on a low-calorie diet (which usually starts 2 weeks before surgery), in immediate postoperative period, and after hospital discharge by endocrinologists and diabetes nurse practitioners is critical in patients with type 1 diabetes and insulin-deficient type 2 diabetes. In addition, the insulin regimen and dosage have to be tailored after the development of postoperative infection in such patients.

5. Postbariatric surgery DKA can present with abdominal pain, nausea, and vomiting, which can lead to unnecessary imaging studies to rule out intra-abdominal surgical complications, such as leak, abscess, gastric stenosis, and intestinal obstruction.

6. Early detection and aggressive diabetes care are needed to treat this serious adverse event.

Duality of Interest. No potential conflicts of interest relevant to this article were reported.

Author Contributions. A.A. was responsible for concept development and study design. A.A., S.R.K., B.B., D.F., S.A.B., and P.R.S. were involved in the management of patients. A.A., S.P., G.S., and D.F. performed data collection and analysis. All coauthors reviewed the data. A.A. drafted the manuscript, and all coauthors revised and edited the final version. A.A. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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