



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

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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  $49.1 \pm 11.0$  years, and a mean preoperative BMI of  $43.1 \pm 5.6$  kg/m<sup>2</sup>. 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 glycosylated 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. Nausea and vomiting and abdominal pain were common presenting symptoms.

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 undertreatment 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

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**Table 1—Characteristics of individual patients with DKA after bariatric surgery (n = 12)**

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

*Continued on p. e52*

**Table 1—Continued**

Patient no.	Sex	Age (years)	BMI (kg/m <sup>2</sup> )	Prior DKA	Drugs before surgery	Preoperative A1C (%)	Surgery	Interval (days) <sup>Δ</sup>	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: • 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	None
8	M	65	40	No	Insulin	7.8	LAGB	1	• Immediate postoperative	Mild	• Surgical stress DKA 1 day after surgery: • Inadequate insulin treatment: not taking basal insulin since the day of surgery; not on insulin intravenous infusion in perioperative period • Surgical stress	None
Type 2 diabetes												
1	F	53	35	No	Insulin, metformin	11.4	LRYGB	8	• Fever and chills • Nausea and vomiting • Abdominal pain	Moderate	• Infection: abdominal wall (laparoscopic port site) and intra-abdominal abscesses	None
2	F	53	51	No	Insulin	9.5	LRYGB	17	• Nausea and vomiting • Abdominal pain	Mild	• Omission of insulin: on insulin for many years, discharged home on no insulin	None
3	F	39	42	No	Insulin	9.4	LSG	15	• Nausea and vomiting • Abdominal pain	Mild	• Omission of insulin: on insulin for many years, discharged home on no insulin • Septicemia secondary to urinary tract infection with <i>Klebsiella pneumoniae</i>	• Acute kidney injury in patient with history of renal transplant
4	F	66	40	No	Diet control	10.5	LAGB	24	• Fever and chills • Nausea and vomiting • Loss of appetite	Mild	• Infection: septicemia with β-hemolytic group A (unknown source) • Poor oral intake for 5 days	None

F, female; LAGB, laparoscopic adjustable gastric banding; LRYGB, laparoscopic Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy; M, male. <sup>Δ</sup>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.

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