Celiac Disease and Bariatric Surgery: A Systematic Review of Current Literature

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Abstract
Background: Celiac disease (CD) is a clinical entity increasingly recognized in the severe obese population and its impact on outcomes following bariatric surgery is not currently understood. We aimed to systematically review the nutritional and clinical outcomes for patients with obesity and CD following bariatric surgery.

Methods: Systematic search of MEDLINE, Embase, Scopus, and Web of Science was conducted in September 2021. Study followed PRISMA guidelines. Studies evaluating adult patients with CD undergoing bariatric surgery were included. Outcomes were descriptive due to limited studies.

Results: Our literature review produced 9 studies with 152 patients. The weighted mean age of included patients was 44.2 years (±9.55 years) and 98% (n = 149) were female. Patients diagnosed with CD post-operatively appear to experience substantial perioperative and nutritional complications following bariatric surgery. However, pre-operative diagnosis may allow patient optimization and current studies suggest similar bariatric surgery outcomes can be achieved in these patients when the diagnosis is known. However, this study also highlights a scarcity of evidence evaluating the rate of CD and outcomes for these patients after bariatric surgery.

Conclusion: Current literature lacks quality, comparative studies investigating the short- and long-term surgical complications and nutritional outcomes of bariatric surgery within patients who have co-diagnoses of obesity and CD. Despite these limitations, our group recommends pre-operative CD screening in patients experiencing either classical GI symptoms of CD including diarrhea, steatorrhea, bloating, or undifferentiated abdominal pain.

Keywords
bariatric surgery, celiac disease, RYGB, sleeve gastrectomy

Key Learning Points
• CD and bariatric surgery can produce similar nutritional deficiencies.
• Missed pre-operative CD diagnoses reportedly experience severe GI symptoms post-operatively.
• Literature lacks studies on clinical outcomes of bariatric surgery in patients with obesity and CD.

Introduction
Celiac disease (CD) is an autoimmune disorder characterized by a localized pathologic immune response to gliadin at the intestinal mucosa.¹ This results in an inflammatory environment that leads to declines in micro- and macro-nutrient absorption. The identification of subclinical phenotypes of CD has led to an increase in its diagnosis across all weight spectrums,² with the prevalence of CD in individuals with obesity ranging from 3% to 13%.³⁻⁵

For patients with a BMI ≥40 kg/m² without co-morbidities and those with a BMI ≥35 kg/m² and co-morbidities, metabolic surgery confers the most sustained long-term treatment that not only offers rapid weight loss and glycemic control but improves metabolic outcomes like dyslipidemia, hypertension, and obstructive
sleep apnea. While regarded as safe and highly-effective procedures, both malabsorptive and restrictive bariatric procedures can lead to macro- and micronutrient deficiencies in a subset of patients. The growing need for bariatric surgery worldwide together with the increasing prevalence of subclinical CD poses a challenging dilemma regarding how patients are screened, selected, and managed peri-operatively to avoid the potentially disastrous consequences of malnutrition. Unfortunately, this relationship is currently poorly understood, and represents a potential clinical challenge if not diagnosed pre-operatively.

This study aims to systematically search and summarize the current literature regarding celiac disease in the context of bariatric surgery. Our primary outcomes were to evaluate differences in nutritional deficiencies and post-operative outcomes between CD and non-CD counterparts following bariatric surgery.

Methods
Search Strategy
The medical librarian (JK) developed and executed comprehensive searches in Ovid MEDLINE, Ovid Embase, Scopus, and Cochrane Library (Wiley) on June 4, 2021. The search terms can be found in Appendix 1. The search was updated on September 27, 2021. All relevant keywords pertaining to celiac disease and bariatric surgery were included in the search strategies. No language or date limits were applied. Refer to the appendices for full-text search strategies. In addition to subscription databases, the research team searched Google Scholar and evaluated the first 200 results for inclusion. Bibliographies from included studies were also reviewed. The reporting of this systematic review was guided by the standards of the 2020 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement with checklist provided as per the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) guidelines (Supplemental Material 1).

Selection Criteria
Titles and abstracts were first screened for inclusion by 2 independent reviewers (LR and VM). Studies meeting inclusion criteria then underwent dual-author full text review. Screening was based on the following inclusion criteria: adult patients (age ≥ 18 years), patients with a history of bariatric surgery, and patients diagnosed with CD. Diagnosis of CD was defined as having either positive serological findings (at least one of [IgA or IgG]: anti-tissue transglutaminase, anti-endomysial, anti-gliadin antibody), or positive intestinal mucosal biopsy (partial/subtotal/complete villous atrophy, with or without crypt hyperplasia), and if initiated, a response to a gluten-free diet (GFD). Studies which only reported gastric banding procedures were excluded due to the historical nature of this procedure. Other exclusion criteria included studies published solely as abstracts, letters, reviews, or were duplicates. Our key outcomes of interest included nutritional deficiencies and clinical course following bariatric surgery.

Assessment of Risk of Bias
Included studies were assessed for methodological quality and bias utilizing the methodological index for non-randomized studies (MINORS) criteria for non-randomized cohort studies.

Data Analysis
Continuous data was reported as absolute numbers and weighted means, while categorical data was represented as proportions. A meta-analysis was conducted if there were a minimum of 3 studies of high quality (low risk of bias) examining the same outcome.

Results
Study Selection
Search results yielded 562 results, and after eliminating duplicates, 334 unique studies from Ovid MEDLINE, Ovid Embase, Scopus, and Cochrane Library databases, and 200 studies from Google Scholar were screened (Figure 1). Following title and abstract screening, 518 studies were excluded, and 16 studies were included for full-text review. Full-text review further excluded 7 studies; reasons for exclusion can be found in Figure 1. A total of 9 studies9-17 were deemed acceptable for the present review, these included: 1 retrospective case series, 1 case series, 5 case reports, and 2 retrospective cohort study (Table 1).

Study Demographics
The 9 studies reported a total of 152 patients who underwent bariatric surgery for obesity management and had a diagnosis of CD (Table 1).9-17 The weighted mean age at time of surgery was 44.2 years (± 9.55 years) and 98% of reported patients were female. Reported patient co-morbidities are found in Table 1. Eighteen patients had a pre-operative CD diagnosis, 6 had a post-operative CD diagnosis, and the time of CD diagnosis for the remaining 126 was not reported. Regarding type of bariatric procedure performed, 9 patients underwent RYGB, 2 received
a jejunoileal bypass, 9 had a sleeve gastrectomy, 3 underwent duodenal switch, 1 patient was reported to have gastric bypass with no specific indication to type of procedure, 2 patients had yet to undergo bariatric surgery at time of report, and the remaining 126 patients were reported to have either a laparoscopic or open RYGB, gastric band, or SG with no indication to how this was stratified. Follow-up after bariatric surgery ranged from none to 6.9 years.

**Patient Outcomes**

Freeman et al\(^9\) reported 3 patients with a pre-operative diagnosis of CD via serology and biopsy findings, with whom 2 adhered to a strict GFD prior to surgery. Of these 3 patients who underwent RYGB for treatment of obesity, only 2 developed postoperative vitamin D deficiencies, which were correctable by oral supplementation (Table 2). No other deficiencies were identified in these patients. Similarly, Cuenca-Abenta et al\(^15\) described 5 patients who were diagnosed with CD during pre-operative evaluation due to abnormal endoscopic findings and subsequent confirmation via duodenal biopsy. Three of the 5 patients underwent sleeve gastrectomy and were reported to have an uneventful post-operative course.

Four case reports\(^{10-12,16}\) outlined patients experiencing either nausea, vomiting, diarrhea, and, in 1 instance,\(^{10}\) mental status fluctuations and eventual death following bariatric surgery (Table 2). In all cases, post-operative biopsies demonstrated jejunal villous atrophy and crypt hyperplasia, and a diagnosis of CD\(^{11,12,16}\) or subclinical CD\(^{10}\) were made. Marini et al\(^{11}\), Owen et al\(^{12}\), and Pané et al\(^{16}\) reported symptom alleviation following implementation of a GFD. Logan and Ferguson\(^{10}\) initiated a non-strict GFD and eventual reversal of the jejunoileal bypass; the patient died shortly after these measures. Conversely,
# Table 1. Characteristics of Included Studies.

| Study                  | Study design    | Patients (n) | Gender (% female) | Treatment arms (n) | Mean age (y) | Co-morbidities                                                                 | Time of CD diagnosis | Bariatric procedure (n) | Follow-up |
|------------------------|-----------------|--------------|-------------------|-------------------|--------------|--------------------------------------------------------------------------------|----------------------|-------------------------|-----------|
| Freeman et al⁹         | Retrospective Case Series | 3            | 100               | —                 | 45           | OSA, asthma, NIDT2DM, GERD, NAFLD, PF, CTS, depression, anxiety, HL, PCOS       | All Pre-op           | RYGB                    | 1-5 y     |
| Logan and Ferguson¹⁰   | Case Report      | 1            | 100               | —                 | 49           | Not reported                                                                    | Post-op              | Jejunooileal bypass     | 5 mo      |
| Marini et al¹¹         | Case Report      | 1            | 100               | —                 | 36           | Not reported                                                                    | Post-op              | Gastric bypass          | 1 y       |
| Owen et al¹²           | Case Report      | 1            | 100               | —                 | 28           | Chronic lymphedema                                                               | Post-op              | Jejunooileal bypass     | 5 mo      |
| Sharma et al¹³         | Retrospective Cohort | 1499         | 79.7              | CSO + CD (1373)    | 53.1         | HTN, CAD, HL, PCOS                                                               | —                    | Lap or open RYGB or lap gastric band or lap SG | None      |
| Sharma et al           | Case Report      | 1499         | 79.7              | CSO + CD + BSx (126) | 44.2         | Unknown⁴                                                                       | —                    | RYGB (6) or SG (5) or duodenal switch (2) | 2.4-6.9 y |
| Hurtado et al¹⁴        | Retrospective Matched Case-Control | 78          | 84.6              | CD + BSx (13)      | 44.7         | GERD, OSA, Depression, CVD, DJD, HTN, IFG, T1DM, T2DM, dyslipidemia             | Pre-op (11)          | —                      |           |
| Cuenca-Abente et al¹⁵  | Case Series      | 3            | 100               | —                 | 40           | Not reported                                                                    | All Pre-op           | SG (3)⁵                 | 16 mo     |
| Pané et al¹⁶           | Case Report      | 1            | 100               | —                 | 61           | HTN, T2DM                                                                       | Post-op              | Duodenal switch         | 4 mo      |
| Ramraj et al¹⁷         | Case Report      | 1            | 100               | —                 | 53           | Thalassemia minor, T2DM, OSA                                                   | Pre-op              | SG                      | 1 y       |

Note. BSx = bariatric surgery; CAD = coronary artery disease; CD = celiac disease; CSO = clinically severe obesity; CTS = carpal tunnel syndrome; CVD = cerebrovascular disease; DJD = degenerative joint disease; GERD = gastroesophageal reflux disease; HL = hyperlipidia; HTN = hypertension; IFG = impaired fasting glucose; NAFLD = non-alcoholic fatty liver disease; NIDT2M = non-insulin dependent type 2 diabetes mellitus; OSA = obstructive sleep apnea; PCOS = polycystic ovarian syndrome; PF = plantar fasciitis; RYGB = Roux-en-Y Gastric Bypass; SG = sleeve gastrectomy; T1 or 2DM = type 1 or 2 diabetes mellitus.

⁴Hospital records with co-diagnoses of celiac disease and history of bariatric surgery were utilized; no indication of when celiac disease diagnosis occurred was given.

⁵At time of report only 3 patients had undergone sleeve gastrectomy while 2 were undergoing pre-operative evaluation.
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Ramraj et al\textsuperscript{17} reported an uneventful post-sleeve gastrectomy course in a patient with celiac disease whose nutrient deficiencies were corrected pre-operatively. Nutritional status was not thoroughly assessed in all case reports (Table 2).

Sharma et al\textsuperscript{13} reported the impact of bariatric surgery (RYGB, gastric banding, or SG) on clinical, surgical, and nutritional outcomes in patients with obesity and CD. Patients who underwent bariatric surgery did experience vitamin D and zinc deficiencies, and anemia but were statistically only shown to have an increased prevalence and risk of vitamin D deficiency (Table 2). When compared to patients with obesity and CD who did not undergo bariatric surgery, those that received surgery had a reduced risk of renal failure, sepsis, respiratory failure, and urinary tract infections (UTI), and an increased risk of strictures. No differences in anemia, thiamine, or zinc levels were detected between the groups. However, comparisons between type of bariatric surgery and clinical outcomes were not made and several confounding variables, including patient demographics and control groups which are discussed below, raise concerns about the widespread applicability of their results.

Lastly, Hurtado et al\textsuperscript{14} was the only cohort study comparing the effects of bariatric surgery (RYGB, SG, and duodenal switch) in patients with CD against a demographically similar control group who did not have CD. Patients with CD did not experience any statistically different nutritional deficiency and clinical outcomes than those without CD (Table 2). Vitamin D and iron were the most common deficiencies amongst both groups. Those with CD were significantly more likely to experience malodorous and oily stools post-operatively and were found to have lower levels of HDL 12-months following surgery. When stratified by procedure there was no difference in the incidence of nutritional deficiencies in patients with CD.

### Table 2. Reported Post-Operative Nutritional Deficiencies and Clinical Outcomes Experienced by Patients With Celiac Disease and Their Response to Treatment.

| Study               | Patients (n) | Nutritional deficiencies | Other clinical outcomes                                                                 | Treatment (response)                                                                 |
|---------------------|--------------|--------------------------|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Freeman et al\textsuperscript{9} | 3            | Vitamin D (2); None (1)  | None                                                                                     | Oral supplementation (return to baseline)                                           |
| Logan and Ferguson\textsuperscript{10} | 1            | Nutritional status not assessed | Vomiting; hepatic encephalopathy; elevated serum bilirubin, LFTs, urea; decreased serum albumin; altered mental status | Non-strict GFD; reversal of bypass 6 mo post-op (patient demise 1 wk later)           |
| Marini et al\textsuperscript{11} | 1            | Anemia; Vitamin D, and B\textsubscript{12} | Hair loss; nausea, vomiting, diarrhea, nocturnal diarrhea, asthenia, post-prandial pain; decreased albumin; elevated AST | Enteral GFD ×3 d followed with GFD PO (all symptoms resolved and 4.6 kg weight regain) |
| Owen et al\textsuperscript{12} | 1            | Anemia\textsuperscript{a} | Nausea, vomiting, diarrhea; anorexic, cachexia, dehydration | Parenteral diet (symptoms subsided) with transition to GFD (5 mo later weight regain, asymptomatic, return of normal jejunal mucosal architecture) |
| Sharma et al\textsuperscript{13} | 126\textsuperscript{b} | Vitamin D (12.7%); Anemia\textsuperscript{a} (7.2%); Zinc (0.8%) | Strictures (12.7%); Hemorrhage (0.8%); Pneumonia (0.8%); Malnutrition (0.8%) | Did not report on long-term outcomes or patient management |
| Hurtado et al\textsuperscript{14} | 13\textsuperscript{c} | Anemia, Iron, Vitamins B\textsubscript{12}, D, A, and E, Calcium, Magnesium, Zinc | Dumping Syndrome (7.7%); Malodorous/oily stools (23.1%); Diarrhea (15.4%); Bloating (30.8%); Abdominal pain (23.1%) | Did not report patient management. All nutritional outcomes did not significantly differ from controls. |
| Cuenca-Abente et al\textsuperscript{15} | 3            | Did not report | Reported as uneventful | — |
| Pané et al\textsuperscript{16} | 1            | Vitamins A and D | Severe diarrhea (15->30 stools/day); postprandial pain and nausea | Parenteral nutrition and initiation of GFD (symptom resolution 1 wk post-GFD initiation) |
| Ramraj et al\textsuperscript{17} | 1            | Corrected pre-op; Did not report post-op | None reported | — |

\textsuperscript{Note.} AST = aspartate aminotransferase; GFD = gluten-free diet; LFT = liver function tests (AST, ALT).

\textsuperscript{a}Type of anemia was not specified, iron and ferritin levels were not reported on.

\textsuperscript{b}Of the 1499 patients included in the study, 126 had co-diagnoses of obesity and CD, and underwent bariatric surgery.

\textsuperscript{c}Of the 78 patients included in the study, 13 had a diagnosis of CD and underwent bariatric surgery.
Risk of Bias for Included Study

The MINORS criteria was used to assess the included retrospective cohort studies for risk of bias (Supplemental Material 2, Table S1). Sharma et al did not meet ideal criteria as the compared groups had differences within their demographics, there was a lack of prospective calculation of study size, and there was no follow-up with patients. Similarly, Hurtado et al also did not meet ideal criteria as study design prevented blinding and study size was not calculated.

Discussion

Due to the potential for nutritional deficiency to occur in both CD and bariatric procedures, we aimed to investigate the impact these have together on nutritional status, disease progression, and clinical outcomes. The current review systematically included 2 case series, 5 case reports, and 2 retrospective cohort studies discussing patient outcomes in patients with CD undergoing bariatric surgery. Apparent from the included studies is the potential for adverse outcomes to occur when CD exists following metabolic surgery. We also highlight the sparsity of current studies, highlighting the need for further investigations outlining the prevalence and impact of CD within this population.

A notable finding in this study was the variability of outcomes following bariatric surgery dependent on the timing of CD diagnosis, either being pre-operative or post-operative. In patients with a post-operative CD diagnosis, persistent diarrhea, vomiting, malodorous stools, clinically severe weight loss, abdominal pain, and hospitalization occurred. Although these patients returned to near or fully asymptomatic levels following their post-operative diagnosis and introduction of a GFD, they experienced a myriad of additional symptoms than those with a pre-operative CD diagnosis. Comparatively, patients with pre-operative CD diagnoses appeared to have unremarkable post-operative courses following either RYGB or SG. This should also raise awareness about the potential for persistent severe nutritional deficiencies following bariatric surgery in patients with CD who are non-adherent to a GFD. Further, these outcomes suggest that awareness of CD diagnosis prior to bariatric intervention may enable diet, procedural, and follow-up optimization to reduce potential malabsorptive complications. To assist with both pre-operative diagnosis and post-operative consideration Table 3 summarizes various nutritional deficiencies that are seen in CD, RYGB, and SG along with possible clinical presentations and recommended nutritional screening procedures.

On the other hand, 2 retrospective cohort studies demonstrated that bariatric surgery can be performed relatively safely in patients with CD when the diagnosis is known pre-operatively. Sharma et al investigated outcomes in patients with CD, comparing those who underwent bariatric surgery with those who did not. While rates of sepsis, UTI, renal failure, and respiratory failure were similar, there appeared to a small be increased risk of vitamin D deficiency and strictures for patients receiving bariatric surgery. However, the comparator group (those receiving bariatric surgery) were predominantly hospitalized non-electively, were younger, and lacked prospective data collection. Furthermore, clinical outcomes assessed were not specifically outlined in their methods, comparisons were not stratified by procedure type, and no follow-up period was assessed, which should be considered when interpreting results. Further investigations evaluating more similar comparator groups should be done to adequately ascertain the safety profile of bariatric surgery in those with pre-operative CD diagnoses. The second cohort study was the only study to compare nutritional, clinical, and comorbid outcomes following a variety of bariatric procedures (RYGB, SG, and duodenal switch) in patients with CD compared to those without CD. No statistical significance in nutritional deficiencies were found, and malodorous and oily stools were the only significant GI symptoms experienced more in those with CD. However, the study only included 13 patients with CD and did not specify timing of CD diagnosis. There continues to be a need for more robust investigations elucidating the safest means of metabolic surgery for those with CD.

Overall, in terms of managing patients with CD who are being considered for bariatric surgery, limited evidence, and guidelines currently exist. Currently, the American Society for Metabolic and Bariatric Surgery (ASMBS) recommends a preprocedural history, physical exam, and nutrient screening in all patients, and suggests that routine upper endoscopy prior to bariatric surgery is justifiable based on the surgeon’s discretion. However, the ASMBS does not make recommendations on screening for specific enteropathies unless clinically indicated during the pre-procedure work-up. It is noted that if persistent and severe GI symptoms occur ≥5 days post-operatively then a thorough history, physical and upper endoscopy with small bowel biopsies should be done to evaluate for CD. In patients with CD, 3% to 13% are estimated to have a co-diagnosis of obesity, inclusion of a simple intestinal biopsy during pre-procedure endoscopy may elucidate both the true prevalence of CD in patients with obesity who undergo bariatric surgery, and aid in the
Table 3. Nutritional Deficiencies, Their Clinical Presentations, and Recommended Nutritional Screening Recommendations in CD, and RYGB and SG, post-operatively. 1,19-23

| Nutritional deficiencies | Clinical presentation | Screening recommendations |
|--------------------------|-----------------------|--------------------------|
| **Celiac Disease**       |                       |                          |
| Iron                     | Anemia                | Nutritional screening in place during CD work-up; no other nutritional screening recommendations unless clinically indicated. |
| B Vitamins               | Malabsorption syndrome|                          |
| Fat-soluble vitamins     | Fractures/Osteoporosis|                          |
| (A, D, E, K)             | Lactose Intolerance   |                          |
| Calcium                  | Muscle Wasting        |                          |
| Zinc                     | Stomatitis            |                          |
| Magnesium                | Pallor                |                          |
|                          | Easy bruising         |                          |
| **RYGB**                 |                       |                          |
| Vitamin B$_1$            | Anemia                | B$_1$: For high-risk groups; presence of signs and symptoms or risk factors should be assessed within first 6-mo post-WLS and then every 3-6 mo until symptoms resolve. |
| Vitamin B$_{12}$         | Malabsorption Syndrome| B$_{12}$: Every 3 mo in first year post-WLS and then annually or as clinically indicated in those on medications worsening B$_{12}$ deficiency |
| Folate                   | Fractures/osteoporosis| Folate: Screening recommended for all patients |
| Iron                     | Neurological abnormalities| Iron: Screen within 3 mo post-WLS, then every 3-6 mo for 12 mo, and then annually |
| Vitamin D and Calcium    | Anorexia              | D and Calcium: Routine screening recommended |
| Vitamins A, E, and K     | Weakness/fatigue      | A: screening recommended within first year post-WLS |
| Zinc                     | Nighttime blindness   | E and K: Deficiency uncommon, screen only if symptomatic |
| Copper                   |                       | Zinc: Annual screening  |
|                          |                       | Copper: Annual screening|
| **Sleeve Gastrectomy**   |                       |                          |
| Vitamin B$_1$            | Anemia                | B$_1$: For high-risk groups; presence of signs and symptoms or risk factors should be assessed within first 6-mo post-WLS and then every 3-6 mo until symptoms resolve. |
| Vitamin B$_{12}$         | Fractures/osteoporosis| B$_{12}$: Every 3 mo in first year post-WLS and then annually or as clinically indicated in those on medications worsening B$_{12}$ deficiency |
| Folate                   | Neurological abnormalities| Folate: Screening recommended for all patients |
| Iron                     | Weakness/fatigue      | Iron: Screen within 3 mo post-WLS, then every 3-6 mo for 12 mo, and then annually |
| Vitamin D and Calcium    | Nighttime blindness   | D and Calcium: Routine screening recommended |
| Vitamins A, E, and K     |                       | A: No screening recommendation post-SG |
| Zinc                     |                       | E and K: Deficiency uncommon, screen only if symptomatic |
|                          |                       | Zinc: No screening recommendation post-SG |

**Note.** SG = sleeve gastrectomy; WLS = weight-loss surgery.

*Females, blacks, patients not attending clinic after surgery, those with thiamine deficiency risk factors, patients with: GI symptoms (intractable nausea, vomiting, constipation, jejunal dilation, megacolon), concomitant diseases, small bowel bacterial overgrowth; other risk factors: excessive alcohol consumptions, rapid weight loss, or malnutrition. 19

*bDue to the restrictive nature of SG, nutritional deficiencies are far less common than in RYGB.
prevention of severe post-surgical GI symptoms. Another consideration is that many patients with obesity are prescribed weight-loss medications, like GLP-1 agonists and SGLT-2 inhibitors, that can contribute to symptoms synonymous with those of classical CD; in those patients, having histology available may reveal CD in individuals undergoing surgery in whom medications may mask the diagnosis.

Along with CD screening, consideration should be given for what type of bariatric procedure should be offered for obesity management in the setting of co-existing CD. The malabsorptive state imposed by CD could place a patient at risk for severe nutritional deficiencies if given a procedure that produces similar effects. RYGB has been shown to be a more effective procedure in reducing comorbidities and managing weight in obesity, although more complications have been reported with this procedure.24,25 Similarly, procedures such as single anastomosis duodenal switch may place patients at greater risk of malabsorption, and avoiding these complications may be wise in patients with CD. However, this risk remains only theoretical because studies have yet to comparatively evaluated malabsorptive and restrictive procedures in patients with CD. Similarly, these more complex procedures have higher risk of complications including marginal ulceration, anastomotic stricture and leak, and bowel obstruction. It remains unknown how the inflammatory state imposed by CD interplays with the development of these complications and future studies evaluating these questions would be of interest.

A major limitation of the current review is the paucity of studies investigating the relationship between CD and bariatric surgery, type of bariatric surgery safest in this patient population, and the long-term outcomes of patients with obesity and CD who are treated with metabolic surgery. The low number of patients reported and wide variety of metabolic procedures performed limited the ability for meta-analysis of current literature. Also, lack of and/or inadequate follow-up in several studies may have reduced the number of nutritional deficiencies reported. Another limitation is the risk of bias within the cohort studies3,14 included in our review. As these were the only cohort studies found that investigated this patient population in the context of bariatric surgery, we opted for inclusion and considered their bias when interpreting their results.

Despite these limitations, our work provides the first systematic review demonstrating the large gap of knowledge elucidating the safety and outcomes of bariatric surgery on patients with obesity and CD. Future research should include comparative studies investigating the short- and long-term surgical complications and nutritional outcomes of bariatric surgery within this patient population. Also, comparative evaluation of outcomes following SG versus RYGB would be beneficial to further guide procedure selection. Despite the above limitations, given the potential adverse consequences associated with a missed CD diagnosis in the context of metabolic surgery predisposing for malnutrition we propose that intestinal biopsy during pre-operative upper GI endoscopy and serum anti-TTG should be done in patients who are experiencing symptoms of CD including diarrhea with or without abdominal pain, steatorrhea, bloating, flatulence, or undifferentiated abdominal pain.5 For symptomatic individuals, serum anti-TTG is both sensitive and specific (>95%), while >4 biopsies offer the best for CD diagnosis, with a duodenal bulb biopsy from either the 9- or 12-o’clock position in addition to biopsies of the distal duodenum having a sensitivity of 96%.8 The American College of Gastroenterology guidelines provide a review of the diagnostic yield, criteria, and ongoing management of CD, which may be useful for surgeons hoping to implement screening and management strategies.5 While little evidence exists to guide this screening, this screening approach would be feasible, low risk, and may enable patient optimization with GF diet preoperatively to reduce risks of serious complications. Future investigations should aim to explore the utility of this measure in bariatric surgery work-up and its impact on long-term outcomes following surgery.

Conclusion

With improvements in diagnostic measures, CD is becoming increasingly recognized in patients with obesity. However, the true prevalence of CD in patients who undergo bariatric surgery is not yet known. There is a large gap of knowledge investigating the impact CD has on clinical and nutritional outcomes following bariatric surgery. Further studies should define the value of preprocedural enteropathy screening in bariatric surgery and delineate the most effective and safe bariatric procedure for patients with obesity and CD co-diagnoses.
### Appendix 1. Database Search Strategies.

| Database          | Search strategy                                                                                      |
|-------------------|-------------------------------------------------------------------------------------------------------|
| **MEDLINE**       | 1. bariatric*.mp. or exp Bariatric Surgery/                                                          |
| **Ovid MEDLINE(R)** | 2. exp Biliopancreatic Diversion/or (biliopancreatic diversion* or biliopancreatic bypass).mp.       |
| **ALL 1946 to**   | 3. duodenal switch*.mp.                                                                             |
| **September 24, 2021** | 4. (gastric bypass* or gastric surgery*).mp.                                                          |
| **Ovid Embase**   | 5. exp Gastroenterostomy/or gastroenterostom*.mp.                                                    |
| **1974 to 2021**  | 6. gastrogastrostom*.mp.                                                                             |
| **September 24**  | 7. gastrojejunostom*.mp.                                                                            |
| **Intervention**  | 8. gastroileal bypass.mp.                                                                           |
| **Strategies**    | 9. gastroplast*.mp.                                                                                 |
| **or/1-20**       | 10. intestin* bypass.mp. or exp Jejunoileal Bypass/                                                   |
| **or/1-19**       | 11. ((jejunoileal or jejuno-ileal or jejunoiilial or jejuno-ilial or jejunocolic) adj bypass).mp.     |
| **or/1-18**       | 12. mason* procedure*.mp.                                                                          |
| **or/1-17**       | 13. ((obesity or obese or weight) adj5 surg*).mp.                                                     |
| **or/1-16**       | 14. exp Obesity/su [Surgery]                                                                          |
| **or/1-15**       | 15. restrictive surg*.mp.                                                                            |
| **or/1-14**       | 16. roux-en-y.mp. or exp Anastomosis, Roux-en-Y/                                                      |
| **or/1-13**       | 17. scopinaro.mp.                                                                                    |
| **or/1-12**       | 18. sleeve gastrectom*.mp.                                                                           |
| **or/1-11**       | 19. ((stomach or gastric) adj5 stapl*).mp.                                                            |
| **or/1-10**       | 20. (SADI or SADI-S or single anastomosis duodeno*).mp.                                              |
| **or/1-9**        | 21. exp Celiac Disease/                                                                              |
| **or/1-8**        | 22. ((celiac or coeliac) adj1 (disease* or syndrome*)).mp.                                           |
| **or/1-7**        | 23. tissue transglutaminase antibod*.mp.                                                             |
| **or/1-6**        | 24. anti-endomysium antibod*.mp.                                                                     |
| **or/1-5**        | 25. endomysis* antibod*.mp.                                                                          |
| **or/1-4**        | 26. exp protein glutamine gamma glutamyltransferase antibody/                                        |
| **or/1-3**        | 27. exp endomysium antibody/                                                                         |
| **or/1-2**        | 28. or/21-27                                                                                         |
| **or/1**          | 29. 20 and 28                                                                                        |

(continued)
### Database Search strategy

**Cochrane Library (via Wiley)**
1. MeSH descriptor: [Bariatric Surgery] 2 tree(s) exploded
2. bariatric
3. MeSH descriptor: [Biliopancreatic Diversion] explode all trees
4. “biliopancreatic diversion” or “biliopancreatic bypass” or “duodenal switch”
5. “gastric bypass” or “gastric surgery”
6. MeSH descriptor: [Gastroenterostomy] explode all trees
7. gastroenterostomy or gastrogastrostomy or gastrojejunostomy or “gastroileal bypass”
8. gastroplasty or “intestin” bypass
9. MeSH descriptor: [Jejunoileal Bypass] 4 tree(s) exploded
10. ((jejunoileal or jejuno-ileal or jejunoilial or jejuno-ilial or jejunoocolic) near/1 bypass)
11. “mason” procedure or “restrictive surgery”
12. ((obesity or obese or weight) near/5 surg)
13. roux-en-y
14. MeSH descriptor: [Anastomosis, Roux-en-Y] explode all trees
15. scopinaro
16. “sleeve gastrectomy”
17. ((stomach or gastric) near/5 stapl)
18. SADI or SADI-S or “single anastomosis duodeno”
19. (OR #1-#18)
20. MeSH descriptor: [Celiac Disease] explode all trees
21. ((celiac or coeliac) near/1 (disease or syndrome))
22. tissue transglutaminase antibody
23. anti-endomysium antibody
24. endomysium antibody
25. (OR #20-#24)
26. #19 AND #25

**Scopus**
1. bariatric*.mp. or exp Bariatric Surgery/
2. “biliopancreatic diversion” or “biliopancreatic bypass”
3. duodenal switch*.mp. or “gastric bypass” or “gastric surgery”
4. gastroplasty or “intestin” bypass or “jejunoileal bypass” or “jejuno-ileal bypass” or “jejunoilial bypass” or “jejuno-ilial bypass” or “jejunoocolic bypass” or “mason” procedure or “roux-en-y” or “sleeve gastrectomy”
5. TITL-ABS-KEY ( ( (stomach OR gastric ) W/5 stapl ) OR sadi OR sadi-s OR “single anastomosis duodeno” ) AND TITL-ABS-KEY ( ( (celiac OR coeliac) W/1 disease ) OR ( (celiac OR coeliac) W/1 syndrome ) OR “tissue transglutaminase antibody” OR “anti-endomysium antibody” OR “endomysium antibody” )

**Google Scholar**
1. bariatric surgery OR gastroplasty OR roux-en-y OR sleeve gastrectomy AND (celiac disease OR coeliac disease)

**Database Search strategy**

**MEDLINE**
1. bariatric*.mp. or exp Bariatric Surgery/
2. exp Biliopancreatic Diversion/ or (biliopancreatic diversion or biliopancreatic bypass).mp.
3. duodenal switch*.mp.
4. (gastric bypass or gastric surgery).mp.
5. exp Gastroenterostomy/ or gastroenterostom*.mp.
6. gastrogastrostom*.mp.
7. gastrojejunostom*.mp.
8. gastroileal bypass.mp.
9. gastroplast*.mp.
10. intestin* bypass.mp. or exp Jejunoileal Bypass/
11. ( (jejunoileal or jejuno-ileal or jejunoilial or jejuno-ilial or jejunoocolic) adj bypass).mp.
12. mason* procedure*.mp.
13. (obesity or obese or weight) adj5 surg*.mp.
14. exp Obesity/su [Surgery]
15. restrictive surgery*.mp.
16. roux-en-y.mp. or exp Anastomosis, Roux-en-Y/
17. scopinaro.mp.
18. sleeve gastrectom*.mp.
19. ( (stomach or gastric) adj5 stapl)*.mp.
20. (SADI or SADI-S or single anastomosis duodeno).mp.
21. or/1-20
22. exp Celiac Disease/
23. ((celiac or coeliac) adj1 (disease* or syndrome*)).mp.
24. tissue transglutaminase antibod*.mp.
25. anti-endomysium antibod*.mp.
26. endomysi* antibod*.mp.
27. or/22-26
28. 21 and 27

Ovid Embase 1974 to 2021
June 03
1. bariatric*.mp. or exp bariatric surgery/
2. (biliopancreatic diversion* or biliopancreatic bypass).mp.
3. duodenal switch*.mp.
4. (gastric bypass* or gastric surger*).mp.
5. exp gastroenterostomy/ or gastroenterostom*.mp.
6. gastrogastrostom*.mp.
7. gastrojejunostom*.mp. or gastrojejunostomy/
8. gastroileal bypass.mp.
9. gastroplast*.mp. or gastroplasty/
10. intestin* bypass.mp. or exp intestine bypass/
11. ((jejunoileal or jejuno-ileal or jejunoiilal or jejuno-ilial or jejunocolic) adj bypass).mp.
12. mason* procedure*.mp.
13. ((obesity or obese or weight) adj5 surg*).mp.
14. restrictive surger*.mp.
15. roux-en-y.mp. or Roux Y anastomosis/
16. scopinaro.mp.
17. sleeve gastrectom*.mp.
18. ((stomach or gastric) adj5 stapl*).mp.
19. (SADI or SADI-S or single anastomosis duodeno*).mp.
20. or/1-19
21. exp celiac disease/
22. ((celiac or coeliac) adj1 (disease* or syndrome*)).mp.
23. tissue transglutaminase antibod*.mp.
24. anti-endomysium antibod*.mp.
25. endomysi* antibod*.mp.
26. exp protein glutamine gamma glutamyltransferase antibody/
27. exp endomysium antibody/
28. 20 and 27
29. 20 and 28

Cochrane Library
(via Wiley)
#1 MeSH descriptor: [Bariatric Surgery] 2 tree(s) exploded
#2 bariatric*
#3 MeSH descriptor: [Biliopancreatic Diversion] explode all trees
#4 "biliopancreatic diversion" or "biliopancreatic bypass" or "duodenal switch"
#5 "gastric bypass" or "gastric surger*"
#6 MeSH descriptor: [Gastroenterostomy] explode all trees
#7 gastroenterostom* or gastrogastrostom* or gastrojejunostom* or "gastroileal bypass"
#8 gastroplast* or "intestin* bypass"
#9 MeSH descriptor: [Jejunoeileal Bypass] 4 tree(s) exploded
#10 ((jejunoileal or jejuno-ileal or jejunoiilal or jejuno-ilial or jejunocolic) near/1 bypass)
#11 "mason* procedure" or "restrictive surger*"
#12 ((obesity or obese or weight) near/5 surg*)
#13 roux-en-y
#14 MeSH descriptor: [Anastomosis, Roux-en-Y] explode all trees
#15 scopinaro
#16 "sleeve gastrectomy"
#17 ((stomach or gastric) near/5 stapl*)
#18 SADI or SADI-S or "single anastomosis duodeno*"
#19 (OR #1-#18)
#20 MeSH descriptor: [Celiac Disease] explode all trees

(continued)
### Appendix 1. (continued)

| Database | Search strategy |
|----------|-----------------|
| #21 ((celiac or coeliac) near/1 (disease* or syndrome*)) |  |
| #22 tissue transglutaminase antibod* |  |
| #23 anti-endomysium antibod* |  |
| #24 endomysi* antibod* |  |
| #25 (OR #20-#24) |  |
| #26 #19 AND #25 |  |
| Scopus | ( TITLE-ABS-KEY ( bariatric OR "biliopancreatic diversion" OR "biliopancreatic bypass" OR "duodenal switch" OR "gastric bypass" OR "gastric surger" OR "gastroileal bypass" OR gastroplast OR "intestin* bypass" OR "jejunoileal bypass" OR "jejuno-ileal bypass" OR "jejuno-illal bypass" OR "jejunoocolic bypass" OR "mason procedure" OR "roux-en-y" OR "sleeve gastrectom*" ) OR TITLE-ABS-KEY ( ( ( stomach OR gastric ) W/5 stapl* ) OR sadi OR sadi-s OR "single anastomosis duodeno*" ) ) AND TITLE-ABS-KEY ( ( ( celiac OR coeliac ) W/1 disease* ) OR ( ( celiac OR coeliac ) W/1 syndrome* ) OR "tissue transglutaminase antibod*" OR "anti-endomysium antibod*" OR "endomysi* antibod*" ) |
| Google Scholar | ("bariatric surgery" OR gastroplasty OR roux-en-y OR sleeve gastrectomy) AND (celiac disease OR coeliac disease) |

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