# Management of Patients with Abdominal Malignancy after Remote Jejunoileal Bypass: Surgical Considerations Decades Later

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Jejunoileal bypass (JIB) operations were introduced in 1963 as a surgical treatment for morbid obesity.[1] The procedure gained popularity in the 1960s and 1970s as the most effective surgical intervention at the time for achieving and maintaining weight loss. However, both short- and long-term follow-up after these operations revealed a barrage of metabolic complications, including diarrhea, acute liver failure, cirrhosis, renal lithiasis, and renal insufficiency. Mortality and morbidity rates associated with the procedure were considerable and the procedure was eventually abandoned in favor of safer bariatric surgery alternatives.[2] As a result, up to 33% of patients who had received a JIB underwent a reversal procedure.[3] The most compelling reasons for reversal were life-threatening malnutrition, immune complex disease, renal oxalate stones, osteomalacia, and severe electrolyte disturbance. A small group of patients underwent reversal secondary to the reduced quality of life caused by severe diarrhea and foul-smelling stools. Those patients that survived the procedure and metabolic sequelae were found to compensate for the profound malabsorption with hypertrophy of the minimally functional small bowel and profound hypertrophy of the entire colon.[4-8]

Four decades after the peak of these operations, this aging population is now presenting with surgical gastrointestinal diseases to a younger generation of surgeons who likely never performed these historical operations or managed their metabolic needs. Long-term follow-up of post-bariatric surgery patients, including those who underwent JIB, has revealed that the most common cause of death more than 12 months from the procedure is malignancy and not cardiovascular causes, as might have been suspected.[9] Survivors are presenting with abdominal malignancies that our current generation of surgeons needs to manage. This article reviews preclinical and clinical data of the preoperative, operative, and postoperative considerations necessary to ideally manage these patients with a bowel resection.

## HISTORY OF THE JEJUNOILEAL BYPASS PROCEDURE

The surgical treatment of obesity can be traced back to the 1950s; however, it came into the mainstream once the medical community recognized that obesity was a disease with life-threatening comorbidities and that it was becoming an epidemic. In 1962, 12.8% of Americans were considered obese; the current figure is 35%.[10] The first recorded operation for weight reduction was performed in 1952 by Viktor Henrikson of Sweden.[11] Subsequently, Kremen and colleagues from the University of Minnesota performed JIB operations on dogs, followed by a JIB in a human patient in 1954.[12] Payne and colleagues were the first group to publish a case series of JIB in patients that showed weight loss. The first attempt[1] involved 10 patients in whom a segment of proximal jejunum was anastomosed to the transverse colon; however, the debilitating diarrhea, dehydration, and severe electrolyte imbalances led to either complete reversal of the procedure or conversion to a JIB. Eventually, they advised against the jejunocolic anastomosis and recommended the JIB procedure.[13] This involved transecting the jejunum 15 inches past the ligament of Treitz and attaching it end-to-side to the ileum 10 inches proximal to the ileocecal valve. When it was discovered that about 10% of these patients either regained the weight or did not have satisfactory weight loss due to reflux into the bypassed segment, an end-to-end anastomosis with the bypassed limb draining into the cecum, transverse colon, or sigmoid colon was suggested by Scott and colleagues.[14] Scott's end-to-end operation involved 30 cm of jejunum anastomosed to either the last 30,

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20, or 15 cm of ileum[14-17] and the 90% bypassed small bowel was drained into the colon.[14] Other variations of the JIB procedure included anastomosis of the gallbladder to the proximal excluded loop to reduce diarrhea, stapling techniques, or plication of the ileum.[18] The classic JIB anatomy consisted of 15 inches of jejunum anastomosed side-to-side to the distal 10 inches of ileum (Fig. 1).

Initially, patients with JIB had substantial weight loss and many of the comorbidities related to their obesity disappeared. However, most of these patients had severe complications develop that were worse than the initial advantages of the procedure.

## PREOPERATIVE CONSIDERATIONS

In the evaluation and preparation of a patient with an earlier JIB for colon surgery, certain preoperative considerations must be addressed. Many of these patients have compensated for the severe alterations in gastrointestinal physiology caused by the JIB, and are living precariously with metabolic/electrolyte imbalances, micronutrient deficiencies, hepatic insufficiency, biliary and renal stone disease, osteomalacia, autoimmune diseases, gout, or renal insufficiency. Each of these must be recognized and evaluated to determine suitability for major surgery and to optimize the patient for the procedure. In addition, many of these patients have or had functional gastrointestinal complications that might have affected normal gastrointestinal pliability and caliber. Also critical to assess is the JIB as a possible cause for a colon malignancy. In some experimental models, JIB is believed to be a risk factor for developing colorectal cancer. These issues are addressed here.

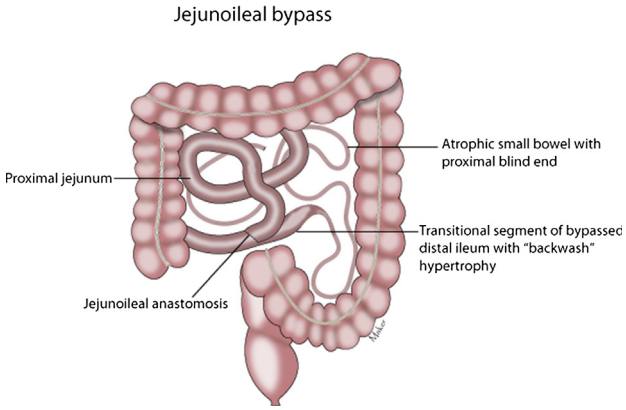



**Figure 1.** Anatomy of the jejunoileal bypass (JIB) and surgical considerations. Scott's end-to-end operation involved 30 cm of jejunum anastomosed to the last 30, 20, or 15 cm of ileum and the 90% bypassed small bowel was drained into the colon. The classic JIB anatomy (shown) consisted of 15 inches of jejunum anastomosed side-to-side to the distal 10 inches of ileum. During a period of several years post JIB, the proximal jejunum and terminal ileum distal to the anastomosis become longer, thickened, and dilated due to adaptive hyperplasia and hypertrophy. The bypassed proximal bowel develops 2 zones; a proximal longer segment that atrophies in length and diameter, and a second zone of terminal ileum just proximal to the jejunoileal anastomosis. We have found that this second transitional zone has the same anatomical and physiological characteristics as the distal "in-line" terminal ileum due to backwash reflux and, as a result, plays a role in the functional adaptive response of the small bowel.

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## COMPLICATIONS OF THE JEJUNOILEAL BYPASS

### Electrolyte imbalance

Diarrhea developed after the operation in most patients, leading to substantial electrolyte abnormalities, especially hypokalemia. Persistent diarrhea occurred in 17% to 45% of patients, depending on the type of JIB performed,[19] leading to deficits in potassium, magnesium, and calcium. Most of these patients were given oral supplementation until the diarrhea was under control; however, a small percentage had to be hospitalized for more severe deficits that required parenteral supplementation. Potassium and calcium losses that required hospitalization were seen in patients up to 15 years after the initial JIB.[2] Two mechanisms responsible for this diarrhea included decreased transit time and decreased surface area for absorption. The small amount of ileum left in these patients resulted in increased concentrations of bile acids in the colon, where they induced secretion of water, sodium, and chloride into the large bowel lumen, causing diarrhea. The enterohepatic cycle was also altered substantially in these patients, resulting in bile-salt wasting, decreased fat emulsification, and steatorrhea. The loss of bile salts and functional ileum compounded the already malnourished patient with micronutrient deficiencies, including the fat-soluble vitamins A, D, E, K, and B-12. In addition, with increased fat malabsorption, larger amounts of fatty acids were presented into the colon, where colonic bacteria transformed them into cathartic hydroxyl fatty acids.[20] Excessive intake of liquids and foods high in fat and lactose were other reasons for refractory diarrhea. However, after 12 to 18 months, severe diarrhea usually ceased, as the remaining functional bowel adapted to increase absorption of nutrients by hypertrophy of individual enterocytes, as described by Wright and Tilson.[21]

### Hepatic insufficiency

Although many of the patients had fatty livers before the operation, these worsened after surgery. Hepatic fibrosis developed in 29% and liver failure developed in 7% to

10%.[2,22] Liver complications ranged from asymptomatic elevations in liver enzymes to death secondary to acute liver failure,[2,23,24] which, when present, usually occurred within the first 2 years after JIB. The most common effects included elevated liver enzymes, hepatic steatosis, and increased fatty metamorphosis. Progressive hepatic abnormalities of the liver leading to cirrhosis and liver failure continued to occur even 15 years after the operation.[2] The cause of liver disease after bypass included multiple factors, such as increased fat deposition, protein deficiency, and exposure to toxic substances from bacterial overgrowth and bile salts.[25-29]

### Biliary and renal lithiasis

Gallstones and kidney stones were both common after JIB surgery.[19] Gallstones occurred due to disruption of the enterohepatic circulation, as is seen in patients with a diseased ileum or after ileal resection. Biliary calculi were found in 30% of morbidly obese patients before bypass surgery, and after bypass increased by 5% per year.[30-32] Lithogenic factors included alterations in cholesterol and bile-salt metabolism and bacterial infection.[30,32,33] Kidney stones were predominantly calcium oxalate. Urinary calculi and nephrocalcinosis occurred in 1% of patients,[34] with incidence varying up to 32%[15,35-37] within the first 2 years.[34] However, stones formed up to 10 years after surgery.[38] Factors involved in nephrolithiasis included increased absorption of exogenous oxalates, especially in colon,[39-41] and alterations in either the hepatic or enteric oxalate pathway.[34]

### Bone disease

Bone disease occurred in 17% to 48% of patients 1 to 14 years after the operation.[42-44] Clinical symptoms, laboratory tests, and radiological investigations tended to correlate poorly with the degree of bone loss.[42,44] Plasma 25-OH vitamin $D_3$ was low[42-45] and plasma parathyroid hormone was elevated.[43] Alterations in vitamin D metabolism were attributed to malabsorption, steatorrhea, liver disease, and the blind loop syndrome.[45] Arthromyalgia was found in up to 20% of patients within 3 years after a JIB,[46-48] and some form of skin rash, polyarticular arthritis, or cryoprecipitate immune complexes in the circulation developed in >50% of patients after surgery.[49] The arthritis was with or without bony erosions, and presented with symmetrical involvement of the hands, feet, wrists, and ankles. Etiologic factors involved in this arthritis−dermatitis bypass syndrome included abnormal circulating immune complexes, antibodies to *Balantidium coli* and *Bacterioides fragilis*, and a blind loop syndrome with bacterial overgrowth.[46,47,50,51]

### Gout

Although transitory hyperuricemia is common after bypass, clinical gout is rare.[16,52,53] Patients suffering from gouty episodes after the operation were generally those who had a history of gout before the operation. Most were treated as outpatients and only 1 patient was reported in the literature to require in-hospital care for his gouty nephropathy.[53]

### Renal insufficiency

The probability of renal insufficiency developing up to 15 years after JIB was found to be 9%.[2] The progressive nature of this disease resulted in 2% of patients requiring permanent dialysis and <1% undergoing renal transplantation.[2] One major cause of renal insufficiency was the considerable risk of renal stones developing, as described earlier; another was prerenal. This was secondary to decreased bowel absorptive surface area and chronic loss of fluid in diarrhea.[20] Another mechanism of renal insufficiency involved oxalate deposition damaging the renal parenchyma, causing an interstitial nephritis-like picture affecting primarily the renal cortex.[54-57]

### Intestinal complications

Intestinal complications occurring in this patient population included intussusception, bypass enteropathy, intestinal pneumatosis, pseudo-obstruction, transmural ileocolitis, and the blind loop syndrome.[18] Colonic pseudo-obstruction[24,58] presented with abdominal pain and distention, but usually resolved with conservative treatment. Antibiotics were often given because anaerobes have been implicated in the pathogenesis of this complication for these patients.[59] Intestinal pneumatosis occurred in asymptomatic patients 16% of the time,[60] but also presented along with bypass enteritis[61,62] and colonic pseudo-obstruction.[58,63] Surgical resection was pursued only when bleeding or obstruction were observed clinically.[64] Otherwise, conservative treatment with oxygen and antibiotics was often elected.[61,62]

### Colorectal carcinogenesis

Obesity itself is a major risk factor for malignancy,[65] however, the post-JIB anatomy can predispose patients to specific cancers. There are reports of gastric remnant lymphomas in gastric bypass patients,[66-68] and the senior author has anecdotally noticed an association between gastrointestinal lymphoma and JIB in 3 patients, although the correlation is not proven. Colorectal carcinogenesis has been a concern in patients with JIB secondary to the increased amount of bile acids, regarded as a carcinogenic substance to colonic mucosa,[69] found in JIB patient colons—about 10 times the amount of bile

acids compared with other patients.[70] In addition, several experimental animal studies have shown an increased risk of colon carcinoma in rats with JIB compared with controls with sham operations.[71-73] Jejunoileal bypass patients have a marked and persistent increase in cell proliferation in the large intestine compared with non-JIB patients.[74] Although there have been patients reported in the literature with clinical evidence of colon carcinoma or dysplasia[75,76] after JIB, a more recent clinical study demonstrated no increased risk of colon cancer in JIB patients on colonoscopy surveillance up to 17 years after the surgery.[77] As the pathogenesis of colorectal carcinoma requires extended time, additional follow-up is needed in these patients.

Based on these complications and on several studies showing gastric bypass as a superior procedure,[78,79] the jejunoileal bypass operation was almost completely discontinued by the early 1980s. By 1981, >10,000 JIBs had been reported in >400 publications in the English-language literature, and an estimated 25,000 had been performed in the United States alone. The perioperative mortality of the procedure ranged between 1.8% and 4%, and the mortality within 2 years of the bypass had been reported to be as high as 4.2%.[18] One series reported 9% mortality on 15-year follow-up.[2] The exact number of patients living with JIB is unknown; however, if an estimated 20% of patients had life-threatening complications develop[2,80,81] and underwent reversal, and another 10% have died, then about 18,000 people might be living with a JIB in the United States today. Many of these patients are living with metabolic/electrolyte imbalances, micronutrient deficiencies, hepatic insufficiency, biliary and renal stone disease, osteomalacia, autoimmune diseases, gout, or renal insufficiency. Long-term morbidity has persisted, and in patients with hepatic and renal disease, there did not appear to be a plateau even after more than 10 to 15 years.[2] Therefore, before embarking on intestinal resection in these patients, these preoperative comorbidities should be investigated, appropriately supported, and optimized.

## Parenteral nutrition

The nonalcoholic fatty liver changes seen in patients after JIB were found to be similar to those induced with total parental nutrition (TPN) use.[82] Therefore, although not explicitly studied, it would follow that TPN use in a post-JIB patient could compound the liver toxicity already present. However, for most patients to survive decades after the procedure, they are likely borderline malnourished rather than severely malnourished. This is possibly and likely due to longer functional segments and increased "backwash" hypertrophy as described previously. If necessary to prepare the patient for major surgery, TPN can be used and there is precedent in the literature. In one study, 5 of 37 patients preparing for reversal of their JIB required preoperative parenteral alimentation to correct protein and electrolyte imbalances for 10 to 40 days. In this group of patients, ileus was the most common early postoperative complication for which TPN was required in 7 patients.[80] Even in patients with severe liver disease and malnutrition after JIB, there are reports of recuperation with parenteral nutrition as a life-saving measure.[83] Therefore, parenteral nutrition can have a place in the management of the severely malnourished JIB patient before major abdominal operation. The nutritional parameters, for example, albumin <2.8 g/dL, to determine which patient can benefit from preoperative TPN have been studied in multiple trials, including by the Veterans Affairs TPN Cooperative Group[84] and might be applicable to JIB patients. We have not found it necessary preoperatively, but have used postoperative TPN in a patient with a prolonged postoperative ileus after reversal without major complications or liver toxicity.

## Operative considerations

More than 30 years later, some individuals with this anatomy still remain. At the time of surgery for intestinal tract disease, the bowel will need to be assessed and the exact anatomy understood to proceed safely and to not leave the patient with severe metabolic problems.

## Intraoperative assessment

In our experience with this anatomy, we have found large-caliber and substantially thickened segments of proximal jejunum and distal ileum, with highly atrophic and pencil thin, but pliable, bypassed small intestine. A short segment of the distal ileum proximal to the jejunal anastomosis can also be hypertrophic, likely from anteperistaltic reflux up the defunctionalized limb. Recognition of these characteristics will make intraoperative identification of the anatomy easier (Fig. 1). In addition, the colon can be absolutely massive, >7 feet long, hypervascular, and with an abnormally thickened wall, as is depicted in a recent total colectomy specimen we performed for colonic polyposis in a patient that had undergone a JIB 30 years ago (Fig. 2). Based on these findings, we surmise that both the small and large bowel compensate both anatomically and physiologically for the loss of the absorptive capacity of the majority of the small bowel over time (Fig. 3). In fact, it is possible that without this compensatory increase in surface area and absorptive capacity, the procedure would be incompatible with life, as a remnant 25 inches of jejunum and ileum would

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**Figure 2.** Demonstrated is a massive (>7.5 ft) tortuous colon, hypervascularized, and with a thickened wall that required total abdominal colectomy for severe polyposis coli unmanageable by endoscopy in a patient that had undergone jejunoileal bypass 30 years ago. Colon caliber reached 14 cm.

otherwise result in "short bowel" syndrome, which was almost universally fatal before the invention of TPN.[85] In the operating room, one will be able to measure the jejunal and ileal segments with hypertrophy and determine the length of functional small bowel (Fig. 1). Added to this distance should be the hypertrophic length of bypassed ileum caused by reflux at the jejunoileal anastomosis, because this portion of small bowel is engaged in nutrient absorption.

We are not aware of any literature that has found differences in the right or left colon absorption capabilities in JIB patients, however, preservation of at least half of the colon is roughly equivalent to 50 cm of small bowel with regard to the need for supplemental parenteral nutrition.[86] In addition, the ileocecal valve can effectively increase the absorptive capacity of the remaining small bowel up to 2 times that expected for the same length of small bowel without an intact ileocecal valve.[87] Therefore, the appropriate operative measures can be taken in JIB patients, depending on the following factors: an intact ileocecal valve, the length of functional (hypertrophied) small bowel, and the amount of functional colon.

## Intestinal surgery for malignancy

Long-term mortality after bariatric surgery, including JIB, was assessed in >12,000 patients for 25 years in Sweden. In this country, all citizens are assigned a unique identification number to which all medical procedures are linked in a national Inpatient Care Registry, which is also linked to the national Cause of Death Registry, providing accurate data on cause-specific mortality.[9] It was determined that after 1 year of follow-up, the most common cause of death after anti-obesity surgery was malignancy, with cancer accounting for 17% of patient deaths. Specific to JIB patients alone, there are additional reports of anorectal carcinoma, malignant lymphoma of the ileum, ileocecal adenocarcinoma, and colon dysplasia/carcinoma.[74-76,88-90] These data, along with the physiology of the JIB that can predispose these patients to colorectal carcinogenesis (previous section), suggest that the surgeon operating on these patients now might be doing so for malignancy.

We recommend treating patients with an intestinal malignancy with the appropriate oncologic operation and not to consider decreased nodal sampling or suboptimal margins. After the appropriate operation, a reversal might not be necessary if the combined length of functional small bowel is 50 to 70 cm (including the area of bypassed ileum with backwash hypertrophy; see Fig. 1) with an intact colon; there is 50 to 70 cm of functional small bowel with an intact ileocecal valve; or there is 100 cm to 150 cm of functional small bowel without any colon or an intact ileocecal valve.[91] If a reversal is necessary, this can be performed at the same operation, knowing that a bridge of parenteral nutrition might be required (see postoperative considerations).[92]

Ramifications of the JIB anatomy and physiology that will be encountered by the operating surgeon include bowel adaptive responses and bypass enteropathy. Intraoperative assessment of the proposed resected segment and its involvement in the functional anatomy of the patient will inform whether a reversal of the bypass must be performed. Unique to the JIB anatomy is the consideration that the colon contributes to nutritional balance and caloric intake,[91] and that if substantial portions of the colon require excision, a reversal of the bypass is indicated.

## Bowel adaptive responses

It has been shown that small bowel adaptation occurs after JIB in the functioning remnant,[93] demonstrating hypertrophy, dilation, and gradual elongation.[4,6,7] In addition, villi lengthening, crypt deepening, and general small intestinal hypertrophy occurred after bypass, which increased the absorptive capability of the small bowel.[21,94,95] Studies have shown that JIB surgery reduced the total intestinal surface area to 8.5%; however, 2 years after bypass, there was a 300% increase in surface area, giving a preoperative net surface area of 26%.[96] The bypassed segment, especially the ileum, atrophied[94,97] and villi were either reduced in size,[94,97] remained unchanged,[98] or hypertrophied at the site of colonic regurgitation.[6]

Animal studies revealed that the bypassed cohorts displayed dilation of the colon with a substantial increase in wall thickness, increased crypt depth, decreased number of goblet cells, and increased number and size

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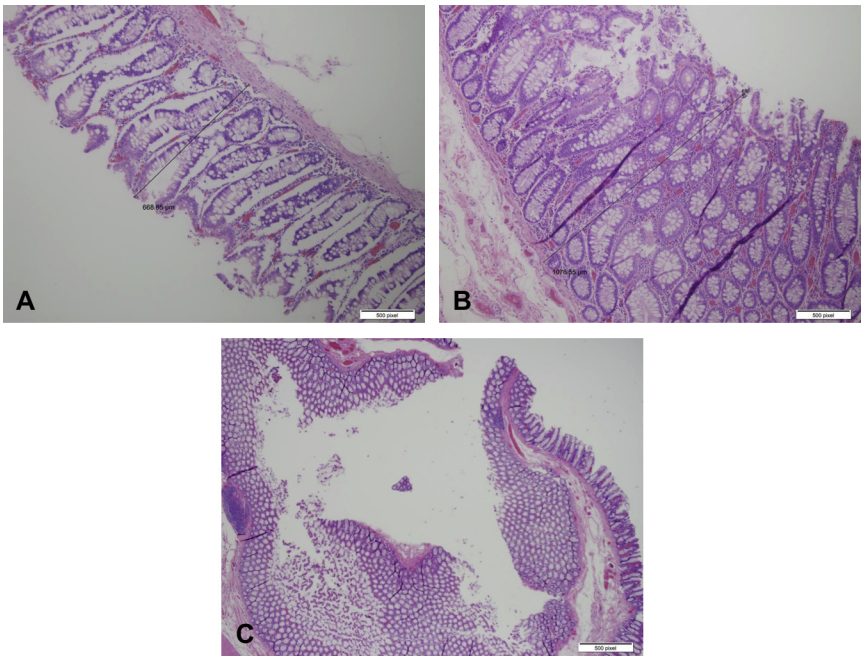



**Figure 3.** Post jejunoileal bypass (JIB), the colon dilates with a considerable increase in wall thickness, increased crypt depth, decreased number of goblet cells, and increased number and size of enterocytes compared with controls. Absorptive capacity can increase by 3 to 5 times. Post-JIB colon with a markedly thickened and hypertrophic wall demonstrates (A) normal mucosa and (B) mucosa almost twice the thickness of normal mucosa, 200×. Severe hypertrophy of the colonic villi is a compensatory mechanism to increase not only fluid reabsorption, but also nutrient acquisition. (C) Note the increased surface area produced by multiple redundant folds of colonic mucosa.

of enterocytes compared with controls.[5] In addition, an increase in the absorptive capacity of the colon was demonstrated in bypassed rats.[8] The colon has been shown to increase its absorptive capacity by 3 to 5 times,[99] and to increase the energy absorption by converting unabsorbed carbohydrates into absorbable short-chain fatty acids.[100-102] The bacteria, mostly anaerobes, such as bacteroides, bifidobacteria, eubacteria, fusobacteria, streptococci, lactobacilli, and enterobacteria,[103] in the colon have been shown to increase the production of short-chain fatty acids when provided with an increased amount of substrates for colonic fermentation, totaling the maximum energy absorption by the colon to up to 500 kcal/d.[104,105] These experiments highlight the adaptive importance of the colon as an energy source for patients after JIB (Fig. 3).

### Bypass enteropathy

Bypass enteropathy (bypass enteritis) likely represents a spectrum of diseases.[62,106-108] It is characterized by dramatic bloating, severe abdominal distention, intestinal pseudo-obstruction, and nocturnal diarrhea. An acute form of enteritis was found in 14% of patients in the early weeks postoperatively,[62] and can progress to gangrene with septicemia or pneumatosis intestinalis.[62,106] The cause is unknown but can include bacterial overgrowth within the excluded bowel,[62,109] changes in intraluminal pH, loss of peristalsis,[107] and mechanical obstruction.[110] Prostigmine, methadone, and other narcotics accentuate the condition[106,107] and antibiotics are often effective in treatment.[62,108] Identification of a history of this complication might alert the operating surgeon to the quality of the bypassed bowel and expectation of adhesions.

## SPECIAL CONSIDERATIONS

### Reversal

The functional jejunal limb is divided at the jejunoileal anastomosis. The proximal end of the defunctionalized jejunum, or its most proximal loop that can be mobilized if severely scarred from previous enteritis, is anastomosed to the functional and hypertrophic jejunal limb. Animal experiments studying intestinal structure and function after JIB in rats found no difference in intestinal structure between the bypassed intestine and intestine from transected controls.[111] Additional experiments demonstrated an increase in seromuscular mass of both the in-continuity

and the bypassed segment in rats after JIB compared with sham operations.[112,113] The bypassed segment is of small caliber, however, and animal studies of 70% bypassed small intestine demonstrated that the collagen content per wet weight of the tissue was less than in tissue from unoperated controls and was considerably less than bowel in the distal in-continuity segment.[113] In addition, after 35 days of feeding, bypassed small bowel transit times were increased indicating a persistent change in smooth muscle function. However, when bypassed intestine was compared with transected controls, there was no indication of muscular atrophy.[111] Therefore, the strength of the anastomosis and integrity of the tissues appear to be maintained. The surgeon should be cognizant of the size mismatch and ensure that a patulous anastomosis is created. This would include a 5- to 6-cm either handsewn or stapled anastomosis performed in a side-to-side, functional end-to-end fashion. Critical to mention, especially if stapled, is the recommendation to triangulate the common enterotomy channel with the GIA staple line. This can be accomplished by placing the GIA staple lines at either end of the TA staple line, rather than to approximate them. This would ensure that the closure of the common enterotomy channel does not partially obstruct the flow into the already small-caliber defunctionalized limb.

## Liver resection

Fatty liver and steatosis develop in morbidly obese patients. To compound this situation, nonalcoholic steatohepatitis with cirrhosis will occur after JIB in up to 10% of patients.[114-116] The JIB has been found to result in liver changes similar to those found in alcoholic liver disease, including progressive steatosis, pericellular fibrosis, and cirrhosis.[92] The common inciting factor is likely acetaldehyde, because it is the primary metabolic product of both alcohol breakdown and enteric bacterial overgrowth.[117] As described previously, hepatic insufficiency is a known complication of JIB and, recently, steatohepatitis with cirrhosis has been described as an indication for liver transplantation. Lowell and colleagues, in their case series of liver transplantation for liver failure after JIB, anticipated that the incidence of patients who would require liver transplantation might begin to increase as the latency period of hepatic damage in these patients now reaches maturation.[92] If liver dysfunction is identified before liver failure, the bypass should be reversed. However, if liver dysfunction and cirrhosis are severe, then reversal can result in acute liver failure, as experienced in 1 patient in their series.[92] In the setting of hepatic malignancy or the need for liver resection, the liver should be assumed to be diseased and parenchymal-sparing procedures performed. The extent of liver disease secondary to hepatitis, steatosis, steatohepatitis, fibrosis, chemotherapy, or cirrhosis should be determined by cross-sectional imaging and a liver biopsy performed if indicated. This information, combined with calculations of the proposed future liver remnant from 3-dimensional cross-sectional imaging and volumetrics, is helpful in predicting the risk of liver failure postoperatively and in surgical planning. Reversal should only be performed if needed and only after adequate liver function has been confirmed. Standard preoperative liver function tests, such as transaminases, alkaline phosphatase, bilirubin, clotting factors, and serum bile acids, are sufficient most of the time[118]; however, high-risk cirrhotic patients can benefit from an indocyanine green clearance test, which has been used to estimate hepatic functional reserve in cirrhotic patients undergoing hepatectomy for hepatocellular carcinoma.[119,120]

## Postoperative considerations

Management of the JIB patient after bowel resection has added challenges to the usual postoperative management of patients after gastrointestinal resection. The existing preoperative metabolic, electrolyte, hepatic, bone, and renal imbalances must all be consciously and aggressively supported; however, nutritional support is paramount and the patient will not tolerate long periods of a negative protein calorie balance. These patients already have poor tissue consistency and relative malnourishment preoperatively. Postoperatively, they will have increased metabolic needs without adequate enteric ability to absorb nutrients, either secondary to a loss of portions of small and/or large bowel that was used before, or from impotent and newly bypassed small intestine that is now "online," but with chronically atrophic villi and poor absorptive capacity.

## Metabolic and nutritional support

Early TPN use can be considered and used to transition to enteral feeds once bowel function returns. We have used an elemental formula via the nasogastric tube to augment oral intake because these elemental feeds have been shown to be efficiently absorbed by the proximal small intestine and to facilitate adaptation by preserving intestinal mass in the proximal small bowel.[85,91] As oral intake increases, the patient can be transitioned to a regular diet with a focus on constipating foods, such as boiled milk, rice, toast, and peanut butter, to help normalize evacuation times.[91] We have also used bananas and apples as part of the diet to act as natural binding agents.

Specific supplements to support the atrophied bowel can also be used, including glutamine, medium-chain triglycerides oil, calcium lactate, and cholestyramine.

Glutamine is a locally acting fuel source for rapidly dividing enterocytes and has been shown to accelerate hyperplasia, enhance intestinal sodium absorption,[121,122] preserve mucosal integrity, enhance various T-cell functions after colorectal resection, and improve nitrogen balance.[123] Medium-chain triglycerides, such as coconut oil, are an economical way to increase caloric intake with an oral diet because they can be absorbed directly by the proximal small bowel.[87] We have used this supplement for up to 1 month after discharge from the hospital. Cholestyramine, a bile-salt–binding agent, can relieve diarrhea caused by bile salts[91] until the small bowel regains the capacity to absorb most of the bile-acid pool. This agent also aids in prevention of nephrolithiasis by binding to intraluminal oxalate.[124] Calcium supplements have been used similarly to prevent nephrolithiasis by increasing calcium oxalate-insoluble complexes until the small bowel regained capacity for bile-acid absorption.

Knowledge of the clinical use of these agents was common to the generation of surgeons that originally cared for these patients (eg, the senior author, V K Maker, who performed >40 JIBs before they were discontinued), but not traditionally part of the education of the current younger generation of gastrointestinal and oncologic surgeons (eg, A V Maker, who was trained in the era of gastric bypass and restrictive bariatric procedures). Currently, many of the nutritional considerations of our patients have been delegated to the metabolic or nutrition services of our hospitals; however, with the rare presentation of these problems now, the clinical use of these agents is not part of their clinical armamentarium in our experience. Therefore, the metabolic and nutritional support of these patients will be dependent on the operating surgeon who needs to be familiar with the supplements.

### Infectious complications: *Clostridium difficile*

Human and animal JIB studies have shown that both the excluded loop of small bowel and the intact small bowel grow bacteria normally present in the large intestine, especially *Escherichia coli* and *B fragilis*.[109,125,126] Other native colonic bacteria, such as *C difficile,* can be found at higher concentrations in the small intestine of a patient after a JIB. Therefore, even after a total colectomy, there is an increased risk of a *C difficile* infection. Diarrhea and fever workup postoperatively should include *C difficile* tests and appropriate treatment if discovered as a pathogen.

## CONCLUSIONS

Past research validated the use of the JIB in patients with morbid obesity, and the short- and long-term complications were well documented in both preclinical models and patients. Reversal of the bypass in the short term was studied as it related to life-threatening complications; however, indications for bypass reversal are again resurfacing with an aging survivor population that is now presenting with intestinal diseases and malignancies. There is a gap in knowledge for the current generation of surgeons that must now care for these patients in the preoperative, operative, and postoperative setting. This review details the studies surrounding the metabolic derangements that must be addressed preoperatively, the intraoperative findings to be expected and determined to establish if a reversal will need to be performed, and the nutritional and infectious issues that need to be supported for the patient to successfully recover from surgery. The study is limited in that there is a paucity of research on this topic in the last few decades and that our personal experiences are often limited to a small number of patients. However, this review is even more relevant, as a result, in that it distills for the current cadre of surgeons the highlights of the published data with the experiences of a junior oncology surgeon managing these patients currently with the experiences of a senior surgeon who experienced them from the beginning. In patients with an earlier JIB presenting with gastrointestinal neoplasia, bowel resection can be performed safely with particular attention to the perioperative considerations unique to this patient population.

### Author Contributions

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