Intestinal Atresia and Stenosis

A 25-Year Experience With 277 Cases

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Objective: To evaluate the causes, clinical presentation, diagnosis, operative management, postoperative care, and outcome in infants with intestinal atresia.

Design: Retrospective case series.

Setting: Pediatric tertiary care teaching hospital.

Patients: A population-based sample of 277 neonates with intestinal atresia and stenosis treated from July 1, 1972, through April 30, 1997. The level of obstruction was duodenal in 138 infants, jejunoileal in 128, and colonic in 21. Of the 277 neonates, 10 had obstruction in more than 1 site. Duodenal atresia was associated with prematurity (46%), maternal polyhydramnios (33%), Down syndrome (24%), annular pancreas (33%), and malrotation (28%). Jejunoileal atresia was associated with intrauterine volvulus, (27%), gastroschisis (16%), and meconium ileus (11.7%).

Interventions: Patients with duodenal obstruction were treated by duodenoduodenostomy in 119 (86%), of 138 patients duodenotomy with web excision in 9 (7%), and duodenojejunostomy in 7 (5%) A duodenostomy tube was placed in 3 critically ill neonates. Patients with jejunoileal atresia were treated with resection in 97 (76%) of 128 patients (anastomosis, 45 [46%]; tapering enteroplasty, 23 [24%]; or temporary ostomy, 29 [30%]), ostomy alone in 25 (20%), web

excision in 5 (4%), and the Bianchi procedure in 1 (0.8%). Patients with colon atresia were managed with initial ostomy and delayed anastomosis in 18 (86%) of 21 patients and resection with primary anastomosis in 3 (14%). Short-bowel syndrome was noted in 32 neonates.

Main Outcome Measures: Morbidity and early and late mortality.

Results: Operative mortality for neonates with duodenal atresia was 4%, with jejunoileal atresia, 0.8%, and with colonic atresia, 0%. The long-term survival rate for children with duodenal atresia was 86%; with jejunoileal atresia, 84%; and with colon atresia, 100%. The Bianchi procedure (1 patient, 0.8%) and growth hormone, glutamine, and modified diet (4 patients, 1%) reduced total parenteral nutrition dependence.

Conclusions: Cardiac anomalies (with duodenal atresia) and ultrashort-bowel syndrome (<40 cm) requiring long-term total parenteral nutrition, which can be complicated by liver disease (with jejunoileal atresia), are the major causes of morbidity and mortality in these patients. Use of growth factors to enhance adaptation and advances in small bowel transplantation may improve long-term outcomes.

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INTESTINAL ATRESIA is a well-recognized cause of bowel obstruction in the newborn. The management of neonates with intestinal atresia has improved in recent decades due to refinements in neonatal intensive care, operative technique, use of total parenteral nutrition (TPN), and neonatal anesthesia. This review evaluates the causes, clinical presentation, diagnosis, operative management, postoperative care, and outcomes of 277 patients with intestinal atresia treated at a pediatric tertiary facility for a 25-year period.

RESULTS

DUODENAL ATRESIA AND STENOSIS

Duodenal obstruction was found in 138 (50%) of the 277 neonates enrolled in the study, including 79 females (57%) and 59 males (43%). Prematurity, defined as a gestational age of 37 weeks or less, was noted in 64 neonates (46%). Maternal polyhydramnios was noted in 45 neonates (33%) and evidence of duodenal obstruction on prenatal ultrasonograms was observed in 22 (16%). In addition, the conditions of
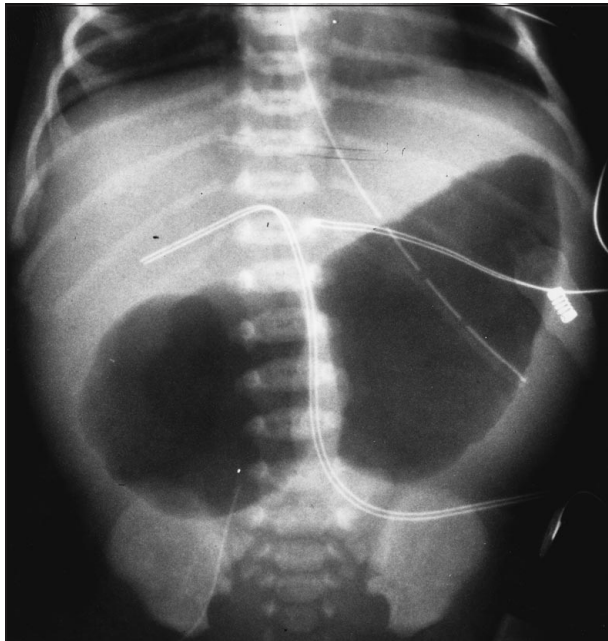
Figure 1. *Abdominal radiograph demonstrating the characteristic "double-bubble" sign associated with duodenal atresia.*

Figure 2. *Pathological types of duodenal atresia and stenosis noted in the current series.*

Table 1. Congenital Anomalies Associated With Duodenal Atresia

Type	No. (%) of Cases
Cardiac	53 (38)
Renal	19 (14)
Esophageal atresia or tracheoesophageal fistula	8 (6)
Imperforate anus	7 (5)
Skeletal	8 (6)
Central nervous system	4 (3)
Other*	11 (8)

*Other indicates additional anomalies.

Table 2. Associated Operative Findings With Duodenal Atresia and Stenosis

Pathologic Type	No. (%) of Cases
Annular pancreas	46 (33)
Malrotation	39 (28)
Anterior portal vein	7 (5)
Jejunoileal atresia	5 (3.6)
Second distal web	2 (1.5)
Colonic atresia	2 (1.5)
Ectopic pancreatic rests	2 (1.5)
Meckel diverticulum	2 (1.5)
Jejunal duplication cysts	1 (<1)

1 patient with omphalocele and 2 patients with gastroschisis had been diagnosed prenatally by ultrasonogram. Down syndrome (trisomy 21) was present in 33 neonates (24%). Clinical presentation included bilious emesis or aspirates in 126 neonates, upper abdominal distension in 13, and feeding intolerance in 13. Diagnosis was achieved in most instances by plain abdominal radiographs, which demonstrated the characteristic "double-bubble" sign in 108 neonates (**Figure 1**). No gas was observed beyond the second bubble in instances of atresia. Upper gastrointestinal contrast-enhanced examination showed partial duodenal obstruction in 48 neonates with duodenal stenosis. A variety of associated congenital anomalies was noted, with cardiac or renal abnormalities most frequently documented (**Table 1**).

Surgery was performed after administration of intravenous fluids to correct hypovolemia and electrolyte abnormalities. Findings at the time of operation included atresia in 92 neonates (67%) (mucosal web [type I] in 59 [64%], fibrous cord [type II] in 16 [17%], or complete separation [type III] in 17 [18%]) and stenosis in 46 (33%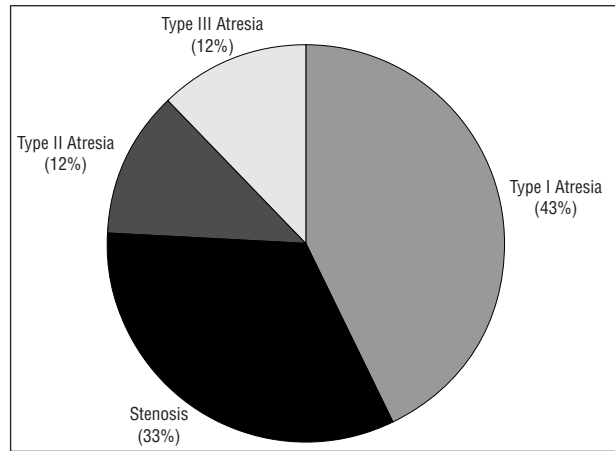) (**Figure 2**). Two patients had a second, more distal duodenal atresia. Duodenoduodenostomy was performed in 119 neonates (86%), duodenotomy with web excision in 9 (7%), and duodenojejunostomy in 7 (5%). Three neonates underwent placement of a duodenostomy tube because of their critical condition. Additional intraoperative findings included malrotation, annular pancreas, and anterior portal vein (**Table 2**). Ladd procedure with appendectomy was performed in patients with evidence of malrotation. A concomitant gastrostomy tube was placed in 50 neonates, most in the first 10 years of this series. In patients with esophageal atresia, the duodenal repair was performed prior to treating the esophageal atresia. Neonates with high imperforate anus also had a colostomy performed at the time of their duodenal atresia repair.

Postoperative complications included anastomotic obstruction in 4 neonates (3%), congestive heart failure in 13 (9%), prolonged adynamic ileus in 6 (4%), pneumonia in 7 (5%), and superficial wound infection in 4 (3%). Late complications included adhesive bowel obstruction in 13 children (9%), late duodenal dysmotility resulting in megaduodenum that required tapering duodenoplasty in 5 (4%), and gastroesophageal reflux disease unresponsive to medical management that required antireflux surgery (Nissen fundoplication) in 7 (5%). A late-appearing choledochal cyst that required excision and Roux-en-Y hepaticoenterostomy occurred in 2 teenagers (1%).
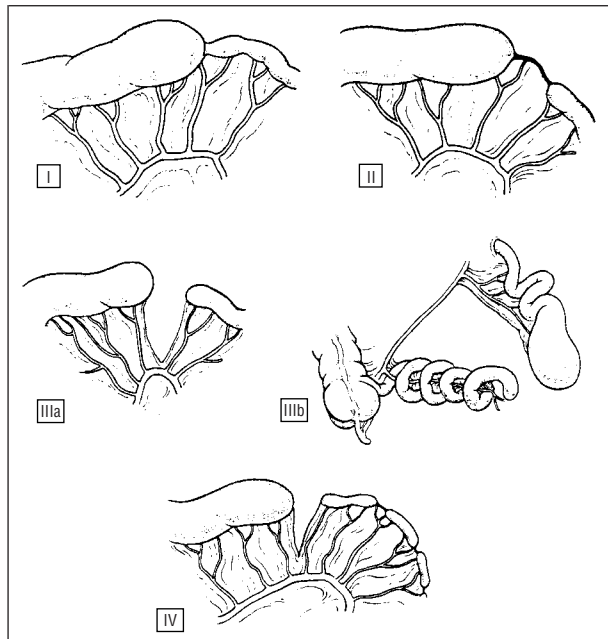
Figure 3. *Classification of jejunoileal atresia describes the pathology as type I (mucosal web), type II (fibrous cord), type IIIa (mesenteric gap defect), type IIIb ("apple peel"), or type IV (multiple atresias). Reprinted from* Pediatric Surgery[1(p843)] *with permission from Mosby–Year Book Inc, formerly Year Book.*

The operative mortality rate was 4% (5/138) for these patients. All 5 deaths occurred within 30 days of surgery and were attributed to complex congenital heart anomalies. Additional late deaths that occurred in 14 (10%) of the children were related to sepsis and multisystem organ failure (including cardiac failure) in 6 (4%), meningitis in 1 (0.7%), hepatic failure following orthotopic liver transplantation for biliary atresia in 1 (0.7%), and complex congenital heart disease in 4 (3%). Two children (1%) died at home of unknown causes. The overall long-term survival rate in up to 15 years' follow-up was 86% (119/138).

JEJUNOILEAL ATRESIA

Jejunoileal obstruction was found in 128 (46%) of the 277 neonates including 61 females (48%) and 67 males (52%). Fifty-seven neonates (44%) were premature. Jejunoileal atresia was associated with gastroschisis in 21 neonates (16%) and omphalocele in 2 (1.5%). Prenatal ultrasonography was suggestive of intestinal obstruction in 37 fetuses (29%), with maternal polyhydramnios noted in 21 (16%), evidence of overt obstruction in 9 (7%), gastroschisis in 19 (15%), and massive ascites in 1 (0.7%). Fifteen neonates (12%) had cystic fibrosis documented by sweat chloride determinations. Common clinical findings included bilious emesis, abdominal distension, and failure to pass meconium through the anus. The atresia in patients with gastroschisis or omphalocele was recognized at the time of surgery. Plain abdominal radiographs aided in the diagnosis of obstruction in other patients who demonstrated dilated intestinal loops often associated with air-fluid levels. A contrast barium enema was frequently administered, and radio-

graphs usually showed an unused microcolon, a finding that reveals the obstruction is limited to the small intestine. The barium enema also documented the location of the cecum, alerting us to instances of associated disorders of intestinal rotation and fixation. Free air was observed on plain abdominal radiographs in 2 neonates (1.6%). Associated congenital anomalies included omphalocele in 2 neonates (1.6%), cardiac anomalies in 10 (8%), skeletal anomalies in 3 (2%), gastroschisis in 21 (16%), renal abnormalities in 5 (4%), concurrent duodenal atresia in 5 (4%), associated colonic atresia in 3 (2%), and central nervous system malformations in 4 (3%).

At the time of surgery, 29 (23%) of the jejunoileal atresias were classified as type I (mucosal), 35 (27%) as type II (atretic fibrous cord), 23 (18%) as type IIIa (V-shaped mesenteric defect), 9 (7%) as type IIIb ("apple peel" atresia), and 31 (24%) as type IV (multiple atresias) (**Figure 3**). Other intraoperative findings included volvulus in 34 neonates (27%), malrotation in 24 (19%), meconium peritonitis 10 (8%), Meckel diverticulum in 3 (2%), and intrauterine intussusception in 2 (1.6%). Additional atresias were noted in the colon in 3 patients and in the duodenum in 5 (4%). Operative management included resection of the atresia with primary bowel anastomosis in 45 neonates (35%), resection with tapering enteroplasty in 23 (18%), temporary ostomy in 54 (42%) (with intestinal resection in 29 [57%] of those), enterotomy with web excision in 5 (4%), and a Bianchi longitudinal intestinal lengthening procedure in 1 (0.8%). Ladd procedure was performed in those neonates with malrotation (19%) and Meckel diverticulectomy was performed in 3 (2%) of the 128 neonates. Incidental appendectomy was performed in 13 neonates (10%). Following resection, 32 patients (25%) had resultant short-bowel syndrome, which occurred most commonly in those infants with types IIIa, IIIb, and IV atresias (81%).

Postoperative complications included adhesive bowel obstruction (early and late) in 31 patients (24%), prolonged adynamic ileus in 11 (9%), enterostomy prolapse in 3 (2%), pneumonia in 7 (5.5%), superficial wound infection in 6 (5%), and anastomotic leak with abscess or fistula in 5 (4%). All complications except the late bowel obstructions occurred within 1 month of operation.

The operative mortality rate was 1 (0.8%) in 128, with the only death related to sepsis and multisystem organ failure in a neonate with meconium peritonitis and congenital heart disease. There were 20 late deaths (age range, 1.5 months to 8 years; mean age, 10.5 months; median age, 5 months) for an overall 16% mortality rate. All of the children had prolonged TPN dependence. Sixteen late deaths were due to sepsis and multisystem organ failure. Of these patients, 14 had short-bowel syndrome and TPN-related liver disease. One late death occurred as a result of respiratory failure in an extremely premature neonate of 28 weeks' gestational age who was ventilator dependent, and 1 death was due to massive aspiration. Support was withdrawn 6 weeks postoperatively in 1 infant who had ultrashort-bowel syndrome with approximately 8 cm of bowel remaining, and who failed to thrive. The cause of death in 1 infant was unknown. Four other children with ultrashort-bowel syn-

drome and TPN dependence were treated with growth hormone, glutamine, and modified diets, with a significant reduction in their TPN requirements, increased enteral intake, and general somatic growth. The overall long-term survival rate was 84%.

COLONIC ATRESIA

Twenty-one (8%) of the 277 neonates were found to have colonic atresia, including 13 males (62%) and 8 females (38%). Prematurity was noted in 6 neonates (29%), 5 of whom had associated proximal intestinal atresias. Gastroschisis was observed in 4 neonates (19%). Clinical presentation included bilious emesis, abdominal distension, and failure to pass meconium through the anus. Plain abdominal radiographs performed in most (86%) of the patients showed a dilated intestine with air-fluid levels. Radiographs obtained with contrast barium enemas showed a distal microcolon in 14 neonates (67%). Two neonates (10%) showed a large loop of intestine with a "soap-bubble" appearance in the right lower quadrant of the abdomen. The 4 neonates with gastroschisis had had the abdominal wall defect detected on prenatal ultrasonograms.

At the time of surgery, 19 patients (90%) had colon atresias, 3 (16%) with type I (mucosal web), 1 (5%) with type II (fibrous cord), and 15 (79%) with type IIIa (mesenteric gap defect). Two patients (9.5%) had colonic stenosis. The colonic atresia was located in the right colon in 8 patients (38%), transverse colon in 10 (48%), and left colon in 3 (14%). Eighteen (95%) of these patients were treated with the formation of a temporary stoma (end ileostomy in 3 [17%], right colostomy in 3 [17%], transverse colostomy in 9 [50%], and left colostomy in 3 [17%]) followed by delayed bowel anastomosis at age 3 to 4 months. Three patients (17%) were treated with resection and primary bowel anastomosis. The postoperative and long-term survival rate was 100%. Complications included wound infection in 1 infant (5%), colostomy prolapse in 1 (5%), prolonged ileus in 2 (9.5%), and late adhesive bowel obstruction in 8 (40%).

COMMENT

Intestinal atresia is a common cause of neonatal intestinal obstruction. The causes, clinical presentation, diagnosis, operative management, postoperative care, and outcome may vary considerably according to the location of the obstruction.

The 2 major theories regarding the etiology of intestinal atresia are Tandler's [2] concept of a lack of revacuolization of the solid cord stage of intestinal development and the classic study by Louw and Barnard[3] suggesting that a late intrauterine mesenteric vascular accident is the cause of most jejunoileal and colonic atresias. While lack of revacuolization is the probable cause for most cases of duodenal atresia, compelling observations from other studies[4-10] demonstrate that jejunoileal atresias occur as a result of intestinal volvulus, intussusception, internal hernia, or strangulation in a tight gastroschisis or omphalocele defect. Familial instances of jejunoileal and colonic atresias have also been observed, suggesting that genetics may play a part in these cases.[11-13]

The classification of intestinal atresias varies somewhat based on the location of the obstruction. Duodenal lesions historically have been classified by the method described by Gray and Skandalakis, [14] with identification of 3 types of lesions. A type I defect represents a mucosal web with normal muscular wall (most common); type II, a short fibrous cord connecting the 2 atretic ends of the duodenum; and type III (least common), one in which there is complete separation of the atretic ends. The classification of jejunoileal atresias initially proposed by Louw[15] also recognized 3 types of lesions. The classification was later refined by Martin and Zerella[16] and by Grosfeld et al[17] to include the apple peel deformity and multiple atresias. According to this method of classification, type I defect represents a mucosal defect with an intact mesentery. Type II defects consist of a fibrous cord connecting the atretic bowel ends. A type IIIa lesion denotes an atretic segment with a V-shaped mesenteric gap defect, while type IIIb defines the apple peel deformity, in which there is a proximal jejunal atresia and the distal bowel is supplied by a single retrograde blood vessel. Type IV describes instances of multiple atresias ("string of sausage" effect). This classification system has also been applied to colonic atresia, with most of those cases demonstrating a type IIIa defect.

The presenting symptoms for patients with any form of intestinal atresia or stenosis are consistent with bowel obstruction and include bilious vomiting, abdominal distension, and failure to pass meconium in instances of lower obstruction. Most infants with duodenal obstruction do not have significant abdominal distension. The number of cases of intestinal atresia that are identified prenatally has increased as a result of the routine use of ultrasonographic monitoring of fetal development. Various studies[18,19] have evaluated the need to perform prenatal examination early ($\geq$18 weeks' gestation) and have shown the benefit of prenatal diagnosis with earlier recognition, prompt surgical intervention, and fewer metabolic complications. Prenatal ultrasonography may identify the presence of maternal polyhydramnios and distension of the stomach and duodenum with swallowed amniotic fluid. These observations are often associated with a high risk of duodenal atresia. Although gastroschisis can frequently be observed on a prenatal ultrasonogram, a notable number of jejunoileal and colonic atresias remain undetected by this method. Because ultrasonography generally has not been an accurate determinant for lower intestinal obstruction, its ability to exclude a malformation is limited.

Postnatally, radiographic studies are useful in the diagnosis of intestinal atresia. Plain abdominal radiographs can identify the classic double-bubble sign (air-filled stomach and proximal duodenum) of duodenal atresia or stenosis. Lack of bowel gas beyond the second bubble is usually diagnostic of an atresia. Jejunoileal or colonic atresias are characterized radiographically by the presence of proximal dilated intestinal loops often associated with air-fluid levels. The presence of intraperitoneal calcifications are indicative of meconium peritonitis and suggest an intrauterine bowel perforation. An upper gastrointestinal contrast-enhanced radiograph should be obtained in cases of partial obstruction and may dem-

onstrate the presence of a stenosis or a mucosal web with a small opening. As the colonic haustral markings are not prominent in the neonate, it may be difficult to discern small bowel from large bowel on plain abdominal radiographs. A barium enema will define the location of a colonic atresia; it is also recommended for instances of presumed jejunoileal atresia to identify whether the colon has been unused (microcolon) during intrauterine life, define the level of obstruction in the small intestine, occasionally identify the presence of obstructing intraluminal meconium pellets in instances of meconium ileus, and identify the location of the cecum to rule out anomalies of rotation and fixation.

PREOPERATIVE TREATMENT involves insertion of an orogastric sump tube to decompress the stomach, and adequate intravenous fluid resuscitation to correct hypovolemia and electrolyte abnormalities and to achieve hemodynamic stabilization. In neonates with duodenal atresia, a careful midline evaluation for associated anomalies is performed, as this defect probably occurs earlier in gestation and is associated with an increased risk of malformations in other organ systems. Cardiac and renal ultrasonographic examination are indicated owing to the high incidence of associated defects.[7,20] Careful assessment of other gastrointestinal malformations such as esophageal atresia and imperforate anus is easily accomplished by passing an orogastric tube and by physical examination of the anorectum. Down syndrome is also commonly identified in 20% to 25% of infants with duodenal atresia.[1(pp829-837),6,21,22] The incidence of associated anomalies is much less with jejunoileal and colonic atresia.

The operative management of intestinal atresias is individualized according to the site of the lesion, the specific anatomical findings, and associated conditions noted at laparotomy. Perioperative antibiotics are administered at least 30 minutes prior to the start of the operation. Duodenal atresia and stenosis were initially managed using duodenojejunostomy, but currently most cases are treated by a direct duodenal approach, performing a duodenoduodenostomy.[23-25] This can be performed with either a side-to-side or a proximal transverse-to-distal longitudinal (diamond-shaped) anastomosis. In our series, 119 (86%) of the 138 neonates with duodenal atresia were treated with a duodenoduodenostomy. In a few cases, simple duodenotomy with web excision was performed, after identifying the windsock nature of the web by using an intraluminal catheter to delineate the position of the obstruction and the site of proximal web attachment.[26,27] Recognition of the location of the Vater ampulla was assisted by gentle compression of the gallbladder, with release of bilious material in the region of the ampulla. The web could then be partially excised, leaving the medial portion intact at the ampulla and preventing inadvertent injury. Tapering duodenoplasty was not required initially in our patients; however, the use of an antimesenteric tapering duodenoplasty is a useful technique in managing duodenal motility disorders related to megaduodenum.[28] This procedure was

subsequently necessary in 5 of our patients. Some surgical centers previously recommended the use of transanastomotic jejunal feeding tubes to initiate early enteral feeding. This practice has been largely abandoned, as it was shown to prolong the time until oral feeding is tolerated and increase the length of the hospital stay.[29] Annular pancreas was a relatively frequent operative finding (33%). It was treated by performing the duodenal anastomosis over the bridge of pancreatic tissue, rather than risk the occurrence of a pancreatic fistula by unnecessarily dividing the tissue. Malrotation was also noted in many neonates and was treated by Ladd procedure. It is also important to recognize whether there is an anterior (preduodenal) portal vein and to avoid injury to this vessel during operative repair.

The choice of operation in instances of jejunoileal atresia depends on the pathological findings encountered, associated findings (malrotation, volvulus, internal hernia, meconium peritonitis, gastroschisis, or omphalocele), and length of the remaining intestines. In patients with a relatively normal length of remaining bowel, resection of proximal atretic bowel should be performed. Failure to do so may result in functional obstruction and abnormal motility in the retained dilated proximal atretic bowel.[7,15,30,31] In instances of short bowel length, a proximal tapering enteroplasty or intestinal plication has been proposed as an alternative to resection in an effort to preserve bowel length.[32-35] Our current practice is to taper the dilated proximal bowel after a minimal resection of the end of the atretic segment and then perform a primary end-to-oblique anastomosis. A temporary enterostomy is performed in instances of perforation with significant contamination or meconium peritonitis, or if there is a question of bowel viability. The management of gastroschisis complicated by bowel atresia remains controversial, with proponents divided among initial exteriorization, primary anastomosis, or replacement of the atretic bowel segment into the peritoneal cavity with abdominal wall closure and definitive repair at a delayed reoperation a few weeks later.[10,36,37] In patients who experience significant bowel loss, preservation of the maximal length of functional bowel is of utmost importance. If adaptation to enteral nutrition is delayed, the longitudinal lengthening procedure as proposed by Bianchi[38] may improve this situation. The mesenteric blood supply is carefully preserved during dissection between the peritoneal leaves, allowing a subsequent longitudinal division of the proximal dilated bowel. An autostapling device is useful in completing the longitudinal division, creating hemiloops of bowel that are then anastomosed in an isoperistaltic fashion. This technique was used in treating 1 infant in the present study and was associated initially with a reasonable outcome. The Bianchi procedure is not a panacea, however, as it is successful in changing the outcome in only about half the patients in whom it is employed. It may not at all improve the outcome in infants with severe TPN-related liver disease.

For neonates with bowel atresia, it is important to document complete distal patency. Use of an intraluminal catheter and a saline solution flush will usually identify additional distal atresias. While primary resection or

Table 3. Survival Data for Intestinal Atresia

Location of Atresia	Source, y	Survival, %
Duodenal	deLorimier et al,[6] 1969	60
	Nixon and Tawes,[7] 1971	60
	Stauffer and Irving,[44] 1977	69
	Kullendorf,[45] 1983	90
	Grosfeld and Rescorla,[20] 1993	95
	Mooney et al,[29] 1987	95
	Current study	86
Jejunoileal	Louw,[15] 1967	94
	deLorimier et al,[6] 1969	64
	Nixon and Tawes,[7] 1971	62
	Martin and Zerella,[16] 1976	64
	Cywes et al,[46] 1980	88
	Rescorla and Grosfeld,[21] 1985	87
	Current study	84
Colon	Coran and Eraklis,[47] 1969	67
	DeFore et al,[41] 1976	70
	Rescorla and Grosfeld,[21] 1985	100
	Davenport et al,[43] 1990	91
	Current study	100

tapering enteroplasty is necessary to deal with the significantly dilated bowel of the initial atresia, in cases with multiple atresias the distal ones are not distended. Direct end-to-end anastomosis without resection for type II or type IIIa distal atresias that are separated by a cord or gap, or an enterotomy and web excision with transverse closure of the enterotomy for distal type I mucosal web, are acceptable.

Operative correction of colonic atresia has been modified over the years. Earlier studies[17,39-41] recommended resection with anastomosis for colon atresia proximal to the splenic flexure, and colostomy with delayed anastomosis for atresia distal to this point. Initial colostomy with delayed anastomosis was the routine practice for most infants in our study. In recent years, however, several authors[42,43] have reported the use of resection and primary anastomosis as a reasonable treatment option regardless of the location of the colon atresia.

The operative mortality for intestinal atresias, in our experience, is very low (duodenal, 4%; jejunoileal, 0.8%; colonic, 0%). The overall mortality noted in this series (duodenal, 14%; jejunoileal, 16%; colonic, 0%) was similar to that in other relatively recent studies concerning bowel atresia (**Table 3**). This study followed the patients up for a longer period than the other studies and demonstrated a slight fall-off in survival with a longer follow-up beyond the operative mortality period. Associated congenital anomalies, particularly severe cardiac defects, account for most of the late deaths in infants with duodenal atresia. Ultrashort-bowel syndrome continues to be a major impediment to improved survival rates. Although TPN is an important treatment adjunct and maintains the infant's weight, it does not enhance intestinal adaptation and may result in TPN-associated cholestasis and subsequent liver damage—a condition with a grave prognosis. Bowel adaptation will occur only if enteral nutrition is offered, and may take from 3 to 27 months before it is adequate enough for the patient to become independent of TPN support. If adaptation is delayed, secondary procedures including tapering enteroplasty or intestinal lengthening can be used to improve tolerance of enteral feedings and overall nutritional status.[48-50] The use of growth hormone, glutamine, and modified diets containing low fat, complex carbohydrates, and protein supplements have been used in adults with short-bowel syndrome to successfully diminish TPN requirements and enhance nutrient absorption.[51-53] Approximately half of the patients treated with this regimen become independent of TPN support. Additional studies suggest that other growth factors such as epidermal growth factor, hepatocyte growth factor, and interleukin 11 enhance intestinal adaptation after massive bowel resection.[54-58] Patients with ultrashort bowel length who fail to adapt following surgical intervention and growth-factor treatment may be candidates for small-bowel transplantation. Because of the presence of significant gut-associated lymphoid tissues, high doses of immunotherapy are required. This immunotherapy is associated with an overall higher surgical complication rate (48%), increased risk of cytomegalic viral infection (20%), and the occurrence of lymphoproliferative disease (29%).[59] Unfortunately, 75% of patients with lymphoproliferative disease develop a highly malignant non-Hodgkin lymphoma and succumb. The overall 5-year patient and graft survival rates are 55% and 45%, respectively.[59]

<div style="text-align:center">CONCLUSIONS</div>

The survival rate for infants with intestinal atresia, in our experience, has remained relatively stable for the last 2 decades. The major obstacles to a successful outcome continue to be complex congenital heart disease in infants with duodenal atresia and the challenges in the treatment of children with jejunoileal atresia and ultrashort-bowel syndrome, especially those cases complicated by TPN-related liver disease. Early use of growth factors to maximize intestinal adaptation, administration of growth hormone to "grow the bowel," and nutritional modifications may improve the status of patients with short-bowel syndrome.[48] Refinements in small-bowel transplantation and advances in the science of immunology should reduce the current high complication rate and improve graft and patient survival, eventually improving the overall survival rate for these young patients.

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DISCUSSION

Thomas R. Weber, MD, St Louis, Mo: Drs Dalla Vecchia and Grosfeld and colleagues from Indiana are to be congratulated for assembling one of the largest series of newborn intestinal atresia reported to date. This beautifully presented study describes in substantial detail the cause, diagnosis, treatment, and short- and long-term outcome for these infants.

The treatment of these patients is frequently complicated by prematurity; serious associated anomalies, especially cardiac; prolonged adynamic bowel peristalsis; sepsis; and the most significant complication, short-bowel syndrome. The need for prolonged TPN in the infant with very short bowel length may result in cholestasis that can be lethal. The medical and surgical treatment for patients with short bowel, as emphasized in this study and many other published series, are less than ideal and result in survival in only 30% to 60% of these infants. Liver and small-bowel transplantation alone or in combination have yet to make a serious impact on these mortality rates. This continuing poor survival rate in infants with short gut leads me to several questions.

First, sepsis is a major cause of death in the infant with short bowel and liver cholestasis, presumably due to bacterial translo-

cation in the majority of patients. Are you using prophylaxis, such as poorly absorbed broad spectrum antibiotics, to attempt prevention of recurrent sepsis in these high-risk infants?

Second, you reported treating several infants with growth hormone and high-glutamine diets as Douglas Wilmore has reported in adult patients. Is it your impression that this has improved gut function, or does it accelerate the adaptation in these infants, or both? Should we start using growth hormone immediately after resection in all infants with short bowel length? Are there any worrisome side effects from this medication?

Frederick M. Karrer, **MD**, **Denver**, **Colo:** This seminal paper is going to be a benchmark for our specialty, as many of the authors' contributions have been. The authors have looked at a very large group of children and carefully studied them over a long period. My question relates to one particular segment of the population, namely, those with jejunoileal atresia. How was the selection of resection and primary anastomosis vs temporary ostomy and later anastomosis made? Were any of the patients in the group who had temporary ostomies "uncomplicated"? If so, how did they fare compared to the ones who had primary anastomosis? One preference is for resection and primary anastomosis whenever possible.

Harlan D. Root, **MD**, **San Antonio**, **Tex:** I have a question based more on curiosity than on advocacy. Is there any role for prenatal predelivery intrauterine procedures? I noticed in the duodenal atresia group there was a 24% recognition predelivery. Is there any role for intrauterine procedures?

Dr Grosfeld: Dr Weber asked about the use of prophylactic antibiotics in patients with short-bowel syndrome receiving TPN. We have not used prophylactic nonabsorbable enteral antibiotics in these patients. We have observed numerous episodes of catheter sepsis, probably related to bacterial translocation. Many of the catheter infections were related to enteric organisms, and perhaps sterilizing the bowel is something we should consider. So far, we only treat the patients with antibiotics when they present with overt infection in a positive blood culture.

In regard to trying to improve the fate of babies with ultrashort bowel, we agree with Dr Weber and have not yet been impressed with the results of small-bowel transplantation alone or in conjunction with liver transplantation in this group. Small-bowel transplantation has a success rate similar to that achieved with liver transplantation 10 or 15 years ago. We hope this will improve with time. Currently the 5-year survival rate in children following small-bowel transplantation is about 50%, and the graft survival rate is about 40%. Small-bowel transplantation requires very complex care. Because of the gut-associated lymphoid tissues, increased doses of immunosuppressant drugs are necessary to try to preserve the bowel graft. This leads to many complications, including lymphoproliferative disease, which occurs in about 30% of the patients and results in a lethal lymphoma in 75% of these patients.

As far as growth hormone is concerned, we are currently testing Dr Wilmore's protocol. His data showed that when growth hormone therapy was initiated in adults with short-bowel syndrome well after (years after) adaptation should have been expected to occur, about half of the patients could be weaned off TPN support. In addition to growth hormone, the Wilmore protocol administers glutamine and complex carbohydrate diets. We have used this protocol in just 4 of the patients with bowel atresia in this group and, indeed, in every one of them their TPN requirements were significantly reduced. One patient is independent of TPN while 3 others receive much more of their intake enterally than they do parenterally. Whether this protocol grows the gut that is already there or whether it accelerates adaptation still remains to be seen. We think it probably does both. We have not used growth hormone early; all of the patients received their treatment a number of years after surgery. Our current concepts regarding the patient with short-bowel syndrome are based on studies in our laboratory to maximize adaptation in patients with ultrashort bowel by using growth factors that enhance the adaptive process, such as interleukin 11 and epidermal growth factor alone or in combination. When maximal adaptation is achieved, then we start using growth hormone. Whether this will alter the long-term outcome is yet to be determined.

In response to Dr Karrer's question about on which patient you perform a resection and primary anastomosis and on which you perform an initial ostomy, we resect most of the dilated atretic loop as long as the overall length of intestine is normal. The only patients who had ostomies performed were infants with evidence of severe peritonitis, or with a volvulus where the color of the intestine looked rather abnormal and we were concerned about performing a primary anastomosis under those circumstances. Otherwise, we would agree with Dr Karrer that a primary anastomosis is advisable in most instances.

In regard to Dr Root's question about the role for intrauterine surgery, in babies with a prenatal diagnosis of atresia, we do not believe there is a role for fetal surgery in these cases. As time has gone by there are fewer and fewer indications for intrauterine surgery.

One group of patients who still are problematic are the babies who have gastroschisis associated with atresia. Their outcome is still somewhat guarded and the best way to manage them varies from institution to institution. Alternatives include simply dropping the atresia back in the abdomen, closing the defect, and then performing a delayed bowel operation; or initially creating an ostomy; or performing a primary anastomosis and dealing with the abdominal defect simultaneously. I do not think all of the answers are yet available. We have treated our patients using all 3 techniques, but they have a prolonged length of hospital stay, bowel dysmotility, high morbidity, and some mortality.