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Adult Intestinal Transplantation

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INTRODUCTION

Adult intestinal transplantation has evolved over the past decades from a rarely performed, immunologically hazardous therapy into a mainstream therapeutic procedure with results that today approach other solid organ transplants.¹ Owing to the large lymphoid load and resultant immunologically reactive graft, the transplanted intestine poses challenges both directly and indirectly on the recipient. Directly, it poses an immediate immunologic confrontation to the recipient immune system, and indirectly on the recipient with the compulsory augmented immuno-suppression and the inherent complications associated with the higher immuno-suppressed state.

Despite the commonality of the transplanted intestine allograft, adult and pediatric intestinal transplantations have differences in nearly all aspects. The etiologies of intestinal failure, intestinal rehabilitative prognosis, graft type use, surgical techniques, nutritional autonomy, and outcomes are a few of the differences that separate adults and children with regard to intestinal transplantation.

CURRENT TRENDS IN ADULT INTESTINAL TRANSPLANTATION

Unlike in the pediatric intestinal transplant population, grafts that include the liver have increased in the adult population globally over the past several years according to the latest data published by the Intestinal Transplant Registry² (Fig. 1). Not surprisingly, pre-transplant death reported from the Organ Procurement and Transplantation Network/Scientific Registry of Transplant Recipients 2015 Annual Data Intestine Report was notably higher for those patients requiring a liver containing graft at 19.9 deaths per 100 waitlist years as compared with 2.8 deaths per 100 waitlist years for recipients with isolated intestine.³ Thus, despite the observed overall decreased morbidity associated with parenteral nutrition, largely owing to the establishment and refinement of specialized intestinal care

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and intestinal rehabilitation centers, pretransplant mortality remains greatest for adult intestine candidates, at 19.6 deaths per 100 waitlist years.³

Adult candidates, however, have differing reasons for requiring a liver-containing graft as compared with pediatric candidates. Whereas the majority of pediatric intestinal candidates that require a liver-containing graft suffer from parenteral nutrition-associated liver disease as the basis for their liver inclusion, adult candidates who require a liver-inclusive graft have other conditions such as malignancy or primary end-stage liver disease with complicated portomesenteric thrombosis that necessitates a combined or multivisceral graft for successful liver transplantation.⁴ As expected, these adult multivisceral candidates do not suffer from intestinal failure and do not fall under the traditional indications of “failure of parenteral nutrition” as an indication for intestinal transplantation. Attempts to directly compare adult and pediatric indications, surgical techniques, and outcomes cannot be done without understanding the major characteristics between the 2 populations.

Adult Intestine Transplant Volume

Overall, with the exception of 2012, the number of adult intestine transplants has remained relatively steady in the United States in the past decade, ranging from 77 to 92 adult intestine transplant cases per calendar year (median, 85 cases)⁵ (Fig. 2). This has differed substantially with the pediatric intestinal transplant experience, which has observed a precipitous decrease in the number of intestinal transplants since 2007.⁶ Much of the decrease in the number of pediatric intestinal transplants can be attributed to specialized intestinal care centers that capitalize on the increased potential that the infant pediatric gut has for adaptation, and thus rehabilitation. This condition differs from the adult patients with a short gut, who have generally maintained and sustained decades of established intestinal function before the loss of gut and, thus, harbors less potential for growth and adaptation of the remnant intestine. Prolonged parenteral nutrition exposure in the adult population, however, does account for the need for a proportion of liver-containing grafts in the adult population, and this is an area for potential improvement in decreasing the high pretransplant mortality in the adult liver–intestine transplant population. Early referral to a specialized adult intestinal transplant center and early recognition of adult recipients with intestinal failure could serve to provide the preferred option of isolated intestine transplant and subsequent withdrawal of parenteral nutrition before the development of irreversible parenteral nutrition-associated liver disease, thus, obviating the requirement for a liver-inclusive graft. Recognizing the extremely high mortality that adult patients have on the combined liver–intestine waiting list, the United Network for Organ Sharing revised allocation policy for this specific subset in 2013, allowing for a greater, nationwide pool of potential adult multivisceral donors to help mitigate the high mortality risk.⁷ Current policy for adults also allocates an additional increase in their Model for End-Stage Liver Disease score equivalent to a 10% increase in risk of 3-month mortality.

Etiologies of Conditions Leading to Adult Intestinal Transplantation

Short gut syndrome remains the most common condition leading to transplant in both the adult and pediatric population, comprising approximately 60% to 65% of all transplanted cases. Conditions that lead to the short gut diagnosis, however, differ significantly between

the 2 populations. Classic neonatal and infant conditions such as gastroschisis, necrotizing enterocolitis, intestinal volvulus, and jejunal ileal atresia account for the vast majority of conditions leading to short gut syndrome and transplantation in the infant and child. In the adult, mesenteric ischemia is the most common etiology of short gut syndrome followed by Crohn's disease, trauma, surgical misadventure, and volvulus.²

Mesenteric Infarction

Acute mesenteric infarction has a low incidence of occurrence, accounting for 0.09% to 0.20% of all acute admissions in the emergency room. The condition, however, has an accompanying mortality rate of up to 80% if not treated in a timely manner.⁸ Given that there is very little collateral circulation to the small intestine, acute arterial occlusion from emboli, which accounts for approximately 50% of all cases of acute mesenteric ischemia, usually results in short gut syndrome in those patients who survive this catastrophic event.⁹ Etiologies of emboli include the left ventricle from cardiac dysrhythmias, cardiac valves from endocarditis, and aortic atherosclerotic plaque, diseases which occur primarily in the adult population. Venous occlusion accounts for less than 10% of cases of mesenteric infarction and is usually associated or precipitated by a hypercoagulable state. Acute mesenteric venous hypertension leads to increased vascular resistance, bowel edema, decreased blood flow, and bowel ischemia. Mandatory thrombophilia workup and hematologic evaluation is warranted in cases of venous mesenteric thrombosis to prevent future thrombotic events, which could have a profound effect on a newly transplanted intestinal graft in the future.⁸

Crohn's Disease

Crohn's disease is the second most common etiology of short gut syndrome leading to transplantation in adults, accounting for approximately 11% of cases.² Common complications such as perforation, stricture, obstruction, and abscess generally lead to multiple surgical procedures over the course of time, eventually rendering the patient with intestinal failure and permanent parenteral nutrition. Nearly one-quarter of patients who recovered from a Crohn's disease-related surgery will require a subsequent surgery within 5 years and 35% within a decade.¹⁰ Despite the general surgical teaching of avoidance of large resections in Crohn's disease complications, recurrent and refractory disease will dictate mandatory resections in life-threatening surgical emergencies. In many cases, this emergent surgery will produce more surgical complications, particularly enterocutaneous fistulae. Efforts to reestablish enteral continuity, such as stoma closure, closure of enteroatmospheric fistulas, and surgically relieving obstructions, are a few of the surgical procedures that need to be performed before establishing a diagnosis of permanent intestinal failure in patients with Crohn's disease. Newer medical treatments and advances have led to a steady decrease in initial surgery rates over the last several decades; however, since the 1980s, the rates of second surgery have not decreased.¹⁰ Mutations of certain alleles of the *NOD2* gene have been identified as risk factors for Crohn's disease. The *NOD2* gene, which encodes for an intracellular protein that serves as a microbial sensor in macrophages, dendritic cells, and Paneth cells, if abnormal, has been identified as having a 2- to 40-fold increased risk of Crohn's disease for certain mutant alleles.¹¹ With regard to intestinal transplant recipients, in several independent center analyses, a higher likelihood of allograft failure has been

observed in recipients with a *NOD2* mutation, some with increased failure rates as high as 97-fold.¹² This finding suggests a similar link between the dysregulated gut innate immune system playing a significant role in the immunologic graft loss of the transplanted intestine. The recognition of potential intestinal transplant recipients with a *NOD2* mutation, particularly those with Crohn's disease, is critically important to risk stratify these potential recipients appropriately.

Acute Volvulus

Unlike the typical case of volvulus, which usually occurs in infants with malrotation, adult cases of volvulus leading to a short gut and transplantation are not always related to the classic congenital mesenteric anatomic defects. Occasionally an adult who has suffered a volvulus as a child and has been maintained on parenteral nutrition until adult years, only to eventually suffer complications, is listed for an intestinal transplant. More commonly observed in the adult experience, however, is a surgically altered mesenteric anatomy that results in an acute volvulus event. An emerging observation of acute short gut has been reported in the Roux-en-Y gastric bypass population that has suffered an intestinal volvulus resulting in intestinal ischemia necessitating a life-saving total enterectomy. Rapid and massive weight loss after Roux-en-Y gastric bypass results in diminished mesenteric fat, which may increase the potential space between the jejunal limb and transverse mesocolon, allowing for a volvulus to occur (Petersen's hernia).¹³ In addition, the standard use of the laparo-scope in Roux-en-Y bypass has been implicated as a causative factor, because less adhesion formation may contribute to a larger open potential space.¹⁴ In these particular cases, reestablishment of gastric continuity and removal of the jejunal limb, if it has survived the ischemic insult, is preferred before listing for intestinal transplantation.

Non-Short Gut Conditions Leading to Adult Intestinal Transplantation

Non-short gut conditions for the adult that lead to intestinal transplantation include intestinal motility disorders, tumors (chiefly desmoid tumors invading the base of the mesentery), and retransplantation.

Adult Motility Disorders

Motility disorders of the intestine are characterized by obstructive gastrointestinal symptoms without any evidence of mechanical occlusion of the gut lumen. Patients are typically symptomatic, with nausea, emesis, abdominal bloating, diffuse chronic abdominal pain, and weight loss. Stasis, bacterial overgrowth with malabsorption, and poor oral intake eventually lead to intestinal failure and the need for parenteral nutrition. Rehabilitative efforts are generally unsuccessful and do not provide any lasting enteral independence; these patients also undergo many futile surgeries, chiefly negative exploratory laparotomies for suspected bowel obstruction.¹⁵ The evaluation includes first eliminating any possibility of a mechanical obstruction or possible causes of secondary forms of motility disorders, performing appropriate motility testing, and possibly a full-thickness biopsy or genetic testing. Typically, the symptoms evolve over many years presenting initially in the pediatric population and progressing into the adult years. It currently accounts for approximately 11% of all adult intestinal transplants.²

Intrabdominal Malignancy

Abdominal desmoid tumors account for the majority of intraabdominal tumors leading to intestinal transplantation in the adult. Desmoid tumors, although a benign fibromatous neoplasm, when it arises at the base of the mesentery, its infiltrative and locally invasive characteristics lead to a diffuse entrapment of the mesenteric vasculature, leading to intestinal complications such as obstruction and fistula formation. Conventional chemotherapy often proves unsatisfactory, and the treatment of choice is complete surgical resection that, owing to the location at the base of the mesentery, will uniformly result in ultrashort gut syndrome. In certain cases where the tumor has progressed and infiltrated cephalad to the root of the mesentery, complete exenteration of the foregut is mandatory, necessitating a modified multivisceral transplant. Recurrence of abdominal desmoids after intestinal transplantation have been reported, although usually are not associated with the transplanted graft and with no significant impact on survival after transplant.¹⁶ Other intrabdominal malignancies have been considered for intestinal transplantation, although with much less frequency than the desmoid. Like with desmoid, the indication for intestinal replacement is usually due to the location of the tumor at the base of the mesentery, and those tumors with an indolent growth pattern, such as neuroendocrine tumors. In these cases, caution must be exercised when considering transplantation, because the biological behavior of many of these tumors, although low grade and indolent, is relatively unknown under long-term compulsory immunosuppression. Recent registry data report approximately 15% of all adult intestinal transplants were performed for malignancy.²

Adult Intestinal Retransplantation

Intestinal retransplantation in the adult population has increased over the past decade at a greater rate than adult primary transplants during the same time period. In an analysis of both adult retransplants from 2001 to 2009, adult retransplantation volume increased almost 5 times than the in preceding decade, whereas primary transplants only increased 3.2 times.¹⁷ In addition, outcomes for retransplantations with an isolated intestine were significantly worse than primary transplants. Rejection, particularly humoral rejection, has been identified as a major barrier to successful retransplantation, primarily owing to the increased allosensitization that frequently accompanies the intestinal retransplant candidate. Adult intestinal retransplantation with a liver-inclusive graft, however, has not shown inferior results, possibly owing to the immunogenic protective effects of the liver allograft.¹⁷ Current registry data report approximately 7% of all adult intestine transplants have been retransplants.²

INDICATIONS FOR ADULT INTESTINAL TRANSPLANTATION

Intestinal transplantation, despite the improvements in patient and graft survival over the past decade, has mostly been reserved for those suffering from the complications of parenteral nutrition or those with a physical inability to attain central venous access for the delivery of parenteral nutrition. Direct complications of parenteral nutrition include the development of overt liver disease, and indirect complications include frequent and/or life-threatening episodes of sepsis as well as loss of central venous access as described. Certain conditions have been recognized as having a high risk of death intrinsic to the disease state,

such as abdominal desmoid tumors; congenital mucosal disorders, which are usually seen in pediatric population such as tufting enteropathy and microvillous inclusion disease; and those with a blind duodenum with retrograde biliopancreatic secretions drained from a gastrostomy tube or those adults with ultrashort bowel (<20 cm of jejunum). Other indications categorized as those with a high morbidity include those such as frequent hospitalizations, narcotic dependency, an inability to tolerate home parenteral nutrition, and those unwilling to accept long-term home parenteral nutrition (Box 1). These indications, published by the US Centers for Medicare and Medicaid Services in 2000 have largely been adopted worldwide as the standard for intestinal transplantation.¹⁸ A more recent analysis performed by European intestinal transplant centers looking at the adult intestinal failure patient essentially parallels US guidelines specifically noting the increased risk of death in patients with parenteral nutrition associated liver disease (relative risk, 3.2) and invasive intrabdominal desmoids (relative risk, 7.1). This analysis, however, did not note an increased risk of death in adult patients with catheter-related complications or ultrashort bowel.¹⁹

SURGICAL PROCEDURE

The intestinal graft comes in many different forms and configurations depending on the needs of the recipient. Central to any type of intestinal graft is the jejunoileum component. Three major categories of intestinal transplant have been classically described: the isolated intestine, the liver–intestine, and the multivisceral transplant. In the adult intestinal recipient, the most common grafts used are the isolated intestine and the multivisceral grafts.

The major indication for isolated intestine transplant in both adult and pediatric patients are those patients with irreversible intestinal failure with preserved liver function who suffer from life-threatening complications of parenteral nutrition. The use of the nomenclature for the “liver–intestine” graft has differing meanings in the adult and pediatric populations. In pediatrics, the liver–intestine graft is generally understood to indicate a composite liver–pancreas–intestine graft and thus must be listed for a liver, pancreas, and intestine on the national United Network for Organ Sharing waiting list. In infants and small children, using the technique of foregut preservation and en bloc transplantation of the liver–pancreas–intestine, no reconstruction of the pediatric hepatic artery, portal vein, or common bile duct is necessary, greatly simplifying the transplant. In this case, because the native stomach, pancreatoduodenal complex, and spleen are preserved, a native portocaval shunt must be constructed before implantation of the organs.²⁰ This situation differs considerably from the adult recipient who requires a concomitant liver graft owing to parenteral nutrition associated liver disease. In these cases, the foregut anatomy is usually preserved and, with an intact and patent portal vein, and an isolated liver transplant can be performed in the standard fashion followed by an isolated intestine transplant. This graft is referred to as a “noncomposite” liver–intestine graft.²¹

Multivisceral graft transplantation entails total exenteration of the native stomach, pancreas, liver, spleen, and remaining intestine and replacement of all abdominal viscera with an en bloc graft. In many cases of adult multivisceral transplantation, the chief indication is the inability to safely delineate and preserve the foregut anatomy owing to multiple previous surgeries, which necessitate complete exenteration along with the diseased native liver. The

most common indications for the adult multivisceral transplant is, as mentioned, portomesenteric thrombosis. Other indications in adults include abdominal desmoids infiltrating the foregut and motility disorders affecting the foregut. In those cases, where the liver is preserved and the foregut diseased, a “modified” multivisceral transplant is performed, transplanting only the stomach, duodenum, pancreas, and intestine. In the “modified” multivisceral transplant, the entire graft venous outflow is the inflow to the intact native liver.

All of these grafts, both pediatric and adult, can be with or without the inclusion of a colon component in continuity with the jejunioileum. Early poor outcomes in intestinal transplantation were thought to be attributed to the inclusion of the colon with the small intestine graft. Later colon inclusion experiences reported a 6% superior graft survival at 3 years ($P = .03$), a higher frequency of formed stool after stoma closure, improved quality of life, and a significantly greater likelihood of complete enteral independence after transplant.²² The latest Intestinal Transplant Registry reports colon inclusion in intestinal allografts has increased from 10% in 2004 to almost 60% in 2015.²

Adult Isolated Intestine

The isolated intestine graft contains the jejunioileum with or without the colon (Fig. 3). Arterial inflow is established via the graft superior mesenteric artery, and venous outflow via the graft superior mesenteric vein. Vascular conduits are universally used to facilitate the placement of the intestine graft without undue tension on the vessels as well as providing a more technically favorable condition for the vascular anastomoses, thus reducing the warm ischemic time. Arterial and venous conduits for adult intestinal recipients are obtained during the donor procedure from the donor external iliac artery and vein. In the common scenario of a simultaneous adult pancreas and liver procurement by separate teams, the external iliac artery is usually obtained from the liver donor vessels, and the external iliac vein obtained from the pancreas donor vessels.

There are 2 techniques for isolated intestine vascular reconstruction, either portal (orthotopic) or systemic (heterotopic) venous drainage (Fig. 4). In many cases of recipients with short gut, the proximal native mesenteric pedicle is chronically occluded and atrophic, rendering the vessels unsuitable for the transplant graft. In those cases, systemic drainage is used by exposing the infrarenal aorta and vena cava. The donor iliac interposition grafts are anastomosed in an end-to-side fashion directed caudally (Fig. 5). Once the extension grafts are in place, the intestine graft is brought up into the field and the graft mesenteric vessels are anastomosed to the interposition grafts in an end-to-end fashion. It is critical that the interposition grafts are cut to an appropriate length to prevent undue tension on the vessels after reperfusion when the intestine graft size and weight increases significantly. After releasing the arterial clamp and before the release of the venous clamp, a blood flush is performed through the superior mesenteric vein anastomosis. After reperfusion and hemostasis, it is critical to immediately affix the base of the graft mesentery to avoid graft volvulus of the mesenteric pedicle. In cases where the infrarenal vena cava is not patent owing to thrombosis from chronic indwelling femoral central venous lines, the suprarenal

vena cava can be used for outflow. The extension graft is routed behind the mobilized duodenum to lie adjacent to the thrombosed infrarenal vena cava.

In recipients with functional disorders such as pseudoobstruction, where the native intestine is typically preserved before transplantation, the mesenteric vascular pedicle can be suitable for use as inflow and outflow of the intestine graft. The undisturbed base of the small intestine mesentery allows for exposure of the proximal superior mesenteric artery and vein (Fig. 6). Extension grafts are used in a similar fashion and anastomosed to the native mesenteric vessels. Placement of the graft is performed with an end-to-end anastomosis to the graft mesenteric vessels and blood flush performed through the mesenteric vein anastomosis. Regardless of which anatomic venous drainage is used, however, no significant adverse outcomes have been reported with either technique.²³

Graft Selection

Proper graft selection for the adult isolated intestinal recipient is paramount for a successful outcome. Many donor factors, all equally important, are evaluated on an individualized manner based on the recipient's condition at the time of the organ offer. In the current condition of adult intestine supply and demand, and in the absence of requiring a liver-inclusive graft, great latitude is afforded in selecting the most appropriate isolated intestinal graft for the stable adult recipient. General standard criteria such as donor normal gastrointestinal history and absence of any evidence of intestine trauma apply to all donors considered. Specific to the adult intestine donor, which need a high level of scrutiny before acceptance, are donor hemodynamic stability, graft size, and immunologic compatibility.

Hemodynamic stability must be established in the intestinal donor. The intestine is exquisitely sensitive to hemodynamic instability in the donor because splanchnic blood flow is reduced on a greater scale during periods of hypotension. In particular, donors who have suffered cardiopulmonary arrest and resuscitation pose a challenge to determine its suitability as a donor. Recent literature supports the successful use of intestinal grafts in carefully selected donors that who have undergone cardiopulmonary resuscitation.²⁴

Size is a critical factor in the selection of the appropriate graft. In cases of short gut, significant loss of abdominal domain necessitates the placement of a smaller graft to achieve primary abdominal wall closure. In the adult recipient, this generally requires a donor size up to approximately one-half of the body weight of the recipient depending on the extent of the loss of domain. In a stable potential recipient, the benefits of primary closure with an appropriate-sized graft greatly outweigh the risks of a postoperative chronic open abdomen.

Intestinal transplants candidates, owing to a common history of multiple surgeries, infections, and blood transfusion often are sensitized to HLA antigens at the time of listing for transplantation. Evidence regarding the poor outcome with a positive cross-match in intestinal transplantation, as well as with other solid organ transplants, has been firmly established.²⁵ With a virtual cross-matching strategy, a negative cross-match can be accurately predicted, thus avoiding the adverse sequela of a preformed antibody at the time of transplantation. By using the virtual cross-match, an immunologically suitable intestine donor can be pursued with confidence over great distance without an actual cross-match.

This serves to reduce or eliminate the logistical burden of traveling long distances with the uncertainty of obtaining a negative crossmatch in the highly sensitized recipient. Owing to the variable production of HLA antibody with each recipient, a successful negative virtual cross-match requires at least a monthly analysis of recipient serum for unacceptable antigens to accurately reflect the recipient's antibody profile at the time of transplantation.²⁶

ADULT INTESTINAL TRANSPLANT GRAFT SURVIVAL

The evolution of immunosuppression, refinement of surgical techniques, earlier recognition of complications, and an increased overall experience in intestinal transplantation have improved patient and graft survival. Recent Organ Procurement and Transplantation Network/Scientific Registry of Transplant Recipients data have shown a decrease in graft failure rates for both adult and pediatric transplants that contain an intestinal transplant over the past 2 decades. Much of the decrease in graft failure rates, however, have occurred during the earlier period of the past 2 decades. Data from the past several years have observed a plateau in gains on graft survival for intestinal transplants with or without a liver component.³ In the most recent Scientific Registry of Transplant Recipients report that covered the results from January 2014 through June 2016, in the 6 US centers that performed 10 or more adult intestinal transplants in 2016, the 1-year graft survival ranged from 60.5% to 83.0%. Including all centers that performed at least 1 adult intestinal transplant, the US 1-year graft survival average was 73.6%. The 3-year adult graft survival at these same centers ranged from 28.6% to 72.7% with a US average of 56.3%.²⁷ In an earlier reporting period from 2008 to 2010, the adult 1-year graft survival was 71.2%, illustrating the relatively modest gains achieved over this recent several year period³ (Fig. 7).

SUMMARY

Adult intestinal transplantation is unique in many ways and differs significantly from pediatric intestinal transplantation. Indications for transplant have remained consistent since the introduction of the Centers for Medicare and Medicaid Services guidelines in 2000 particularly with regard to concomitant liver disease and intestinal failure; however, over the past 2 decades, with early improved results, indications for adults have expanded. Intestinal transplantation (multivisceral) for primary end-stage liver disease with portomesenteric thrombosis is a more frequent indication and intestinal transplantation for intraabdominal malignancies other than desmoids has been reported with good results. Graft type use in adult recipients depends on the distinct anatomic characteristics of the adult recipient, particularly in the cases liver-inclusive grafts and the recognition of the hazards of preformed and de novo antibody has led to the effective use of virtual cross-matching and improved pretransplant donor–recipient matching. Colon inclusion has increased over the past 2 decades with improved, sustainable results. Outcomes for adult recipients, as measured by graft survival, has seen a steady improvement since the 1990s; however, in the past several years, has slightly plateaued. Regardless, for adult intestinal transplant candidates, who have the highest pretrans-plant mortality, intestinal transplantation remains a mainstay therapy for those with complicated intestinal failure, as well as other life-threatening and debilitating conditions.

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KEY POINTS

- Owing to the large lymphoid load and resultant immunologically reactive graft, intestinal transplants pose a direct challenge to the recipient's immune system.
- Intestinal transplants also indirectly challenge the recipient with the compulsory augmented immunosuppression and the inherent complications associated with the higher immunosuppressed state.
- The etiologies of intestinal failure, rehabilitative prognosis, graft type, surgical techniques, nutritional autonomy, and outcomes separate adults and children with regard to intestinal transplantation.

Box 1**Centers for Medicare and Medicaid–approved indications for intestinal transplantation****Failure of parenteral nutrition**

- Impending (total bilirubin 3–6 mg/dL, progressive thrombocytopenia, and progressive splenomegaly) or overt liver failure (portal hypertension, hepatosplenomegaly, hepatic fibrosis, or cirrhosis) because of parenteral nutrition liver injury
- Central venous catheter-related thrombosis of 2 central veins
- Frequent central line sepsis
 - Two episodes per year of systemic sepsis secondary to line infections requiring hospitalization
 - A single episode of line-related fungemia
 - Septic shock or acute respiratory distress syndrome
- Frequent episodes of severe dehydration despite intravenous fluid in addition to parenteral nutrition

High risk of death attributable to the underlying disease

- Desmoid tumors associated with familial adenomatous polyposis
- Congenital mucosal disorders
- Ultrashort bowel syndrome (residual bowel 20 cm in adults)

Intestinal failure with high morbidity or low acceptance of parenteral nutrition

- Frequent hospitalization
- Inability to function
- Patient unwillingness to accept long-term parenteral nutrition

Data from Department of Health and Human Services (DHHS) and Centers for Medicare and Medicaid Services (CMS). Intestinal and multi-visceral transplantation: program memorandum intermediaries/carriers. Pub #:60AB; CR #:1629. AB-02-040. 2002. Available at: <https://www.cms.gov/Regulations-and-Guidance/Guidance/Transmittals/downloads/AB02040.pdf>.

Fig. 1. International transplant registry data comparing liver inclusive grafts versus no liver graft in the adult and pediatric population. (*Courtesy of Robert S. Venick, MD, Los Angeles, CA.*)

U.S. Adult Intestinal Transplants 2007–2016

Fig. 2. United Network for Organ Sharing (UNOS) data of total number of adult (≥ 18 years) intestinal transplants from 2007 to 2016. (Data from U.S. Department of Health and Human Services. Organ procurement and transplantation network data reports. Available at: <https://optn.transplant.hrsa.gov/data/view-data-reports/>.)

Fig. 3.
En bloc adult intestine colon transplant graft with graft superior mesenteric artery (SMA) and superior mesenteric vein (SMV) labeled. (*From Hawksworth J, Matsumoto S. Intestinal transplant techniques: from isolated intestine to intestine in continuity with other organs. In: Dunn SP, Horslen S, editors. Solid organ transplantation in infants and children, organ and tissue transplantation. Springer; 2017. p. 1–26; with permission.*)

Fig. 4.

(A) Isolated intestine transplant with the en bloc intestine colon graft implanted in a heterotopic position. (B) Isolated intestine transplant with details of the graft mesenteric reconstruction, either portal (orthotopic) or systemic (heterotopic). SMA, superior mesenteric artery; SMV, superior mesenteric vein. (From Hawksworth J, Matsumoto S. Intestinal transplant techniques: from isolated intestine to intestine in continuity with other organs. In: Dunn SP, Horslen S, editors. Solid organ transplantation in infants and children, organ and tissue transplantation. Springer; 2017. p. 1–26; with permission.)

Fig. 5.

(A) Exposure and clamping of the recipient infrarenal aorta and vena cava. (B) Donor interposition grafts anastomosed in a spatulated end-to-side manner. IVC, inferior vena cava. (From Hawksworth J, Matsumoto S. Intestinal transplant techniques: from isolated intestine to intestine in continuity with other organs. In: Dunn SP, Horslen S, editors. Solid organ transplantation in infants and children, organ and tissue transplantation. Springer; 2017. p. 1–26; with permission.)

Fig. 6.

Exposure of the native superior mesenteric artery (SMA) and superior mesenteric vein (SMV) with donor extension grafts for orthotopic placement of the isolated intestine graft. (From Hawksworth J, Matsumoto S. Intestinal transplant techniques: from isolated intestine to intestine in continuity with other organs. In: Dunn SP, Horslen S, editors. Solid organ transplantation in infants and children, organ and tissue transplantation. Springer; 2017. p. 1–26; with permission.)

Fig. 7.

Graft survival among intestine transplant recipients, 2008 to 2010, by transplant type. (*From* Smith J, Skeans M, Horslen S, et al. OPTN/SRTR 2015 annual data report: intestine. *Am J Transplant* 2017;17 Suppl 1:252–85; with permission.)