Controversies in Hirschsprung surgery

Thomas O Xu [ID] , Marc A Levitt, Christina Feng

ABSTRACT

The treatment of Hirschsprung disease (HSCR) is surgical resection of aganglionic bowel and subsequent pull-through of ganglionated bowel. Despite many advances since the initial description of the disease and its surgical management more than half a century ago, there remain considerable controversies regarding the history of the surgical technique, the optimal timing of the primary and multistage pull-through, the best treatment for patients with a delayed diagnosis of HSCR, and the management of post pull-through complications such as soiling due to sphincter incompetence, the presence of a transition zone, and the prevention of enterocolitis. The following review will explore each of these controversies.

Division of Colorectal and Pelvic Reconstruction, Children's National Hospital, Washington, District of Columbia, USA

Correspondence to
Dr. Thomas O Xu; thomas. ouyang.xu@gmail.com

CONTROVERSY IN THE ORIGIN OF THE "YANCEY-SOAVE" PROCEDURE

Historically credited to Italian pediatric surgeon, Franco Soave, in 1964, the "Soave" procedure is a common pull-through method that modified the original Swenson procedure, a full thickness rectal dissection, and instead used a submucosal dissection plane limiting the risk of damage to adjacent structures during the pull-through procedure.[1] Boley subsequently modified this technique in 1968 to include a primary anastomosis rather than a delayed one, and since then, this procedure has carried the eponym as the "Soave" or "Soave-Boley" procedure.[2]

Soave, however, was not the first to describe this submucosal technique. Yancey (figure 1), a black American surgeon, first reported this technique 12 years prior to Soave in 1952 in the *Journal of National Medical Association* (JNMA).[3] This journal was predominately used to publish the work of black health professionals in an era where there were few opportunities for black physicians to share their work. As a result, Yancey was not credited for his work as the journal was not carried by most white institutions at the time. To correct this historical injustice, the pediatric surgical community now refers to the procedure as the Yancey-Soave (or Yancey-Soave-Boley) technique.[4] Yancey (and Soave) originally described the procedure through a transabdominal approach using a submucosal endorectal dissection to avoid injury to the surrounding pelvic structures and positioning

the bowel through an aganglionic muscular "cuff" which was then split and sutured to prevent obstruction.[3]

CONTROVERSY IN PERFORMING A CONTRAST ENEMA PRIOR TO PULL-THROUGH

During the initial workup of a patient suspected of having a distal bowel obstruction, including HSCR, a contrast enema can be a valuable tool in the triage of the patient and the ensuing preoperative planning. However, some surgeons choose to forgo the contrast enema in favor of immediately performing leveling biopsies in cases where HSCR is highly suspected or already confirmed via rectal biopsy. A water-soluble contrast enema, rather than barium, should be performed, which can be both therapeutic and diagnostic, for other causes of distal bowel obstruction, such as meconium ileus or meconium plug syndrome. In patients with HSCR, the contrast enema may reveal a transition zone that lies between normal, dilated bowel and abnormally narrow aganglionic bowel (figure 2). Most patients have a radiographically identifiable transition zone, but the absence of a transition zone does not rule out HSCR, as 10% do not have an obvious transition zone on contrast enema.[5] Occasionally, false-positive studies occur, which is more common in neonates. As such, contrast enemas performed on neonates (<30 days) are less specific and may have a lower role in their diagnostic utility.[5] To help with this, a delayed plain radiograph can be obtained 24 hours later to look for retention of contrast, which can also be very suggestive of HSCR.[6] Ultimately, a rectal biopsy is the gold standard for the diagnosis of HSCR.

Several factors are important in ensuring a contrast study that has the highest chance of identifying a transition zone, including proper technique. To start, a small catheter should be used and inserted only one centermeter (1 cm.) into the rectum. If a Foley catheter is used, the balloon should not be inflated as it may cause false dilation of an otherwise short segment of aganglionosis. Since most patients have rectosigmoid disease, lateral radiographs should be obtained, as a transition zone may
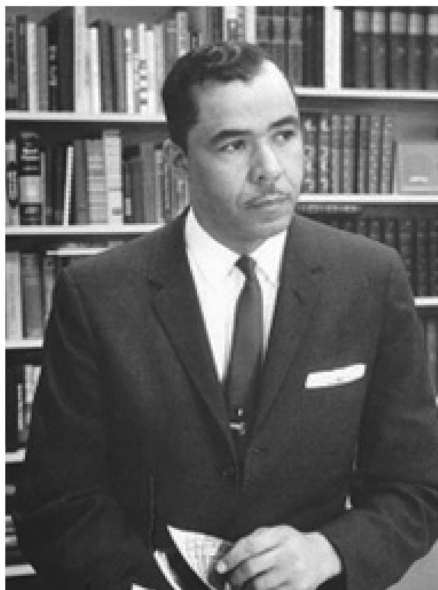
Figure 1 Dr. Asa Yancey, first published on the use of a submucosal endorectal dissection for pull-through in Hirschsprung Disease. His publication was in 1952. Soave's was in 1964.

be missed with anteroposterior images. Additionally, patients should not have active colitis at the time of the contrast enema due to the risk of perforation. Diagnostically, colitis may also mask some of the typical signs of HSCR. For example, a spastic colon may be observed during an episode of colitis which may not permit the formation of a classical transition zone. Contrast instillation that is too rapid or too high of a pressure may also reduce the diagnostic yield of a contrast enema.[6 7]

Some centers forgo the contrast enema with the plan to perform leveling biopsies intraoperatively, but this
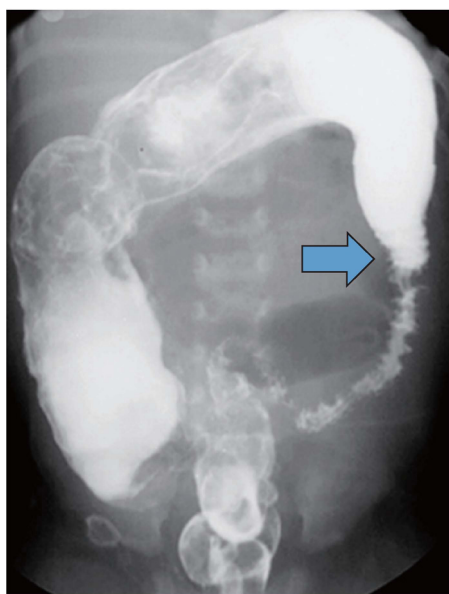
Figure 2 Contrast enema demonstrating clear transition zone between aganglionic and normal ganglionated bowel (blue arrow).

can potentially lead to unnecessary additional biopsies, prolong the operation due to time spent waiting for multiple frozen biopsy results, and introduce the risk of leakage at the biopsy sites.[7] Additionally, some surgeons may fall into the trap of mapping the colon without a confirmatory rectal biopsy in cases of short segment HSCR in which the transition zone is below the level of the peritoneal reflection. This scenario arises when a newborn undergoes "urgent" exploration for lower intestinal obstruction and all that is found is a dilated colon. In cases in which the aganglionosis is limited to the rectum, biopsies taken of the colon only will result in the false assumption that HSCR has been ruled out. Rectal aganglionosis must be excluded before definitely ruling out HD. Ultimately, the contrast enema is important in preoperative planning and intraoperative guidance with very little downside—if the resources are available. Moreover, a good colonic map produced by a contrast study can reassure the surgeon that irrigations will work if they know that the irrigation catheter can easily reach the dilated portion of colon.

Understanding the possible length of aganglionosis can minimize unexpected surprises in the operating room. Take, for example, a situation where the patient may have long segment disease/total colonic HSCR. If the surgeon goes into the operation via a transanal approach only, unsuspecting of a longer segment of disease, they may end up creating an anastomosis with unnecessarily high tension. Additionally, unexpected findings during a transanal case may lead to sphincter damage due to prolonged overstretching. Even worse would be a conversion to an open procedure, only to find that the blood supply has not been optimally preserved. A contrast enema in this situation may help guide when a patient could have benefited from an initial ileostomy.[7] While not all contrast enemas are diagnostically clear, the absence of an obvious transition zone in patients with confirmed HSCR is also a useful sign as it highlights the need for a more thorough investigation or the need for additional biopsies beyond the rectosigmoid. In summary, the contrast enema is a very valuable preoperative tool as it can guide the intraoperative plan and avoid unnecessary biopsies and minimize unanticipated findings.

CONTROVERSIES IN TIMING AND CHOICE OF PULL-THROUGH

The age when patients undergo their pull-through has evolved throughout the years due to advancements in early diagnosis, newborn management, and surgical technique. However, the optimal timing for a pull-through continues to be debated. When Swenson first described the pull-through technique in 1949, he recommended first diverting with a colostomy and delaying the pull-through procedure beyond 4 months of age due to the high mortality associated with the procedure in younger infants, as these patients were frequently malnourished.[8] As a result, the pull-through operation was historically done in a multistage approach with the definitive repair

delayed until the child had gained weight and was older. Over the years, a single-stage approach has become more popular with increasing awareness for HSCR,[9] the advent of the rectal suction biopsy,[10] and new staining techniques for pathology,[11] all of which gradually lowered the age of diagnosis.[12] In 1980, So *et al.* described performing a single-stage operation in neonates with HSCR and demonstrated comparable results to the traditional multistage method. He did this single stage in desperation while working in the Philippines as he found that patients he diverted often died at home due to the social stigma of having a stoma.[13] As a modification of the single-stage approach, Carcassonne *et al.* described treating neonates with daily rectal irrigations at home before they returned for a single-stage pull-through procedure by 3 months of age.[14] Earlier diagnosis in combination with minimally invasive surgical innovations, such as the use of laparoscopy[15] or a totally transanal approach,[16] also lowered the age at which pull-throughs were being done as many surgeons began to perform the operation soon after diagnosis to increase the likelihood for a single-stage operation.[17]

Timing of the single-stage operation

In contemporary practice, the single-stage operation is the preferred approach for a majority of patients, and it has been shown to be just as safe compared with multi-stage procedures.[18–20] The timing of the single stage pull-through varies significantly and remains controversial, with practice patterns divided between pull-through within the newborn period, for example, within 30 days of birth, versus delayed, typically after 2–3 months of age or based on a certain size cut-off (in kilograms). However, there is no standard recommendation for the age at time of surgery.[21] The decision for the timing of the pull-through can be based on numerous factors, including patient gestational age, weight, age at diagnosis, comorbidities, socioeconomic circumstances, and surgeon practice preferences. Proponents of an early repair argue that it may lessen the risk of enterocolitis by decreasing the time to operation, avoids need for preoperative irrigations which can be burdensome for some families, and limits the patient to a single hospitalization.[22] On the other hand, a delayed pull-through operation will allow for the child to gain weight, allow care givers to gain experience with rectal irrigations, and allow for the maturation and growth of the anal canal and sphincter complex which will help facilitate a better anastomosis.[23 24] Furthermore, some studies have suggested that a delayed operation may reduce healthcare utilization by decreasing either the neonatal intensive care unit or postoperative length of stay.[25 26]

Overall, the two strategies for the timing of repair have similar rates of perioperative complications and functional outcomes. A multi-institutional retrospective study through the Pediatric Colorectal and Pelvic Learning Consortium (PCPLC) performed in 2021, specifically comparing neonatal (<31 days) versus delayed

pull-through, demonstrated that a delayed neonatal pull-through offers similar outcomes regarding rates of complication and functional outcome across experienced centers in the USA. Rates of preoperative and postoperative enterocolitis were similar between the neonatal versus delayed group, as well as rates of constipation (60% *vs.* 67%), incontinence (30 % *vs.* 15%), and the need for a bowel management program (93% *vs.* 81%).[27] In 2023, a UK-based study by Roy *et al.* compared neonatal surgery (median age 18 days) versus surgery after delayed "rectal washouts" (median age 310 days) and found that immediate surgery was not associated with increased complications, need for revision, or need for subsequent stomas.[28] This study did not specifically examine functional outcomes, but it did find that those who underwent immediate surgery had a statistically significant higher rate of using antegrade continence enemas later in life (11% *vs.* 6%). Notably, this study included those with stomas or delayed diagnoses in the "delayed" cohort. Ultimately, the authors advocated for surgery within the first month of life.

Some studies have examined the age at time of surgery and functional outcomes more specifically. In a cross-sectional study from the Netherlands, Roorda *et al.* found that there was no association of age at surgery with long-term probability and severity of constipation and fecal incontinence, even after adjusting for operative technique, extent of aganglionosis, and if a diverting stoma was used.[29] In contrast, a meta-analysis of five studies (three from China, one from Japan, one from the USA) by Westfal *et al.* suggested that patients who receive surgery before 2.5 months of age are at a higher risk for adverse outcomes and worse function later in life. Patients repaired before 2.5 months of age had higher rates of constipation and/or soiling (26% *vs.* 11%), stricture (10% *vs.* 2%), and leak (6% *vs.* 1%).[30] It is postulated that these outcomes may be because the sphincters and muscles of a neonate are less developed and more prone to damage, leading to worse outcomes.

In summary, the timing of the primary pull-through still varies widely across institutions. Although some studies suggest advantages to a delayed procedure in terms of certain postoperative complications and long-term outcomes, recently published multi-institutional data from US hospitals with a dedicated colorectal program suggest that outcomes are at least similar between early versus delayed single-stage pull-through.[27] Further multi-institutional studies are required to explore this relationship between age and functional outcomes. Future studies should also look at other indirect benefits to each repair approach, such as caregiver perspectives in relation to the timing of surgery and healthcare utilization. Given the apparent clinical equivalence currently demonstrated in the literature, we recommend that surgeons with familiarity and comfort with the single-stage pull-through may do so in the neonatal period.

When to choose a multistage pull-through

The single-stage pull-through has been shown to be safe and is now the most performed approach, but there is still a subset of patients who may not be candidates for this operation.[31] These include patients with severe enterocolitis, perforation, malnutrition, long segment disease, extreme bowel dilation, and other factors such as poor healthcare access or inability to reliably perform decompressive irrigations. For these patients who typically start with a leveling colostomy or an ileostomy, the timing of the pull-through is not clear.

For patients initially diverted with an ileostomy due to failure to thrive, it is important to ensure that the patient is optimized nutritionally prior to the pull-through. In addition to dehydration, patients with an ileostomy are at risk for electrolyte derangements, especially enteral sodium losses. Gastrointestinal sodium has a critical role in the transport and uptake of glucose, therefore excessive sodium losses place the patient at risk for poor weight gain.[32] Ideally, patients should have urine sodium levels of at least 30 mmol/L. Those with levels below 30 mmol/L have significantly lower weight gain and require supplementation.[33] Additionally, these patients should be screened for nutritional markers such anemia and hypoalbuminemia which have been well established to be associated with worse surgical outcomes.[34] Our institution employs a nutritional screening protocol which helps guide timing of surgery (figure 3). Studies of the relationship between urine sodium and post operative outcomes for patients with HSCR and a diverting ileostomy are still warranted.

Controversies in determining the level of the transition zone

When a patient is ready for the pull-through procedure, laparoscopy is helpful in enabling improved visualization and confirmation via biopsy of the location of the transition zone, especially in cases of diagnostic uncertainty or in patients who present with disease behavior concerning for long segment HSCR. In cases in which the ganglion cells are absent proximal to the splenic flexure, reliance on frozen section pathology is not recommended for the evaluation of ganglion cells as the frozen technique has good sensitivity for the presence of ganglion cells but poor specificity in determining the lack of ganglion cells. In other words, frozen section can rule out HSCR but cannot rule in HSCR due to the process of frozen sectioning, which can create artifact as a result of cracking of the tissue during freezing. As a result, ganglion cells might be missed, leading to a false diagnosis of HSCR in bowel that is otherwise normal. Furthermore, there are usually no hypertrophic nerves in the transverse and more proximal parts of the colon as this section of colon does not have any contribution from the sacral plexus innervation. Therefore, interpretation in this section of bowel using frozen section is solely dependent on the presence or absence of ganglion cells. In summary, in such cases in which ganglion cells are not found proximal to the splenic flexure, waiting on the results of
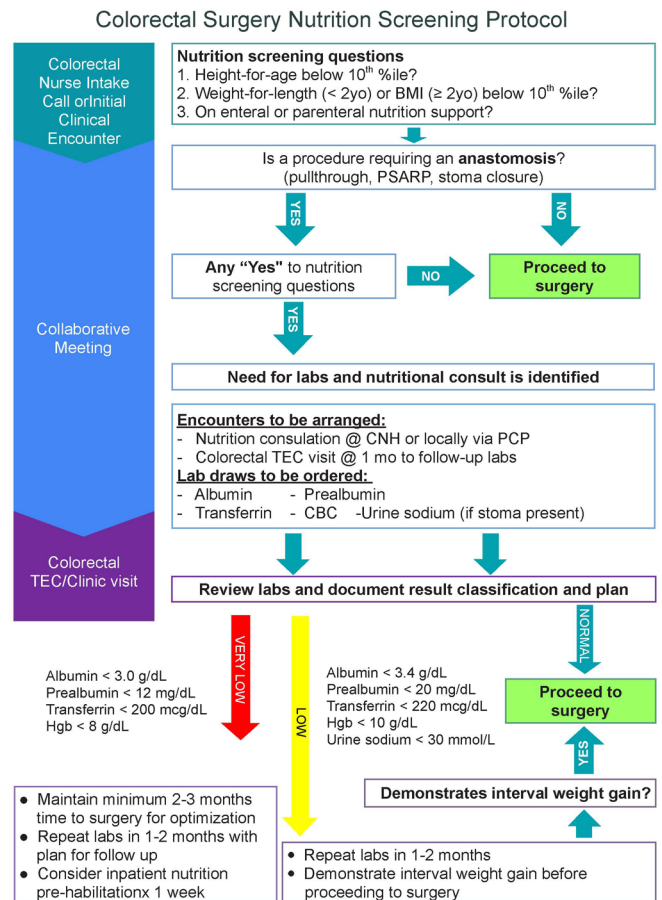

Figure 3 Sample nutritional screening protocol and supplementation guidelines. %tile, percentile; BMI, body mass index; CBC, complete blood count; CNH, Children's National Hospital; f/u, follow-up; Hgb, hemoglobin; PCP, primary care provider; PSARP, posterior sagittal anorectal plasty; TEC, televisit clinic; Wt, weight; YO, years old.

permanent section is recommended. Failure to recognize these subtleties in colonic sampling can lead to false-negative results which subsequently can lead to unnecessary resections of healthy colon. Therefore, instead of progressing with bowel resection, an ileostomy should be performed with further colonic mapping (figure 4). A frozen section of small bowel should also be performed to ensure proper leveling of the ileostomy/jejunostomy as cases of total colonic HSCR can extend even more proximally than the terminal ileum in rare cases.[35]

Controversy in the timing of the pull-through in total colonic Hirschsprung disease

The timing of the pull-through in cases of total colonic HSCR is often a difficult choice as these patients are more likely to suffer from failure to thrive and short bowel syndrome depending on the extent of aganglionosis involving the small bowel.[36] Similar to patients who present with malnutrition, these patients should be nutritionally optimized prior to reversal and ileal-anal pull-through. Patients with total colonic HSCR will likely suffer from severe perianal rash once the pull-through is

Laparoscopic assisted pull-through

Ganglion cells present in frozen section
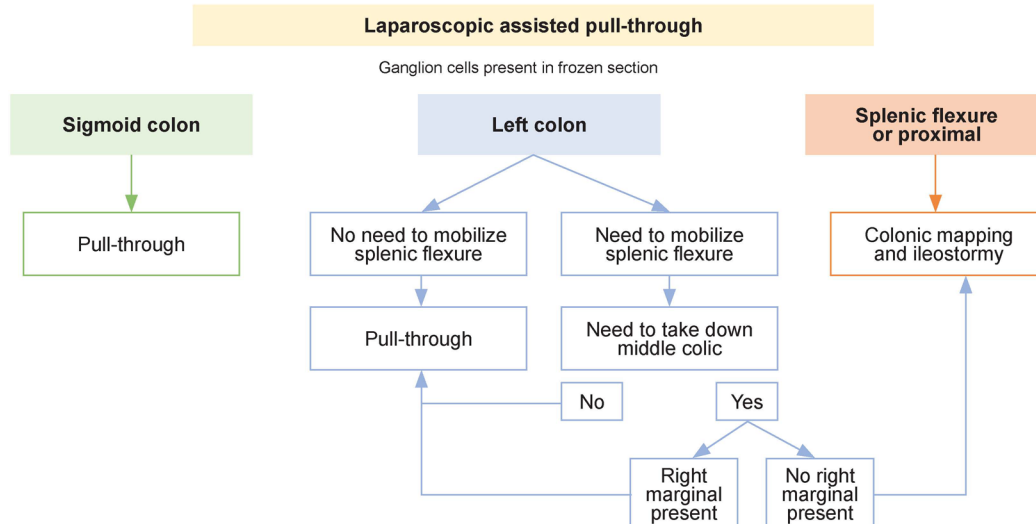
Figure 4 Algorithm for determining the level of transition zone intraoperatively and decision-making based on anatomy and frozen section results.

performed due to the liquid stools evacuated as a result of an ileal-anal anastomosis. Previously it was thought that patients should wait until toilet-training age prior to pull-through because the increased maturity and ability to sit on a toilet trainer would help avoid the ensuing diaper rash.[37] This paradigm was, however, found to be incorrect by a systematic review done in 2020 by Lamoshi *et al.* who demonstrated that the timing of the pull-through for total colonic HSCR had no effect on the development of a diaper rash.[38] In fact, delaying the pull-through until toilet training age can actually be problematic as older patients were able to associate stooling with the pain of the diaper rash. As a result, some children developed severe withholding behaviors and anal proctalgia, a very problematic clinical scenario which sometimes required a rediversion.[39] Implementation of proper bowel management care and perianal skin protection protocols have been shown to minimize symptoms in patients who receive their pull-through prior to toilet training age. This includes the use of proactive skin barriers to prevent excessive skin contact with the stool and use of diet and transit-slowing medications to provide better stool consistency (figure 5).[40] Consequently, patients can undergo their pull-through between 6 and 18 months of age provided that they have demonstrated good nutritional parameters (figure 3), weight gain, and the ability to produce non-liquid stool from the stoma.[40]

In patients who struggle with weight gain, particularly those with short bowel syndrome, sometimes an interval enterectomy of the diverted aganglionic small bowel and subtotal colectomy of the aganglionic colon should be considered and may help them thrive.[41] This

Figure 5 Proposed skin care and hypermotility protocol following definitive pull-through for total colonic Hirschsprung disease. EUA, examination under anesthesia; POD, postoperative day; PPI, proton pump inhibitor; PT, pull-through.[40]

phenomenon may be due to the fact that, despite diversion, the aganglionic bowel may act as an inflammatory nidus which may increase overall stoma output, thus potentially contributing to a patient's failure to thrive. Removal of the aganglionic bowel may help the patient become a better short gut patient and improve the efficacy of their nutritional rehabilitation. This area warrants further study.

Timing of the pull-through in patients with a delayed presentation of HSCR

Patients with a delayed presentation of HSCR require special attention when considering diversion. Although HSCR is often thought of as a disease diagnosed in the newborn period, there is recent evidence to suggest that a large number are diagnosed after 1 year of age.[11 42] When considering diversion in this patient population, factors that affect decision-making may include the degree of bowel dilation, location of the transition zone, and presence of malnutrition.[43–45] Patients with a late diagnosis typically have a distal transition zone, a longstanding history of constipation, and fewer enterocolitis episodes. Additionally, they tend to have more significant degree of bowel dilation proximal to the transition zone and may be malnourished due chronic distension, constipation, and poor overall oral intake. Increased bowel dilation creates several technical challenges such as decreased visualization during laparoscopy, the need for extensive stretching of the anal sphincter during a transanal dissection which could lead to incontinence, and a considerable size mismatch for the anastomosis, which is a risk factor for anastomotic dehiscence and further exacerbated by malnourishment.[45 46] To address these issues, most of these patients should be initially diverted. A leveling colostomy may be preferred in some settings, but bowel dilation may limit the ability to reliably identify a transition zone visually and a frozen section diagnosis is needed. A leveling ileostomy is also a good option, allowing for simultaneous colonic mapping and preservation of the colonic blood supply, as there would be no need for a colostomy. An ileostomy, however, places patients at risk for dehydration, especially in low-resource settings.[47] Recently, a multi-institutional study highlighted the importance of considering a diversion in patients with a delayed HSCR diagnosis. In this study, Ullrich et al. found that older age at diagnosis (stratified across neonates <29 days; infants 29 days–12 months; toddler 1–5 years and child >5 years) was associated with a greater likelihood of requiring a diverting stoma after pull-through. Infants and older children were also more likely to have a diverting stoma prior to pull-through. Although the rate of perioperative complications and redo operation were similar, older patients (toddler and child) were more likely to require a redo for an anastomotic leak compared with younger patients. Finally, bowel function outcomes were equivocal but older patients were more likely to require intervention for constipation or incontinence.[42] Thus, despite the preference for many to perform single-stage operations,

diversion should be considered in patients who present in a delayed fashion, especially after 1 year of age.

CONTROVERSY IN LAPAROSCOPIC-ASSISTED VERSUS TRANSANAL ONLY PULL-THROUGH

A completely transanal approach was first described by de la Torre-Mondragón and Ortega-Salgado in 1998[16] and then by Langer et al. in 1999.[48] The benefits of the procedure include the avoidance of any abdominal incision which may lead to fewer complications, less scarring, and the potential for better cosmetic results and reduced postoperative pain.[49] Furthermore, a transanal only dissection has shorter operating time and may be more appropriate for low-resource settings where laparoscopic equipment is not readily available.[47 50 51] On the other hand, a totally transanal approach may place the patient at higher risk for sphincter damage due to prolonged sphincter muscle stretching during dissection, which may affect future continence.[52] There is a also risk for colonic torsion, and perhaps most importantly, the inability to confirm the histologic transition zone before starting the colonic mobilization.

There is controversy regarding whether the histologic transition zone can be reliably determined before the transanal dissection, that is, only from the contrast enema, as discussed previously.[53 54] This would be concerning for a surgeon performing a transanal only operation as the approach for long-segment HSCR would be different. Given the risk of finding a transition zone higher than the sigmoid, many advocate for preliminary biopsy, especially with the prevalence of laparoscopy in contemporary practice. An open biopsy via an umbilical incision without laparoscopy is doable as well, with the trick of using a Hegar dilator to elevate the sigmoid into the umbilical incision. Overall, functional and clinical outcomes are equal when comparing transanal only endorectal pull-through and laparoscopic/transabdominal-assisted pull-through.[44 47 49 55 56] In certain cases of a late diagnosis of HSCR with mild symptoms or a clinical scenario that is very consistent with low disease (i.e., a rectal transition zone), a transanal only approach may still be appropriate without preliminary biopsy.[57]

CONTROVERSIES IN THE MANAGEMENT OF POST PULL-THROUGH OBSTRUCTION

Up to 50% of children have ongoing bowel issues after their HSCR pull-through surgery including enterocolitis, constipation, and/or fecal soiling.[58 59] Even with a technically appropriate and precise operation, some patients may still struggle, which is why it is important for the surgeon to follow pull-through patients closely after their procedure to identify symptoms related to functional changes, many of which can improve over time. All patients with HSCR have a non-relaxing internal anal sphincter (absent rectoanal inhibitory reflex (RAIR)), which may be difficult to effectively overcome in the neonatal and toddler period and can lead to recurrent
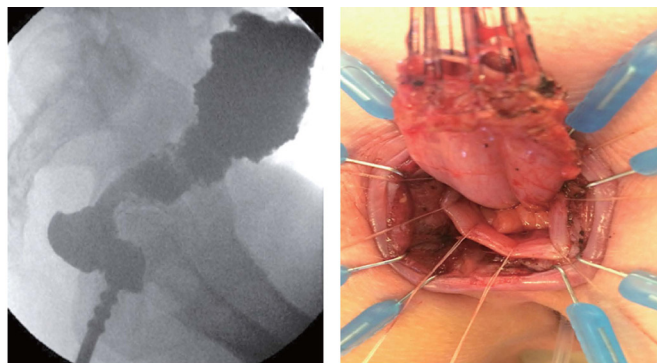
Figure 6 Yancy-Soave cuff (blue arrow). On the left is a contrast enema demonstrating an area of narrowing due to the cuff, an enlarged presacral space, and on the right is a corresponding finding from the operating room of the ring of the cuff around the pull-through seen during a redo operation.

episodes of enterocolitis. This should be the only anatomic residua of their initial disease after successful surgery, but even ganglionated bowel after a successful pull-through can still behave in a hypomotile manner.[60] The original operation may add additional confounding factors that can cause obstructive symptoms, such as a retained cuff (figure 6) related to a Yancey-Soave pull-through or a Duhamel pouch which is either too large, or problematic due to a retained spur (figure 7). In addition, the original pull-through may have been done in transition zone bowel which can lead to obstruction.
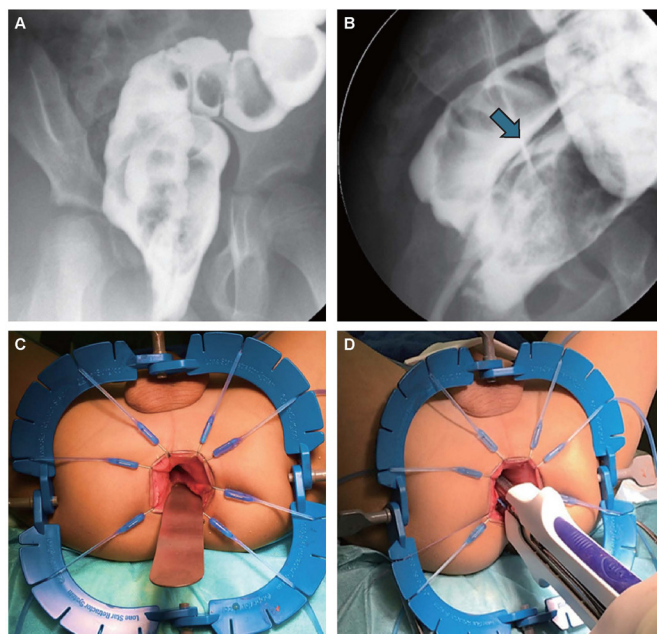
Figure 7 Retained Duhamel spur demonstrated on contrast study (A/B) and in the corresponding operative photo (C/D). This occurs when the top of the rectal pouch is not resected flush with the Duhamel anastomosis. A retained spur may be managed by extending the staple line transanally (D). Blue arrow is pointing to the spur that requires transanal stapling.

Obstructive symptoms may take the form of abdominal distension, bloating, poor oral intake, severe constipation, failure to thrive, and enterocolitis. There are five major explanations for such post pull-through behavior which include mechanical obstruction, recurrent or acquired aganglionosis, disorders of motility in the residual bowel, internal sphincter dysfunction, or functional megacolon caused by stool-holding behavior.[61–63] Algorithms for the diagnosis and management of obstructive symptoms are well detailed. However, the management of recurrent or acquired aganglionosis (*i.e.,* transition zone pull-through) is still debated.[59] Additionally, the most severe sequela of persistent obstruction is enterocolitis, and in the absence of any other identifiable causes of obstruction, it is usually due to non-relaxing sphincters/internal sphincter dysfunction. Management of this entity has evolved over time and now involves the use of botulinum toxin injections to treat non-relaxing sphincter to prevent Hirschsprung-associated enterocolitis (HAEC), which can be given at the time of pull-through or in follow-up if patient exhibits obstructive symptoms. The timing of the botox injection, however, has not been well studied in terms of optimal outcomes and minimizing enterocolitis episodes.

Controversy in the management of a transition zone pull-through

Pathologic causes of obstruction include persistent/acquired aganglionosis or a transition zone pull-through. Aganglionosis in the distal pull-through may be due to an error in the original pull-through's histologic analysis,[64] or rarely, a loss of ganglion cells.[65] Such a pull-through will not function well. A much more debated area lies in the significance of a "transition zone pullthrough" which can be unrelated to any error at the initial pull-through.[66] Such a patient who is evaluated for obstructive symptoms may be found to have a distal pull-through with hypoganglionated bowel and may be associated with hypertrophied nerve fibers (40 microns or more is considered hypertrophic).[67 68] The measurement of nerve trunk diameter is a useful marker for transition zone, but this remains debated, particularly because these measurements were established in patients under the age of one, and no standard measurements for older children have been determined.[66 69] It is possible that the nerve hypertrophy found could be due to a secondary phenomenon in that the bowel dilates over time and "decompensates" because it has now chronically encountered a distal obstruction due to the inherent non-relaxing sphincters or some other cause of obstruction. This is similar to the finding of ganglion cells plus hypertrophic nerves in patients with severe functional constipation. So, is this an "acquired transition zone?" If so, how should it be managed?

It has been demonstrated that removal of the pathologic segment can resolve obstructive symptoms.[70] However recently, there are some people who contend that certain short segment "transition zones" do not cause significant

obstructive symptoms and will not benefit from re-resection.[71 72] Re-operative surgery is not without risk and may lead to higher rates of fecal incontinence.[73 74] De la Torre *et al.* demonstrated that there was no difference in rates of HAEC or constipation between patients with normo-ganglionated and transition zone neorectum. Though, this study was performed with very few patients and no statistical significance was calculated.[71] Beltman *et al.* compared those who received conservative management vs redo and found no difference in rates of HAEC, laxative use, rectal irrigation use, botox use, and functional outcomes.[72] These studies are limited by their retrospective nature and small cohorts.

While some patients may be adequately managed without reoperation, they often require additional therapy such as botulinum toxin injections into the anal sphincter, laxatives, and rectal irrigations[67 74 75] Some patients have severe obstructive symptoms such as recurrent enterocolitis, and for them, these measures do not help. Ultimately, clinical behavior and patient symptoms should be the driving consideration of reoperation. Our practice is to offer a redo pull-through for transition zone documented on a repeat biopsy in patients with ongoing obstructive symptoms such as severe constipation or those with multiple episodes of HAEC in whom medical management has not helped. Anatomic problems can also be helped with reoperation, including cuff resection (figure 6), mega-Duhamel pouch resection, resection of a Duhamel spur (figure 7), and management of a twisted pull-through (figure 8).[76–78]

Controversies in the management of non-relaxing sphincters

If there are no mechanical or histopathologic etiologies found, the cause of obstruction may be due to non-relaxing sphincters, related to the lack of a normal RAIR that is inherent to all patients with HSCR. Most children learn to overcome their non-relaxing internal sphincter by the age of 5 with compensatory abdominal and pelvic pressure.[79] For those younger or unable to overcome the lack of a RAIR, this is not the case. Such patients may also exhibit external anal sphincter tightness which manifests
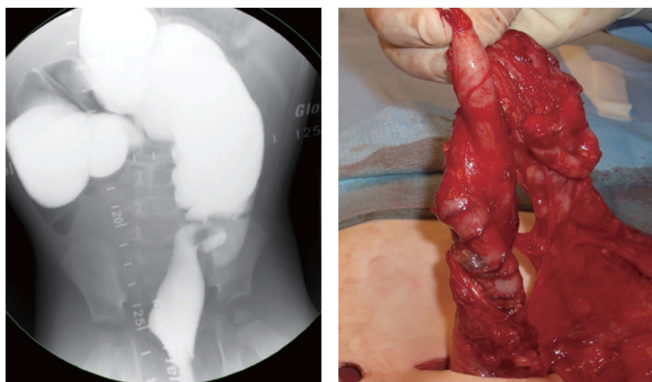

Figure 8 Twisted pull-through. On the left is a representative contrast enema and on the right is the twisted pull-through which was found intraoperatively.

as behavioral withholding. For both issues, botulinum toxin injections to the internal and external anal sphincters may help.[59 79] The diagnosis may be confirmed with anorectal manometry[80] or in many cases, a clinical response to internal anal sphincter botulinum toxin injections (IAS botox).[81–83]

Historically, some physicians advocated for the use of myectomy to treat internal sphincter dysfunction[84 85] and cases of "ultra short segment HSCR".[86] These approaches however have fallen out of favor as they do not improve the quality of life for most children and needlessly increase the risk of permanent fecal incontinence. In most of these cases, chemical sphincterotomy with IAS botox is a preferred and more conservative approach which spares the sphincter from any permanent damage and provides good results.[87–89] Furthermore, as noted above, internal sphincter dysfunction tends to resolve on its own as the child grows.[79] Repeated injections of botulinum toxin, nitroglycerine paste, or topical nifedipine are helpful while waiting for the resolution of this problem. As the child gets older, biofeedback and pelvic floor physical therapy may be helpful in improving their defecation technique which helps them become adept at overcoming their non-relaxing internal anal sphincters.[90]

Controversies in the prevention of HSCR-associated enterocolitis

In addition to treating non-relaxing sphincters and episodes of active enterocolitis, internal anal sphincter (IAS) botox has also been used in an attempt to prevent repeated episodes of HAEC as enterocolitis is one of the most common causes of readmission and death for children with HSCR.[91] There is a great interest in the idea of using botox at the time of the pull-through procedure to prevent early enterocolitis. It is thought that the first month after pull-through is most critical in preventing obstruction as these patients are otherwise unable to perform rectal irrigations given the colo-anal anastomosis. So far, IAS botox has at least been shown to decrease the duration of treatment and prevent recurrent episodes for those with active enterocolitis.[81 91–93] The ability for botox to proactively prevent enterocolitis and the optimal timing for administration still remains unclear.

Data regarding the efficacy of proactive botox are still developing but show initial promise. In a single institution study in 2021, Ahmad *et al.* first examined the use of routine IAS botox 1 month after the initial pull-through but unfortunately did not find any significant differences in the rate of postoperative HAEC.[94] On the other hand, there are now studies exploring the use of upfront IAS botox, given at the time of the pull-through. Early results have suggested that the use of upfront botox may reduce the number of postoperative enterocolitis, although investigations are still actively ongoing.[95] Other postoperative measures to prevent HAEC such as the daily use of rectal irrigations, probiotics, anal dilations, routine antibiotics, and rectal tube placement have also

been suggested.[61 96–100] All have mixed results and there is still no clear consensus on the optimal way to prevent enterocolitis.

Ultimately, surgeons and institutions lack consensus regarding the treatment and prevention of HAEC. An international survey in 2022 demonstrated that there is still wide variation in practice between using routine botulinum toxin, anal dilation, prophylactic antibiotics, probiotics, and routine home irrigations.[101] Further standardization of care is needed to improve clinical outcomes and guide future research efforts. Promising research into the pathogenesis of HAEC may also lead to potential targeted or personalized therapies.[100] One interesting new effort is to identify high-risk groups and treat accordingly. It has been shown that patients with lower social determinants of health and a lower childhood opportunity index are significantly associated with a higher risk of HAEC even after adjusting for anatomical and clinical factors.[102 103] It is important to educate families on how to recognize the symptoms and perform rectal irrigations if needed, which may prevent additional emergency room visits or hospital admissions.

FECAL INCONTINENCE AND SPHINCTER RECONSTRUCTION FOR INJURED SPHINCTERS

Up to half of patients with HSCR may experience fecal soiling after their pull-through surgery.[104] Some have incontinence due to overflow related to constipation, while others, especially early after pull-through, suffer from hypermotility.[59] However, there is a proportion of patients who suffer from true fecal incontinence due to a damaged sphincters or dentate lines that occurred during their initial surgery, usually from inadvertent resection of the anal canal or over stretching of the anal sphincters.[59 63] Such sphincter or anal canal injuries are likely more common than we thought and can lead to incontinence, especially in cases of patients that underwent a total transanal dissection.[79] Sphincters are required for tone around the pull-through to allow for the ability to close the neo rectum and hold stool.

Until recently, incontinence due to sphincter damage has had no optimal treatments. Most published techniques to treat sphincter injuries involve adult patients with sphincter damage due to obstetric trauma or complications of anorectal surgery.[105–107] Techniques, such as the use of an elastic band encircling the anus[108] or the use of autologous expanded mesenchymal stem cell infusions, have been introduced but are still lacking demonstrated efficacy.[109]

Recently, a novel sphincter reconstruction technique has been introduced for patients with HSCR with persistent fecal soiling due to overstretched, patulous internal anal sphincters (figure 9).[110] The technique involves "re-tacking" of the overstretched anal sphincters to the neo-rectal wall to allow for the sphincters to encircle the neo-rectum more tightly, thereby providing the patient with a better ability to hold in stool. A
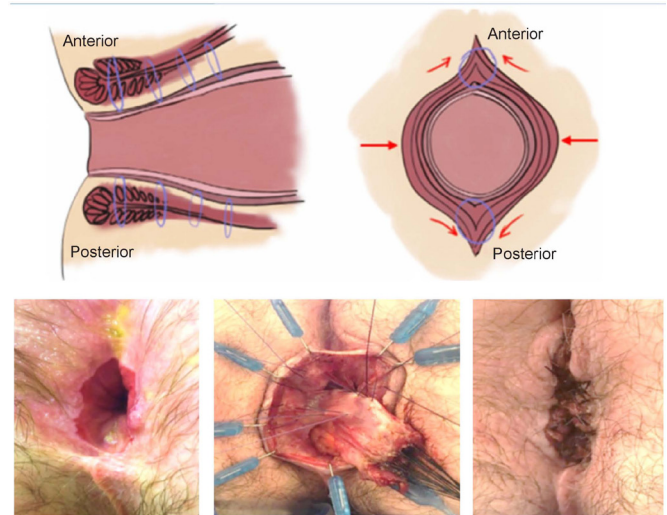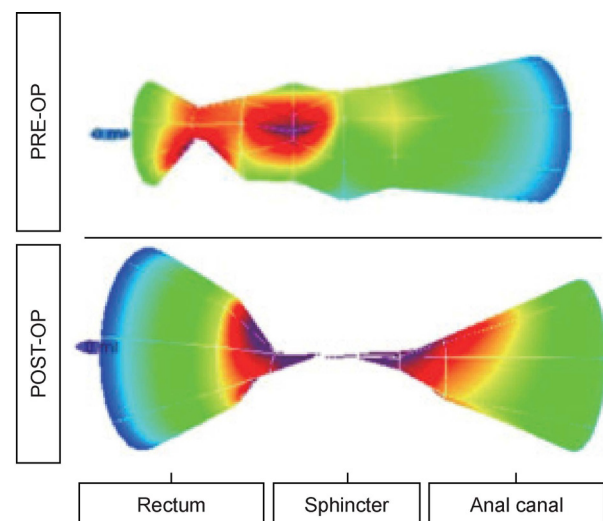

Figure 9 Diagram of sphincter reconstruction operative technique.[110]

follow-up of this pilot study reported good early outcomes and patients were able to achieve voluntary bowel control after sphincter reconstruction. Furthermore, the authors were able to demonstrate objective evidence of increased sphincter function shown on preoperative[111] and postoperative three-dimensional anal manometry[111] (figure 10).

This new technique shows promise and is now an option for such patients, who, up until this point, only had medical management, such as with an enema program, as an option to get them clean of stool. Pelvic floor physical therapy may be used as an adjunct and has shown promising initial results.[112]

CONCLUSION

Great strides have been made in the treatment of children with HSCR. Surgical management has undergone several

Figure 10 Pre and post sphincter reconstruction anorectal manometry demonstrating the inability of the sphincter to completely close followed by good sphincter squeeze after reconstruction.[111]

refinements in technique but the timing of the pull-through remains controversial. Postoperative management of patients with HSCR also continues to be an area of improvement as the use of botulinum toxin continues to grow and as new techniques are developed, such as the use of sphincter reconstruction for fecal incontinence due to iatrogenic sphincter damage.

ORCID iD
Thomas O Xu http://orcid.org/0000-0001-7014-9415

REFERENCES

1 SOAVE F. HIRSCHSPRUNG'S DISEASE: A NEW SURGICAL TECHNIQUE. *Arch Dis Child* 1964;39:116–24.
2 Boley SJ, Lafer DJ, Kleinhaus S, *et al*. Endorectal pull-through procedure for Hirschsprung's disease with and without primary anastomosis. *J Pediatr Surg* 1968;3:258–62.
3 YANCEY AG, CROMARTIE JE, FORD JR, *et al*. A modification of the Swenson technique for congenital megacolon. *J Natl Med Assoc* 1952;44:356–63.
4 Woode D, Avansino J, Sawin R, *et al*. Asa G Yancey: The first to describe a modification of the Swenson Technique for Hirschsprung disease. *J Pediatr Surg* 2022;57:1701–3.
5 Diamond IR, Casadiego G, Traubici J, *et al*. The contrast enema for Hirschsprung disease: predictors of a false-positive result. *J Pediatr Surg* 2007;42:792–5.
6 Garrett KM, Levitt MA, Peña A, *et al*. Contrast enema findings in patients presenting with poor functional outcome after primary repair for Hirschsprung disease. *Pediatr Radiol* 2012;42:1099–106.
7 De La Torre L, Wehrli LA. Error traps and culture of safety in Hirschsprung disease. *Semin Pediatr Surg* 2019;28:151–9.
8 Swenson O, Sherman JO, Fisher JH, *et al*. The treatment and postoperative complications of congenital megacolon: A 25 year followup. *Ann Surg* 1975;182:266–73.
9 Kleinhaus S, Boley SJ, Sheran M, *et al*. Hirschsprung's disease -- a survey of the members of the Surgical Section of the American Academy of Pediatrics. *J Pediatr Surg* 1979;14:588–97.
10 WHITEHOUSE FR, KERNOHAN JW. Myenteric plexus in congenital megacolon; study of 11 cases. *Arch Intern Med (Chic)* 1948;82:75–111.
11 Ambartsumyan L, Smith C, Kapur RP. Diagnosis of Hirschsprung Disease. *Pediatr Dev Pathol* 2020;23:8–22.
12 Yamataka A, Miyano G, Takeda M. Minimally Invasive Neonatal Surgery: Hirschsprung Disease. *Clin Perinatol* 2017;44:851–64.
13 So HB, Schwartz DL, Becker JM, *et al*. Endorectal "pull-through" without preliminary colostomy in neonates with Hirschsprung's disease. *J Pediatr Surg* 1980;15:470–1.
14 Carcassonne M, Guys JM, Morrison-Lacombe G, *et al*. Management of Hirschsprung's disease: curative surgery before 3 months of age. *J Pediatr Surg* 1989;24:1032–4.
15 Georgeson KE, Cohen RD, Hebra A, *et al*. Primary laparoscopic-assisted endorectal colon pull-through for Hirschsprung's disease: a new gold standard. *Ann Surg* 1999;229:678–82; .
16 De la Torre-Mondragón L, Ortega-Salgado JA. Transanal endorectal pull-through for Hirschsprung's disease. *J Pediatr Surg* 1998;33:1283–6.
17 Huang EY, Tolley EA, Blakely ML, *et al*. Changes in hospital utilization and management of Hirschsprung disease: analysis using the kids' inpatient database. *Ann Surg* 2013;257:371–5.
18 Pierro A, Fasoli L, Kiely EM, *et al*. Staged pull-through for rectosigmoid Hirschsprung's disease is not safer than primary pull-through. *J Pediatr Surg* 1997;32:505–9.
19 Langer JC, Durrant AC, de la Torre L, *et al*. One-stage transanal Soave pullthrough for Hirschsprung disease: a multicenter experience with 141 children. *Ann Surg* 2003;238:569–83.
20 Teitelbaum DH, Cilley RE, Sherman NJ, *et al*. A decade of experience with the primary pull-through for hirschsprung disease in the newborn period: a multicenter analysis of outcomes. *Ann Surg* 2000;232:372–80.
21 Bradnock TJ, Walker GM. Evolution in the management of Hirschsprung's disease in the UK and Ireland: a national survey of practice revisited. *Ann R Coll Physicians Surg Can* 2011;93:34–8.
22 Coran AG, Teitelbaum DH. Recent advances in the management of Hirschsprung's disease. *Am J Surg* 2000;180:382–7.
23 Marty TL, Seo T, Sullivan JJ, *et al*. Rectal irrigations for the prevention of postoperative enterocolitis in Hirschsprung's disease. *J Pediatr Surg* 1995;30:652–4.
24 Lu C, Xie H, Li H, *et al*. Feasibility and efficacy of home rectal irrigation in neonates and early infancy with Hirschsprung disease. *Pediatr Surg Int* 2019;35:1245–53.
25 Bokova E, Prasade N, Lewis WE, *et al*. Evaluation of Post-neonatal Intensive Care Unit Home Irrigations Prior to Pull-through: Implications for Hirschsprung Disease Management. *J Pediatr Surg* 2024;59:1245–9.
26 Freedman-Weiss MR, Chiu AS, Caty MG, *et al*. Delay in operation for Hirschsprung Disease is associated with decreased length of stay: a 5-Year NSQIP-Peds analysis. *J Perinatol* 2019;39:1105–10.
27 Kastenberg ZJ, Taylor MA, Durham MM, *et al*. Perioperative and long-term functional outcomes of neonatal versus delayed primary endorectal pull-through for children with Hirschsprung disease: A pediatric colorectal and pelvic learning consortium study. *J Pediatr Surg* 2021;56:1465–9.
28 Roy C, Jaffray B. Pull through for Hirschsprung disease without planned rectal decompression is safe. *J Pediatr Surg* 2023;58:231–5.
29 Roorda D, Verkuijl SJ, Derikx JPM, *et al*. Did Age at Surgery Influence Outcome in Patients With Hirschsprung Disease? A Nationwide Cohort Study in the Netherlands. *J Pediatr Gastroenterol Nutr* 2022;75:431–7.
30 Westfal ML, Okiemy O, Chung PHY, *et al*. Optimal timing for Soave primary pull-through in short-segment Hirschsprung disease: A meta-analysis. *J Pediatr Surg* 2022;57:719–25.
31 Sulkowski JP, Cooper JN, Congeni A, *et al*. Single-stage versus multi-stage pull-through for Hirschsprung's disease: practice trends and outcomes in infants. *J Pediatr Surg* 2014;49:1619–25.
32 Saltzman DA, Rector FC, Fordtran JS. The role of intraluminal sodium in glucose absorption in vivo. *J Clin Invest* 1972;51:876–85.
33 Butterworth SA, Lalari V, Dheensaw K. Evaluation of sodium deficit in infants undergoing intestinal surgery. *J Pediatr Surg* 2014;49:736–40.
34 Choudhuri AH, Uppal R, Kumar M. Influence of non-surgical risk factors on anastomotic leakage after major gastrointestinal surgery: Audit from a tertiary care teaching institute. *Int J Crit Illn Inj Sci* 2013;3:246–9.
35 Moore SW. Total colonic aganglionosis and Hirschsprung's disease: a review. *Pediatr Surg Int* 2015;31:1–9.
36 Payen E, Talbotec C, Chardot C, *et al*. Outcome of Total Colonic Aganglionosis Involving the Small Bowel Depends on Bowel Length, Liver Disease, and Enterocolitis. *J pediatr gastroenterol nutr* 2022;74:582–7.
37 Bischoff A, Levitt MA, Peña A. Total colonic aganglionosis: a surgical challenge. How to avoid complications? *Pediatr Surg Int* 2011;27:1047–52.
38 Lamoshi A, Ham PB, Chen Z, *et al*. Timing of the definitive procedure and ileostomy closure for total colonic aganglionosis HD: Systematic review. *J Pediatr Surg* 2020;55:2366–70.
39 Levitt MA. Regarding: Timing of the definitive procedure and ileostomy closure for total colonic aganglionosis HD: Systematic review. *J Pediatr Surg* 2021;56:1082.
40 Vilanova-Sanchez A, Ivanov M, Halleran DR, *et al*. Total Colonic Hirschsprung's Disease: The Hypermotility and Skin Rash Protocol. *Eur J Pediatr Surg* 2020;30:309–16.
41 Velasquez AR, Xu TO, Liu YT, *et al*. Achieving Digestive Autonomy and Gastrointestinal Continuity in a Patient with Short Bowel Syndrome Secondary to Concomitant Jejunal Atresia and Small Intestinal Hirschsprung's Disease. *European J Pediatr Surg Rep* 2024;12:e45–9.
42 Ullrich S, Austin K, Avansino JR, *et al*. Does Delayed Diagnosis of Hirschsprung Disease Impact Post-operative and Functional

Outcomes? A Multi-Center Review From the Pediatric Colorectal and Pelvic Learning Consortium. *J Pediatr Surg* 2024;59:1250–5.

43 Rentea RM, Halleran DR, Ahmad H, *et al*. Transanal-only Swenson-like pull-through for late diagnosed Hirschsprung disease. *J Surg Case Rep* 2019;2019.

44 De La Torre L, Langer JC. Transanal endorectal pull-through for Hirschsprung disease: technique, controversies, pearls, pitfalls, and an organized approach to the management of postoperative obstructive symptoms. *Semin Pediatr Surg* 2010;19:96–106.

45 Apte A, McKenna E, Levitt MA. Image of the Month: Decision-Making in Surgery for Late Onset Hirschsprung Disease. *European J Pediatr Surg Rep* 2020;08:e99–101.

46 Peña A, Elicevik M, Levitt MA. Reoperations in Hirschsprung disease. *J Pediatr Surg* 2007;42:1008–14.

47 Langer JC. Laparoscopic and transanal pull-through for Hirschsprung disease. *Semin Pediatr Surg* 2012;21:283–90.

48 Langer JC, Minkes RK, Mazziotti MV, *et al*. Transanal one-stage soave procedure for infants with Hirschsprung's disease. *J Pediatr Surg* 1999;34:148–52.

49 Kim AC, Langer JC, Pastor AC, *et al*. Endorectal pull-through for Hirschsprung's disease-a multicenter, long-term comparison of results: transanal vs transabdominal approach. *J Pediatr Surg* 2010;45:1213–20.

50 Rangel SJ, de Blaauw I. Advances in pediatric colorectal surgical techniques. *Semin Pediatr Surg* 2010;19:86–95.

51 Elhalaby EA, Hashish A, Elbarbary MM, *et al*. Transanal one-stage endorectal pull-through for Hirschsprung's disease: a multicenter study. *J Pediatr Surg* 2004;39:345–51; .

52 El-Sawaf MI, Drongowski RA, Chamberlain JN, *et al*. Are the long-term results of the transanal pull-through equal to those of the transabdominal pull-through? A comparison of the 2 approaches for Hirschsprung disease. *J Pediatr Surg* 2007;42:41–7; .

53 Muller CO, Mignot C, Belarbi N, *et al*. Does the radiographic transition zone correlate with the level of aganglionosis on the specimen in Hirschsprung's disease? *Pediatr Surg Int* 2012;28:597–601.

54 Proctor ML, Traubici J, Langer JC, *et al*. Correlation between radiographic transition zone and level of aganglionosis in Hirschsprung's disease: Implications for surgical approach. *J Pediatr Surg* 2003;38:775–8.

55 Fakhry T, Rabee A, Lolah M, *et al*. Laparoscopic-assisted versus complete transanal pull-through using Swenson technique in treatment of Hirschsprung's disease. *Ann Pediatr Surg* 2023;19.

56 Thomson D, Allin B, Long AM, *et al*. Laparoscopic assistance for primary transanal pull-through in Hirschsprung's disease: a systematic review and meta-analysis. *BMJ Open* 2015;5:e006063.

57 Rentea RM, Halleran DR, Ahmad H, *et al*. Transanal-only Swenson-like pull-through for late diagnosed Hirschsprung disease. *J Surg Case Rep* 2019;2019:rjz341.

58 Bokova E, Prasade N, Janumpally S, *et al*. State of the Art Bowel Management for Pediatric Colorectal Problems: Hirschsprung Disease. *Children (Basel)* 2023;10:1418.

59 Ahmad H, Yacob D, Halleran DR, *et al*. Evaluation and treatment of the post pull-through Hirschsprung patient who is not doing well; Update for 2022. *Semin Pediatr Surg* 2022;31:151164.

60 Levitt MA, Hamrick MC, Eradi B, *et al*. Transanal, full-thickness, Swenson-like approach for Hirschsprung disease. *J Pediatr Surg* 2013;48:2289–95.

61 Gosain A, Frykman PK, Cowles RA, *et al*. Guidelines for the diagnosis and management of Hirschsprung-associated enterocolitis. *Pediatr Surg Int* 2017;33:517–21.

62 Langer JC, Rollins MD, Levitt M, *et al*. Guidelines for the management of postoperative obstructive symptoms in children with Hirschsprung disease. *Pediatr Surg Int* 2017;33:523–6.

63 Saadai P, Trappey AF, Goldstein AM, *et al*. Guidelines for the management of postoperative soiling in children with Hirschsprung disease. *Pediatr Surg Int* 2019;35:829–34.

64 Shayan K, Smith C, Langer JC. Reliability of intraoperative frozen sections in the management of Hirschsprung's disease. *J Pediatr Surg* 2004;39:1345–8.

65 West KW, Grosfeld JL, Rescorla FJ, *et al*. Acquired aganglionosis: A rare occurrence following pull-through procedures for Hirschsprung's disease. *J Pediatr Surg* 1990;25:104–9.

66 Kapur RP. Histology of the Transition Zone in Hirschsprung Disease. *Am J Surg Pathol* 2016;40:1637–46.

67 Ghose SI, Squire BR, Stringer MD, *et al*. Hirschsprung's disease: problems with transition-zone pull-through. *J Pediatr Surg* 2000;35:1805–9.

68 Coe A, Collins MH, Lawal T, *et al*. Reoperation for Hirschsprung Disease: Pathology of the Resected Problematic Distal Pull-Through. *Pediatr Dev Pathol* 2012;15:30–8.

69 Kapur RP, Kennedy AJ. Histopathologic Delineation of the Transition Zone in Short-Segment Hirschsprung Disease. *Pediatr Dev Pathol* 2013;16:252–66.

70 Lawal TA, Chatoorgoon K, Collins MH, *et al*. Redo pull-through in Hirschsprung's [corrected] disease for obstructive symptoms due to residual aganglionosis and transition zone bowel. *J Pediatr Surg* 2011;46:342–7.

71 Wehrli LA, Reppucci ML, Stevens J, *et al*. Should we perform a Hirschsprung redo pull-through on patients with retained transition zone? *J Pediatr Surg Open* 2023;3:100058.

72 Beltman L, Labib H, Ahmed H, *et al*. Transition Zone Pull-through in Patients with Hirschsprung Disease: Is Redo Surgery Beneficial for the Long-term Outcomes? *J Pediatr Surg* 2023;58:1903–9.

73 Dingemans A, van der Steeg H, Rassouli-Kirchmeier R, *et al*. Redo pull-through surgery in Hirschsprung disease: Short-term clinical outcome. *J Pediatr Surg* 2017;52:1446–50.

74 Kapur RP, Kennedy AJ. Transitional zone pull through: surgical pathology considerations. *Semin Pediatr Surg* 2012;21:291–301.

75 Farrugia MK, Alexander N, Clarke S, *et al*. Does transitional zone pull-through in Hirschsprung's disease imply a poor prognosis? *J Pediatr Surg* 2003;38:1766–9.

76 Ahmad H, Halleran DR, Quintanilla R, *et al*. A Hirschsprung Pull-through, "with a Twist." *European J Pediatr Surg Rep* 2020;8:e95–8.

77 Chatoorgoon K, Pena A, Lawal TA, *et al*. The problematic Duhamel pouch in Hirschsprung's disease: manifestations and treatment. *Eur J Pediatr Surg* 2011;21:366–9.

78 Dickie BH, Webb KM, Eradi B, *et al*. The problematic Soave cuff in Hirschsprung disease: manifestations and treatment. *J Pediatr Surg* 2014;49:77–80.

79 Levitt MA, Dickie B, Peña A. The Hirschsprungs patient who is soiling after what was considered a "successful" pull-through. *Semin Pediatr Surg* 2012;21:344–53.

80 Sowulewski O, Bubińska M, Zagierska A, *et al*. High-Resolution Anorectal Manometry as a Screening Tool for Hirschsprung's Disease: A Comprehensive Retrospective Analysis. *J Clin Med* 2024;13:1268.

81 Chumpitazi BP, Fishman SJ, Nurko S. Long-term clinical outcome after botulinum toxin injection in children with nonrelaxing internal anal sphincter. *Am J Gastroenterol* 2009;104:976–83.

82 Langer JC, Birnbaum E. Preliminary experience with intrasphincteric botulinum toxin for persistent constipation after pull-through for Hirschsprung's disease. *J Pediatr Surg* 1997;32:1059–62.

83 Minkes RK, Langer JC. A prospective study of botulinum toxin for internal anal sphincter hypertonicity in children with Hirschsprung's disease. *J Pediatr Surg* 2000;35:1733–6.

84 Wildhaber BE, Pakarinen M, Rintala RJ, *et al*. Posterior myotomy/myectomy for persistent stooling problems in Hirschsprung's disease. *J Pediatr Surg* 2004;39:920–6; .

85 Banani SA, Forootan H. Role of anorectal myectomy after failed endorectal pull-through in Hirschsprung's disease. *J Pediatr Surg* 1994;29:1307–9.

86 Bandres D, Prada C, Soto J, *et al*. Per-Anal Endoscopic Myotomy as Rescue Therapy for Hirschsprung Disease After Unsuccessful Surgical Myectomy. *ACG Case Rep J* 2022;9:e00755.

87 Jiang DP, Xu CQ, Wu B, *et al*. Effects of botulinum toxin injection on anal achalasia after pull-through operations for Hirschsprung's disease: a 1-year follow-up study. *Int J Colorectal Dis* 2009;24:597–8.

88 Patrus B, Nasr A, Langer JC, *et al*. Intrasphincteric botulinum toxin decreases the rate of hospitalization for postoperative obstructive symptoms in children with Hirschsprung disease. *J Pediatr Surg* 2011;46:184–7.

89 Koivusalo AI, Pakarinen MP, Rintala RJ. Botox injection treatment for anal outlet obstruction in patients with internal anal sphincter achalasia and Hirschsprung's disease. *Pediatr Surg Int* 2009;25:873–6.

90 Ladi-Seyedian SS, Sharifi-Rad L, Manouchehri N, *et al*. A comparative study of transcutaneous interferential electrical stimulation plus behavioral therapy and behavioral therapy alone on constipation in postoperative Hirschsprung disease children. *J Pediatr Surg* 2017;52:177–83.

91 Marty TL, Matlak ME, Hendrickson M, *et al*. Unexpected death from enterocolitis after surgery for Hirschsprung's disease. *Pediatrics* 1995;96:118–21.

92 Svetanoff WJ, Lopez J, Aguayo P, *et al*. The impact of botulinum injection for hospitalized children with Hirschsprung-associated enterocolitis. *Pediatr Surg Int* 2021;37:1467–72.

93 Svetanoff WJ, Lim-Beutal IIP, Wood RJ, *et al*. The utilization of botulinum toxin for Hirschsprung disease. *Semin Pediatr Surg* 2022;31:151161.

94 Ahmad H, Rentea RM, Knaus ME, *et al*. Routine botulinum toxin injection one month after a Swenson pull-through does not change the incidence of Hirschsprung associated enterocolitis. *J Pediatr Surg* 2022;57:1453–7.

95 Encisco EM, Lim IP, Velazco CS, *et al*. Upfront botox injections and their impact on hirschsprung-associated enterocolitis incidence. APSA 2024 Annual Meeting; 2024:282. Available: https://apsapedsurg.org/continuing-education/events/annual-meeting/program-and-abstracts/ [accessed 25 Jun 2024].

96 Mei F, Wu M, Zhao L, *et al*. Probiotics for the prevention of Hirschsprung-associated enterocolitis. *Cochrane Database Syst Rev* 2022;2022.

97 Nakamura H, Lim T, Puri P. Probiotics for the prevention of Hirschsprung-associated enterocolitis: a systematic review and meta-analysis. *Pediatr Surg Int* 2018;34:189–93.

98 Soh HJ, Nataraja RM, Pacilli M. Prevention and management of recurrent postoperative Hirschsprung's disease obstructive symptoms and enterocolitis: Systematic review and meta-analysis. *J Pediatr Surg* 2018;53:2423–9.

99 Zhang X, Li L, Li S, *et al*. Primary laparoscopic endorectal pull-through procedure with or without a postoperative rectal tube for hirschsprung disease: a multicenter perspective study. *J Pediatr Surg* 2020;55:381–6.

100 Gershon EM, Rodriguez L, Arbizu RA. Hirschsprung's disease associated enterocolitis: A comprehensive review. *World J Clin Pediatr* 2023;12:68–76.

101 Svetanoff WJ, Lopez JJ, Briggs KB, *et al*. Management of Hirschsprung associated enterocolitis-How different are practice strategies? An international pediatric endosurgery group (IPEG) survey. *J Pediatr Surg* 2022;57:1119–26.

102 Knaus ME, Pendola G, Srinivas S, *et al*. Social Determinants of Health and Hirschsprung-associated Enterocolitis. *J Pediatr Surg* 2023;58:1458–62.

103 Srinivas S, Henderson K, Griffin KL, *et al*. Rates of Hirschsprung-Associated Enterocolitis Decrease With Increasing Child Opportunity Index. *J Pediatr Surg* 2024;59:1240–4.

104 Rintala RJ, Pakarinen MP. Outcome of anorectal malformations and Hirschsprung's disease beyond childhood. *Semin Pediatr Surg* 2010;19:160–7.

105 Sentovich SM, Rivela LJ, Blatchford GJ, *et al*. Patterns of male fecal incontinence. *Dis Colon Rectum* 1995;38:281–5.

106 Cook TA, Mortensen NJ. Management of faecal incontinence following obstetric injury. *Br J Surg* 1998;85:293–9.

107 Kamm MA. Obstetric damage and faecal incontinence. *Lancet* 1994;344:730–3.

108 Lim CH, Kang WH, Lee YC, *et al*. Standardized Method of the Thiersch Operation for the Treatment of Fecal Incontinence. *World J Surg* 2020;44:3141–8.

109 de la Portilla F, Guerrero JL, Maestre MV, *et al*. Treatment of faecal incontinence with autologous expanded mesenchymal stem cells: results of a pilot study. *Colorectal Dis* 2021;23:698–709.

110 Krois W, Reck CA, Darbari A, *et al*. A technique to reconstruct the anal sphincters following iatrogenic stretching related to a pull-through for Hirschsprung disease. *J Pediatr Surg* 2021;56:1242–6.

111 Bokova E, McKenna E, Krois W, *et al*. Reconstructing the anal sphincters to reverse iatrogenic overstretching following a pull-through for Hirschsprung disease. One-year outcomes. *J Pediatr Surg* 2023;58:484–9.

112 Sun X, Wang R, Zhang L, *et al*. Efficacy of pelvic floor muscle training for the treatment of fecal incontinence after Soave procedure for Hirschsprung disease. *Eur J Pediatr Surg* 2012;22:300–4.