Multistage surgical repair for split notochord syndrome with neuroenteric fistula: case report

Mansour Mathkour, MD, MSc,1 Tyler Scullen, MD,1 Brendan Huang, BS,1 Cassidy Werner, MSc,1 Edna E. Gouveia, MD,1 Hussam Abou-Al-Shaar, MD,2 Christopher M. Maulucci, MD,1 Rodney B. Steiner, MD,3 Hugo St. Hilaire, MD, DDS,4 and Cuong J. Bui, MD1

1Department of Neurosurgery, Tulane/Ochsner Medical Center, New Orleans, Louisiana; 2Department of Neurological Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania; 3Department of Pediatric Surgery, Ochsner Medical Center, New Orleans; and 4Departments of Plastic and Reconstructive Surgery, LSUHSC School of Medicine, New Orleans, Louisiana

Split notochord syndrome (SNS) is a rare congenital defect of the central nervous system and has been associated with several anomalies affecting multiple organ systems. One association has been communication with the gastrointestinal tract and the spine, previously identified as a neuroenteric fistula (NEF). Here, the authors describe the unique case of a female infant with SNS and NEF treated with a multistage surgical repair. The three-stage operative plan included a two-stage repair of the defect and temporary subgaleal shunting followed by delayed ventriculoperitoneal shunt placement. The infant recovered well post-surgery and over a 5-year follow-up. A case description, surgical techniques, and rationale are reported. Additionally, a systematic review of the literature utilizing the MEDLINE database was performed.

Treatment of SNS with NEF using a multidisciplinary multistaged approach to repair the intestinal defect, close the neural elements, and divert cerebrospinal fluid to the peritoneum is shown to be a safe and viable option for future cases.
39-year-old gravida 3 para 1021. No risk factors for neural tube defect (NTD) were reported. Her prenatal ultrasound at 26 weeks identified a large lumbosacral defect that was presumed to be a complicated spina bifida aperta with myelomeningocele (MMC).

At birth, the lesion was noted to be a more complicated defect than a typical MMC. An intestinal malformation with meconium extrusion was noted protruding through the dorsal midline adjacent to an open NTD and a variant type 2 split cord malformation (SCM) with associated placode (Fig. 2A). After stabilization in the neonatal intensive care unit (NICU), the patient underwent plain radiography of the axial skeleton and MRI (Fig. 3A and B) and CT (Fig. 3C and D) of the entire body, confirming an NTD suspicious for SNS. Abnormalities in endodermal derivatives were noted along the gastrointestinal (GI) tract, including a dorsal NEF with involvement of the distal small bowel, and a proximal colon herniation extending dorsally through the skin with perforation of the cecum. The dorsal skin opening was approximately 6 cm in diameter and contained exposed and healthy intestinal epithelium.

Treatment

Members of the multidisciplinary fetal surgery team (pediatric neurosurgery, plastic surgery, and pediatric surgery) conferred with the neonatal intensivist and pediatric anesthesia teams for postpartum intervention. A three-stage operative treatment plan was developed: a two-stage dysraphism repair focused on the NEF and herniated bowel. Preemptive cerebrospinal fluid (CSF) diversion was accomplished via placement of a right frontal ventriculoperitoneal shunt with a tapping reservoir prior to delayed ventriculoperitoneal shunt (VPS) placement. The rationale for this staging was to minimize blood loss, allow for adequate systemic resuscitation between the abdominal and spinal repair, and optimize the abdominal environment before VPS placement.

Stage one focused on creating separation between neural elements and bowel contents and on obliterating the NEF. Following separation of the ventral endodermal and dorsal neuroectodermal compartments, the bowel defects were repaired and reduced. The team believed that an anterior approach was the best way to identify which segment of the bowel was malformed and to accomplish the initial ventral-dorsal disconnection. The abdominal cavity was entered via a supraumbilical laparotomy transverse incision with identification of the ligament of Treitz. The small bowel was of normal caliber and position, but the colon was abnormal with microcolon herniating dorsally through the NEF between a bony vertebral cleft. The her-
niated bowel was reduced back into the peritoneal cavity by gently pulling it through the fistula. A small nonvi-
able portion of the intestines was resected. The peritoneal cavity was clean, and the colon abnormality was limited enough to perform a direct end-to-end bowel anastomosis, as opposed to a diverting colostomy, after the abnormal section of bowel was removed. An acellular dermal matrix patch graft was used to repair the fistula and isolate the abdominal cavity from the spinal elements. The abdomen was closed in a standard fashion. While the patient was still supine, a right frontal ventriculosubgaleal shunt with a tapping reservoir was placed with CSF removal for culture and chemistry as well as therapeutic ventricular de-
compression. The patient was kept intubated and brought back to the NICU for overnight recovery on broad-spect-
trum antibiotics with meningeal and enteric coverage.

Stage two was conducted the following day to ad-
dress the NTD and dorsally herniated peritoneal con-
tents. Microsurgical technique was used on the patient’s dorsal surface to isolate the placode, identify the SCM, and separate the residual proximal large bowel from the neural elements and soft-tissue attachment of the anterior compartment. The residual cecum and appendix were re-
sected. No bony septum was identified upon SCM inspec-
tion. The ventral-dorsal NTD was identified between the split vertebra and hemicords. A second acellular dermal matrix patch graft was sewn into position from the dorsal side to reinforce the anterior repair (Fig. 2B and C). Once the placode was dissected away from the abnormal skin edge and residual enteric tissue, it was imbricated and cov-
ered with a layer of dissected pseudodura. Bilateral split paraspinal muscle and fascia flaps were raised, reflected medially, and supplemented with an acellular dermal matrix for additional spinal coverage and watertight closure.

Extensive undermining of the soft tissue was employed laterally to the midaxillary line to mobilize enough tissue for a primary skin closure (Fig. 2D and E).

Posttreatment Course

The baby was followed postoperatively in the NICU with weekly cranial ultrasound and daily head circumference, which remained stable and within normal limits. Abdominal and back wounds healed without complica-
tion. Feedings were slowly advanced, and bowel function was normal. Four weeks after the initial anterior-posterior repairs and ventriculosubgaleal shunt placement, the baby returned for permanent CSF diversion with total shunt removal and VPS with laparoscopic peritoneal catheter placement.

After discharge, the baby was followed in our multidisci-
plinary Spina Bifida Clinic. Five years postoperatively, the patient has done well without necessitating VPS revi-
sion or reoperation for spinal cord tethering. Neurologi-
cally, the patient has slight neurocognitive delays and a neurogenic bladder but relatively normal bowel function. The patient remains nonambulatory and with retained movement of both lower extremities. Pediatric spinal de-
formity persists with sagittal imbalance with kyphosis at the lumbosacral junction in the region of the vertebral cleft, a matter to be addressed after skeletal maturity (Fig. 4). Clinically and radiographically (Fig. 5), there has been no sign of spinal cord retethering.

Discussion

Literature Review

Eighty-one papers and abstract titles dating back to 1906 were identified (Fig. 1). Further literature analysis
from relevant articles produced an additional 19 articles. After 11 duplicate articles were removed, titles and abstracts were screened. Forty-five articles that did not fit our inclusion and exclusion criteria were removed. The remaining 44 articles were assessed to find eligible cases involving patients with SNS and a corresponding dorsal enteric fistula, and 19 were excluded. In total, 25 articles with 25 patients with the SNS and NEF combination were identified (Table 1).

Among the cases reviewed, 17 (68%) involved males (Table 1). The average age at the time of presentation was approximately 2.3 months; however, most patients (16 [64%]) presented at day 1 or 2 of life. The most common rostral location of the cleft was the thoracic region (13 [52%]), and the most common caudal location was the sacrum (19 [76%]). Twenty-one cases had an associated dorsal site anomaly, which was most frequently an MMC (13 [52%]). The enteric opening site varied among the rectum (29%), colon (29%), and small intestine (29%). One case involved an enteric opening site spanning parts of both the cecum and rectum. Many cases had additional anomalies that affected various organs, including those of the urogenital, GI, musculoskeletal, and nervous systems. One patient had concurrent hydrocephalus. Sixteen patients (64%) underwent a surgical intervention to treat some aspect of their condition. Of those 16 patients, 15 (94%) had a GI repair, while 1 patient had an MMC repair. Nine (56%) of the patients who had undergone surgical intervention had successful outcomes and/or survived to follow-up, and none of the untreated patients survived. One case provided information regarding the specific surgical approach, which was dorsal.

**Pathogenesis of SNS**

Most cases of SNS occur in children with severe spinal cord dysraphism or GI anomalies, with two milder cases reported in adults. Both male and female patients can be affected, and the syndrome presents with additional

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**FIG. 3.** Sagittal (A) and axial (B) T2-weighted MRI studies demonstrating bowel elements (asterisks) herniating through the split notochord defect and sagittal (C) and coronal (D) CT identifying the split lumbar vertebral elements (arrows).
manifestations of anorectal and urogenital malformations, such as imperforate anus, vesical exstrophy, and hypospadias (Table 1). Our patient demonstrated severe topographical disorganization of endodermal and neuroectodermal tissues with a persistent NEF. This effect likely created a functional tether of the spinal cord during development, with a resulting downward migration of posterior fossa contents and concurrent reactive malformation of the posterior fossa. Herniation of bowel contents through the back in the context of SNS is the clinical result of a persistent NEF and is associated with 50% of previously reported cases. Our patient demonstrated severe topographical disorganization of endodermal and neuroectodermal tissues with a persistent NEF. This effect likely created a functional tether of the spinal cord during development, with a resulting downward migration of posterior fossa contents and concurrent reactive malformation of the posterior fossa.

FIG. 4. 3D spine CT reconstruction, coronal (A) and sagittal (B) views, showing sagittal imbalance with kyphosis at the lumbosacral junction in the region of the vertebral cleft. Figure is available in color online only.

FIG. 5. Sagittal (left) and axial (right) T2-weighted MRI at the last follow-up demonstrating no sign of spinal cord retethering (arrows).
### TABLE 1. Literature review of cases of SNS

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Age</th>
<th>Sex</th>
<th>Cleft Location</th>
<th>Dorsal Anomaly</th>
<th>Enteric Opening Site</th>
<th>Anus</th>
<th>Associated Anomalies</th>
<th>Intervention</th>
<th>Outcome (FU time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keen, 1906¹⁰</td>
<td>2 yrs</td>
<td>F</td>
<td>L3–Sac</td>
<td>Tta</td>
<td>Rec</td>
<td>Norm</td>
<td>Fistula repair</td>
<td>Sinus healed slowly, later reopened; 2nd intervention at 1 yr successful (1 yr)</td>
<td></td>
</tr>
<tr>
<td>Saunders, 1943¹¹</td>
<td>2 days</td>
<td>F</td>
<td>L1–S2</td>
<td>None</td>
<td>Cec, Rec</td>
<td>Norm</td>
<td>GI, urol</td>
<td>None</td>
<td>Death (5 mos)</td>
</tr>
<tr>
<td>Rosselet, 1955¹²</td>
<td>1 day</td>
<td>M</td>
<td>T12–Sac</td>
<td>MMC</td>
<td>Col</td>
<td>Norm</td>
<td>Genital</td>
<td>None</td>
<td>Death due to respiratory distress (3 days)</td>
</tr>
<tr>
<td>Bentley &amp; Smith, 1960</td>
<td>1 yr</td>
<td>F</td>
<td>L2–Sac</td>
<td>None</td>
<td>Rec</td>
<td>Atr</td>
<td>None</td>
<td>None</td>
<td>Death</td>
</tr>
<tr>
<td>Dénes et al., 1967¹³</td>
<td>10 hrs</td>
<td>M</td>
<td>T12–Sac</td>
<td>MMC</td>
<td>NR</td>
<td>Atr</td>
<td>Limb paralysis, hydro</td>
<td>DC, sigmoidostomy</td>
<td>Successful, death due to CV failure</td>
</tr>
<tr>
<td>Faris &amp; Crowe, 1975¹⁴</td>
<td>1 day</td>
<td>M</td>
<td>L9–Sac</td>
<td>MMC</td>
<td>Col</td>
<td>Atr</td>
<td>Genital, GI, increased ICP</td>
<td>MMC repair (1 day), laparotomy (9 days)</td>
<td>Death (1.5 mos)</td>
</tr>
<tr>
<td>Singh &amp; Singh, 1982¹⁵</td>
<td>2 days</td>
<td>M</td>
<td>T10–Sac</td>
<td>MMC</td>
<td>Col</td>
<td>Norm</td>
<td>Facial</td>
<td>None</td>
<td>Death (12 days)</td>
</tr>
<tr>
<td>Gupta &amp; Deodhar, 1987¹⁶</td>
<td>16 days</td>
<td>M</td>
<td>L5–Sac</td>
<td>MMC</td>
<td>Rec</td>
<td>Norm</td>
<td>Fistula resection</td>
<td>Operated at 21 days (1 yr)</td>
<td></td>
</tr>
<tr>
<td>Burrows &amp; Sutcliffe, 1968¹⁷</td>
<td>9 mos</td>
<td>F</td>
<td>L2–Sac</td>
<td>MMC</td>
<td>Col</td>
<td>Norm</td>
<td>Limb paralysis</td>
<td>Mc repair</td>
<td>Mucoid discharge from sinus opening (9 yrs)</td>
</tr>
<tr>
<td>Kheradpir &amp; Ameri, 1983¹⁸</td>
<td>1 day</td>
<td>M</td>
<td>T11–Sac</td>
<td>MMC</td>
<td>NR</td>
<td>Atr</td>
<td>GI</td>
<td>MMC repair, DC</td>
<td>Death due to hydro (7 mos)</td>
</tr>
<tr>
<td>Kramer et al., 1988¹⁹</td>
<td>1 day</td>
<td>M</td>
<td>T10–Sac</td>
<td>MMC</td>
<td>Cec</td>
<td>Atr</td>
<td>None</td>
<td>None</td>
<td>Death (15 days)</td>
</tr>
<tr>
<td>Pathak et al., 1988²⁰</td>
<td>1 day</td>
<td>F</td>
<td>C1–C4, T12–Sac</td>
<td>None</td>
<td>SI</td>
<td>Atr</td>
<td>GI</td>
<td>None</td>
<td>Death (8 mos)</td>
</tr>
<tr>
<td>Meller et al., 1989²¹</td>
<td>1 day</td>
<td>M</td>
<td>L1–Sac</td>
<td>MMC</td>
<td>Cec</td>
<td>Ect</td>
<td>GI</td>
<td>MMC repair, intussusception reduction; cecostomy</td>
<td>Discharged 6 wks</td>
</tr>
<tr>
<td>Hoffman et al., 1993²²</td>
<td>1 day</td>
<td>F</td>
<td>T11–Sac</td>
<td>Mc</td>
<td>NR</td>
<td>Atr</td>
<td>Urogenital</td>
<td>Closure of enteric opening</td>
<td>Death due to electrolyte imbalance (1 day)</td>
</tr>
<tr>
<td>Razack &amp; Page, 1995²³</td>
<td>8 days</td>
<td>F</td>
<td>L2–Sac</td>
<td>Mc, T1a</td>
<td>Col</td>
<td>Norm</td>
<td>Encephalocele</td>
<td>Fistula repair, rectosigmoid opening, suture closure</td>
<td>Postop hydro, discharged at 8 wks</td>
</tr>
<tr>
<td>Akgür et al., 1998²⁴</td>
<td>1 day</td>
<td>M</td>
<td>T10–L5</td>
<td>MMC</td>
<td>Cec</td>
<td>Norm</td>
<td>Ileocolostomy</td>
<td>Death due to sepsis (17 days)</td>
<td></td>
</tr>
<tr>
<td>Kistioğlu et al., 1998²⁵</td>
<td>3 days</td>
<td>M</td>
<td>L1–Sac</td>
<td>Mc</td>
<td>Rec</td>
<td>Atr</td>
<td>None</td>
<td>Mc excision, prolapsed colon reduced</td>
<td>Increased ICP, discharged at 45 days (16 mos)</td>
</tr>
<tr>
<td>Kannaz et al., 2002²⁶</td>
<td>8 mos</td>
<td>M</td>
<td>T11–L4</td>
<td>Mc</td>
<td>Col</td>
<td>Norm</td>
<td>GI</td>
<td>Fistula resection, double barrel colostomy</td>
<td>Death</td>
</tr>
<tr>
<td>Jesus &amp; França, 2004²⁷</td>
<td>2 mos</td>
<td>M</td>
<td>T11–Sac</td>
<td>Mc</td>
<td>SI</td>
<td>Atr</td>
<td>None</td>
<td>None</td>
<td>Death due to sepsis (2 mos)</td>
</tr>
<tr>
<td>van Ramshorst et al., 2006²⁸</td>
<td>4 days</td>
<td>M</td>
<td>T12–L1</td>
<td>None</td>
<td>NR</td>
<td>Norm</td>
<td>GI, facial, genital</td>
<td>Transverse incision laparotomy</td>
<td>Laparotomy for mechanical ileus (5 mos); ventricular distension (10 mos); macrocephaly, gait impairment w/ Babinski sign (4 yrs)</td>
</tr>
<tr>
<td>Agangi et al., 2005²⁹</td>
<td>1 day</td>
<td>F</td>
<td>L4–Sac</td>
<td>Mc</td>
<td>Rec</td>
<td>Atr</td>
<td>Urol</td>
<td>DC, partial colonic resection; 2 mos later, pst sagittal anorectoplasty via combined dorsal &amp; ant approach</td>
<td>Lipo-MMC excision (3 yrs)</td>
</tr>
<tr>
<td>Asagiri et al., 2008³⁰</td>
<td>1 day</td>
<td>M</td>
<td>T10–Sac</td>
<td>Mc</td>
<td>SI</td>
<td>Atr</td>
<td>GI, urol</td>
<td>1st Sx: end ileostomy; 2nd Sx: Mc repair; 3rd Sx (10 mos): DEFx</td>
<td>Death due to DIC (10 mos)</td>
</tr>
</tbody>
</table>
terior fossa cranial vault as it undergoes intramembranous ossification. 8-10

Diagnosis

The majority of SNS cases are diagnosed in the postnatal period based on characteristic syndromic features. 29,30 However, given the unique nature of the condition, successful early diagnosis during pregnancy would allow appropriate counseling should the mother wish to terminate the pregnancy in complex cases or allow for planning with the multidisciplinary team should the decision be made to proceed with pregnancy. While no clear criteria exist, the presence of a posterior mediastinal intrathoracic cyst associated with severe segmental abnormalities of the GI tract and spinal column on in utero ultrasonography have been used for diagnosis from 25 to 39 weeks of gestation. 29,30

Surgical Treatment for SNS

Given its severity, nearly all SNS cases require surgical correction. While SNS more commonly occurs in the thoracic vertebra than the lumbosacral area, any level of the spine can be affected (Table 1). 16,31 The presence and infection risk of CNS and GI abnormalities must be considered when planning surgery. 23 Treatment goals must include the separation of neural elements from intestinal elements, protection and closure of the neural elements from ventral and dorsal openings, and restoration of intestinal continuity and function. Given the wide variability of and complications associated with SNS, 2 the surgeon(s) should approach each case on an individualized basis.

While general convention advocates for a posterior approach because of a better kyphotic angle correction and surgery time, 32,33 the anterior approach in our case offered more benefits in localizing the correct branching point of the protruding GI element without sacrificing too much time for debridement and stabilization. 26,33 Thus, an initial anterior approach may confer the advantage of reducing sepsis. However, traction-related injury from the reduction of enteric contents can occur, which warrants caution by the surgeon. Given that available SNS cases do not provide great detail about their surgical techniques or outcomes, it is difficult to draw meaningful comparisons about the technical differences between the current case and those reported in the literature.

An extended operating time and the blood loss associated with tackling these complex cases in a single stage may contribute to increased morbidity and mortality because of the low blood volume and physiological reserve in newborns. The current three-stage approach differs significantly from the single-stage method that was offered by Srivastava et al., which involved excision and repair of the MMC, disconnection of the NEF, and final repair of the posterior abdominal wall in one operation. 7,16 While these authors reported success with their single-stage surgical management, the long-term prognosis of their patient remains unknown. Staging is important in cases like this when the risk of complications is high, and all anomalies need to be resolved. 3 As an unfortunate example, the patient operated on by Akgür et al. succumbed to sepsis 17 days postoperation. 9

Initial temporizing treatment for hydrocephalus (if present) with subgaleal shunting and providing time for peritoneal space to “recover” from the initial operation may contribute to fewer VPS problems and better outcomes. Providing time for the bowel reanastomosis to heal and bowel function to resume before diverting CSF into the peritoneal space was important in minimizing shunt infection, pseudocyst formation, and/or distal failure. While ventriculooarial or ventriculopleural shunting can be considered as a way to avoid multistaged CSF diversion, consistent evidence suggests that permanent shunting in the

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Age</th>
<th>Sex</th>
<th>Location</th>
<th>Anomaly</th>
<th>Enteric Opening Site</th>
<th>Associated Anomalies</th>
<th>Intervention</th>
<th>Outcome (FU time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Srivastava et al., 2010</td>
<td>1 day</td>
<td>M</td>
<td>LS</td>
<td>MMC</td>
<td>SI</td>
<td>Norm</td>
<td>DEFx, closure of spinal defect</td>
<td>Uneventful postop recovery</td>
</tr>
<tr>
<td>Mirza &amp; Sheikh, 2011</td>
<td>1 day</td>
<td>M</td>
<td>TL</td>
<td>MMC</td>
<td>SI</td>
<td>Atr</td>
<td>None</td>
<td>Death</td>
</tr>
<tr>
<td>Dhawan et al., 2017</td>
<td>1 day</td>
<td>M</td>
<td>T11–L5</td>
<td>MMC</td>
<td>SI</td>
<td>Norm</td>
<td>None</td>
<td>Death (1 day)</td>
</tr>
<tr>
<td>Present study</td>
<td>1 day</td>
<td>F</td>
<td>LS</td>
<td>MMC, Sb, NEF</td>
<td>Col</td>
<td>Norm</td>
<td>Hydro, CMII, partial agenesis of CC</td>
<td>2-stage repair of SNS &amp; NEF w/ delayed VPS placement</td>
</tr>
</tbody>
</table>

Ant = anterior; Atr = atretic; CC = corpus callosum; Cec = cecum; CMII = Arnold-Chiari malformation type II; Col = colon; CV = cardiovascular; DC = decompressive craniectomy; DEFx = dorsal enteric fistula resection; DIC = disseminated intravascular coagulation; Ect = ectopic; FU = follow-up; hydro = hydrocephalus; ICP = intracranial pressure; LS = lumbosacral; Mc = meningocele; norm = normal; NR = not reported; pst = posterior; Rec = rectum; Sac = sacrum; Sb = spina bifida; SI = small intestine; Sx = surgery; TL = thoracolumbar; Tta = teratoma; urol = urological.
immediate postpartum stage carries an increased risk of complications.\(^{34,35}\) Likewise, endoscopic third ventriculocisternostomy carries high failure rates if performed before the patient is 1 month of age.\(^{1–10}\) Early management of all major malpositions can prevent the continued acceleration of pathophysiological processes as the patient begins to interact increasingly with the environment as a mechanism for the continued development of relevant systems.

**Prognosis**

Given the pleomorphic presentation intrinsic to SNS, it is difficult to directly compare reported case outcomes because of a pronounced and broad range of morbidity from multiple complex and interacting sources. In the one other patient with associated hydrocephalus, this condition was left untreated, while GI abnormalities were successfully repaired via decompensatory colostomy and sigmoidostomy, with the patient tolerating per os feeding the following day.\(^{11}\) Unfortunately, the patient later succumbed to cardiovascular complications. Accordingly, there is insufficient evidence to comment on the natural history of the disease in SNS-associated hydrocephalus and whether treatment is strictly necessary. In lieu of available literature, the appropriate management approach should be individualized. In the present case, the relative ease and effectiveness of CSF diversion provided one less insult to an already complex pathophysiology and may be a beneficial option for future cases.

On long-term (5 years) follow-up, the patient presented with normal bowel function, good proximal leg movements with antiguration strength bilaterally, and no signs of shunt malfunction. Furthermore, the patient does not have persistent neurological deficits, as have been reported in another case,\(^{5}\) nor was there any clinical consequence of the perinatal CNS insult.\(^{3}\) The spinal deformity secondary to lumbosacral dysraphism and vertebral cleft development consequent to failure of formation remains a clinically relevant issue, but deferring the intervention as long as possible—ideally until skeletal maturity—would likely increase the long-term success of a spinal deformity operation. The current literature on infantile spinal deformity without cognitive delay likewise argues for conservative management until childhood or adolescence, with surgical intervention reserved for progressive cases.\(^{36}\)

**Conclusions**

SNS is a severe, surgically amenable spinal dysraphism with a variable presentation and often high associated morbidity and mortality. Cases are commonly discovered at birth and frequently involve secondary NEF formation that may present complex surgical challenges. This article presents a multidisciplinary and multistaged approach to reduce endodermal herniation, obliterate NEF and close neural elements, and provide temporizing CSF diversion.

**References**


**Disclosures**

Dr. Maulucci is a consultant for Globus Medical.

**Author Contributions**

Conception and design: Mathkour, Scullen, Bui. Acquisition of data: Mathkour, Scullen, Huang, Bui. Analysis and interpretation of data: Mathkour, Scullen, Bui. Drafting the article: Mathkour, Scullen, Huang, Werner, Gouveia, Steiner, Bui. Critically revising the article: all authors. Reviewed submitted version of manuscript: Mathkour, Scullen, Huang, Werner, Gouveia, Abou-Al-Shaar, Maulucci, St. Hilaire, Bui. Approved the final version of the manuscript on behalf of all authors: Mathkour. Statistical analysis: Mathkour. Administrative/technical/material support: Steiner, St. Hilaire, Bui. Study supervision: St. Hilaire, Bui.

**Correspondence**

Mansour Mathkour: Ochsner Health System, New Orleans, LA. mathkour.mansour@gmail.com.