

Fetal surgeries in utero

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Policy contains: Fetal surgery; fetoscopy; intrauterine surgery; myelomeningocele repair; spina bifida; teratoma; twin reversed arterial perfusion; twin-to-twin transfusion syndrome; urinary tract obstruction.

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Coverage policy

Fetal surgery in utero is clinically proven and, therefore, may be medically necessary to improve fetal survival for the following conditions and/or diagnoses:

- Myelomeningocele repair (American College of Obstetricians and Gynecologists, 2017; Mazzola, 2019).
- Cord occlusion or ablation for twin reversed arterial syndrome (Mone, 2016; Vitucci, 2022).
- Fetoscopic laser photocoagulation, amnioreduction, or radiofrequency ablation for twin-to-twin transfusion syndrome (National Institute for Health and Care Excellence, 2006a, Yoda 2019).
- Vesico-amniotic shunt or cystoscopy for urinary tract infection or obstruction (National Institute for Health and Care Excellence, 2006b, 2007).
- Open surgery, radiofrequency ablation, interstitial laser ablation, or ultrasound-guided aspiration for tumors or cysts (National Institute for Health and Care Excellence, 2006c).
- Thoracoamniotic shunt placement or decompression for macrocystic congenital cystic lung lesions, and high risk for fetal hydrops (Downard, 2017).
- Fetal tracheal occlusion for isolated congenital diaphragmatic hernia and high risk for pulmonary hypoplasia (Li, 2022; Van Calster, 2022).

Limitations

Fetal surgery is investigational/not clinically proven and, therefore, not medically necessary for the following conditions:

- Amnioexchange procedure for gastroschisis.
- Treatment of cleft lip and/or palate.
- Treatment for aqueductal stenosis (i.e., hydrocephalus).
- In utero gene therapy.
- In utero hematopoietic stem cell transplantation for stem cell diseases.

Alternative covered services

- Post-natal surgical intervention.
- Medical management.

Background

For decades, experimental fetal surgery proved essential in studying normal fetal physiology and development and pathophysiology of congenital defects. Clinical fetal surgery started in the 1960s with intrauterine transfusions. While 80% of anomalies develop before the 12th week of gestation, ultrasound technology has improved the sensitivity for diagnosing common fetal malformations. To overcome the limitations of ultrasound, fetal magnetic resonance imaging may also be used to ensure the accuracy of the prenatal diagnosis (Maselli, 2016).

Most detected defects are best treated after birth and require a modification in the time, mode, and place of delivery for optimal obstetrical and neonatal care. The field of fetal surgery has evolved to encompass many types of fetal interventions, including less invasive options, to treat life-threatening conditions of the fetus and to improve postnatal quality of life (Koehler, 2020).

Conditions that may be considered for fetal surgery include the following:

- Cardiac malformations occur in approximately 3.5 per 1000 pregnancies, but only a select proportion of them possibly benefit from in utero surgery (Gardiner, 2016).
- Myelomeningocele is a neural tube defect and the most severe form of spina bifida. It is the most commonly observed malformation of the central nervous system, affecting more than 1,000 fetuses annually in the United States (American College of Obstetricians and Gynecologists, 2017) .
- Twin-to-twin transfusion syndrome is a complication in which twins sharing a common placenta experience unequal blood exchange through placental arteriovenous anastomoses, resulting in different growth rates and complications. This condition occurs in approximately 10% to 15% of identical twins who share a placenta. There are five stages of twin-to-twin transfusion syndrome, each reflecting characteristics of pregnancy changes based on the extra blood supplied from the donor twin to the recipient twin. Treatment options include expectant management, fetoscopic selective laser ablation, amnioreduction, or selective cord occlusion. Treatment goals include stopping the sharing of blood and halt progression of the condition, preserving the survival of the healthier twin, or easing maternal pain or discomfort (Children's Hospital of Philadelphia, 2022b).
- Twin reversed arterial perfusion sequence is a rare condition of monochorionic twin pregnancies in which one twin has an absent or non-functioning heart and receives all of its perfusion from the structurally normal "pump" twin joined by a large blood vessel between their umbilical cords. The acardiac or "parabiotic" twin is not viable and can endanger the pump twin, causing an increased risk of congestive heart failure, intrauterine growth restriction, preterm premature rupture of membranes, and preterm delivery. Intrauterine treatment encompasses hysterotomy and the removal of the acardiac twin and less invasive methods that interrupt cord blood flow to the acardiac fetus through either occlusion or coagulation, depending on the number of amniotic sacs present. The goals of treatment are to preserve the survival of the pump twin and approach a term delivery (Children's Hospital of Philadelphia, 2022a).

- Urinary tract infection or obstruction in the fetus occurs when obstruction to the flow of urine out of the bladder causes backup of urine and damage to the kidneys. The most common cause of bladder obstruction is posterior urethral valves in males, although the condition may be linked to a genetic abnormality. Treatments aim to restore urinary flow through the urethra to the amniotic fluid space. Prenatal surgical options include vesicoamniotic shunt placement and amnioinfusion (Children's Hospital of Philadelphia, 2014).
- Fetal tumors and cysts (mostly abdominal) are rare and mostly benign. The most commonly diagnosed tumors are fetal teratomas, of which sacrococcygeal teratoma is the most prevalent and for which prenatal debulking and neonatal surgical excision are the primary treatments (Children's Hospital of Philadelphia, undated [b]). Intrapericardial teratoma causes a pericardial effusion resulting in tamponade and is fatal if left untreated (Rychik, 2016). In most cases, treatment can be performed successfully in the neonatal period, but some may benefit from fetal intervention. Laparoscopic excision, ultrasound-guided needle aspiration, and drain placement are treatment options depending on the organ involved, the size of the cyst, and symptoms (Children's Hospital Colorado, undated).
- Congenital diaphragmatic hernia occurs when the diaphragm fails to close during prenatal development. This allows abdominal organs to move into the chest, which can affect lung and heart development. Approximately 83% of babies with congenital diaphragmatic hernia have a defect on the left side of the diaphragm. Affected newborns require aggressive surgical repair at delivery and often extracorporeal membrane oxygenation to support heart and lung development. The goal of fetal treatment is to reverse lung damage resulting from lung compression. Fetoscopic endoluminal tracheal occlusion is a procedure that applies a balloon to block the fetus's trachea to prevent fluid from escaping and to increase pressure to stimulate lung growth (Children's Hospital of Philadelphia, undated [a]).

Findings

The evidence for the safety and effectiveness of fetal surgery is of low quality consisting of primarily retrospective observational studies and few randomized controlled trials, which prevents determining the superiority of any intrauterine procedure for a particular condition. Fetal surgical intervention can be considered when preterm delivery is contraindicated and the condition can be corrected allowing for normal development. While early surgical intervention may be recommended after a confirmed diagnosis of fetal decompensation, the benefit of early intrauterine procedures as prophylaxis is unclear. In the latter part of pregnancy, standard treatment consists of early delivery and medically necessary interventions rather than fetal surgery.

Several professional society guidelines have been developed in response to the necessity for correction of various fetal conditions for which surgery is recommended. Most have been provided by the National Institute for Health and Care Excellence (2006a, 2006b, 2006c, 2007) and one by the American College of Obstetricians and Gynecologists (2017).

The American Pediatric Surgical Association found a lack of consensus on the management of congenital pulmonary airway malformation prenatally or postnatally. Thoracoamniotic shunting or decompression may be offered when a fetus has a macrocystic congenital cystic lung lesion and is at risk for hydrops (Level IV evidence, Grade D recommendation) (Downard, 2017).

The Congress of Neurological Surgeons recommends prenatal repair of myelomeningocele in patients who meet maternal and fetal criteria for prenatal surgery, as specified in the Management of Myelomeningocele Study inclusion criteria, to reduce the risk of developing shunt-dependent hydrocephalus (Level I recommendation). The need for permanent cerebrospinal fluid diversion and other relevant maternal and fetal factors should be considered when deciding the optimal method of myelomeningocele closure (Mazzola, 2019).

The Management of Myelomeningocele Study inclusion criteria were singleton pregnancy, myelomeningocele with the upper boundary located between T1 and S1 vertebrae, evidence of hindbrain herniation, a gestational age of 19.0 to 25.9 weeks at randomization, a normal karyotype, and maternal age of at least 18 years (Adzick, 2011; ClinicalTrials.gov identifier NCT00060606).

In 2011, Vanderbilt University researchers prepared a report for the Agency for Healthcare Research and Quality on seven types of fetal surgeries, including interventional literature summaries, for each of the following fetal conditions (Agency for Healthcare Research and Quality, 2011; Walsh, 2011):

- Cardiac malformation.
- Congenital diaphragmatic hernia.
- Myelomeningocele/spina-bifida.
- Obstructive uropathy.
- Sacrococcygeal teratoma.
- Thoracic lesions (congenital pulmonary airway malformations).
- Twin-twin transfusion syndrome.

Cardiac malformations

Congenital cardiac malformations that may benefit from fetal surgery include pulmonary atresia with an intact ventricular septum, severe aortic stenosis with impending hypoplastic left heart syndrome, and hypoplastic left heart syndrome, which, if left untreated, may progress to an intrauterine demise or death shortly after birth (Agency for Healthcare Research and Quality, 2011).

A systematic review and meta-analysis of 29 studies assessed fetal death, preterm delivery less than 37 weeks gestation, live births, and intrauterine complications of fetal interventional congenital heart procedures. Fetal death rates were 31% for aortic valvuloplasty (three studies), 25% for pulmonary valvuloplasty (one study), 14% for septoplasty (one study), and 29% for pericardiocentesis with/without pericardio-amniotic shunt procedures (24 studies). The treatment rate for post-procedural bradycardia was 52% following aortic valvuloplasty, 44% following aortic valvuloplasty (one study), and 27% following septoplasty (one study). Current perinatal evidence, although encouraging in survival terms, is still limited to case reports and few larger studies without randomization and comparison to postnatal interventional success (Araujo, 2016b).

A qualitative analysis of nine studies (n = 101) addressing fetal cardiac interventions found post-valvuloplasty benefits to right ventricular growth and hemodynamic flow in pulmonary stenosis and benefits to left ventricular growth and pressure in critical aortic stenosis, but also high complication rates, morbidity, and mortality. The most common complications were pericardial effusion requiring drainage and bradycardia requiring treatment. Fetal cardiac intervention was usually undertaken once a substantial risk of morbidity and mortality for the fetus was determined, but uniform criteria for fetal cardiac intervention are needed to avoid unnecessary procedures (Diniz, 2023).

Myelomeningocele/spina bifida

The literature on myelomeningocele intrauterine surgery published up to 2011 comprised retrospective cohorts, case series, and one randomized controlled trial comparing the outcomes of prenatal repair to postnatal repair after cesarean delivery. For the composite outcome of death or requiring cerebrospinal fluid shunt/meeting shunt criteria by 12 months, rates favored the prenatal surgery group (68% versus 98%, relative risk 0.70, 95% confidence interval 0.58 to 0.84, $P < .001$). Prenatal surgery favored improved mental development and motor function outcomes but also higher rates of preterm birth, intraoperative complications, maternal transfusion, and uterine scarring (Walsh, 2011).

The first published randomized controlled trial was the Management of Myelomeningocele Study (n = 158 fetuses) that compared the outcomes of prenatal and postnatal myelomeningocele repair. Shunt replacement rates were higher following postnatal surgery (82% versus 40%). At 30 months, the prenatal surgery group had a higher composite score for mental development and motor function ($P = .007$), and improved hindbrain herniation by 12 months and ambulation by 30 months. Rates of preterm delivery and uterine dehiscence at delivery were higher in the prenatal group (Adzick, 2011).

Results of subsequently published systematic reviews and a comparative effectiveness analysis are as follows:

- A review of 19 studies showed that 12 months after treatment, open and endoscopic approaches to fetal surgery for spina bifida had similar ventriculo-peritoneal shunt placement rates (40% versus 45%) (Araujo, 2016a).
- A review of six studies comparing prenatal and postnatal surgical repair for spina bifida found a similar risk of neurodevelopmental impairment at age 12 months (Inversetti, 2019).
- A review of 11 studies comparing fetoscopic and open/laparotomy repair of myelomeningocele documented similar mortality and shunt placement (for hydrocephalus) rates. Fetoscopic repair had elevated rates of premature rupture of membranes ($P < .01$) and preterm births ($P = .04$) compared to open repair, but had lower rates of preterm births compared to laparotomy. Fetoscopic repair had higher rates of dehiscence and leakage from the repair site ($P < .01$) (Kabagambe, 2018).
- A review of five studies comparing fetoscopic and open repair for spina bifida aperta revealed similar perinatal mortality, uterine thinning, dehiscence, and shunt rates at 12 months. In addition, fetoscopic cases resulted in higher rates of prematurity and more postnatal procedures (Joyeux, 2016).
- A review of 11 studies of prenatal surgery for myelomeningocele revealed a 78.6% overall rate of maternal and obstetric complications, mostly obstetric. The most common was spontaneous or preterm membrane rupture (42.0%) (Licci, 2019).
- A comparative effectiveness study of 298 fetoscopic surgical patients and 648 postnatal surgery patients found lower frequencies of hydrocephalus-induced cerebral spinal fluid diversion and Chiari decompression in the fetoscopic cohort (Worley, 2021).

Twin reversed arterial perfusion sequence

A systematic review of 26 studies comparing surgery (cord occlusion or ablation) with conservative management showed superior survival for surgical cases ($P = .008$). Survival was better with ablation than with cord occlusion ($P = .01$) (Mone, 2016).

A meta-analysis of ten studies (n = 156 monochorionic twin pregnancies) found an overall neonatal survival rate after intrafetal laser of 79%. Gestational age at treatment (before or after 16 weeks) did not affect neonatal survival rate. The benefit of early treatment needs to be confirmed in randomized controlled studies (Vitucci, 2022).

Twin-to-twin transfusion syndrome

A meta-analysis of five studies compared the outcomes of fetoscopic laser photocoagulation versus expectant management for stage I twin-to-twin transfusion syndrome. There were no significant differences between interventions in terms of at least one fetal survival at birth, gestational age at delivery, preterm premature rupture of membranes less than 32 weeks, preterm birth less than 32 weeks, or single and dual fetal survival (Nassr, 2023).

A systematic review/meta-analysis of 13 studies found intrauterine death rates were 19.0% in twins managed expectantly, 32.4% in those who received laser treatment, and 12.5% in those treated with amnioreduction. Neonatal death rates were 22.6%, 24.7%, and 20.2%, respectively (Agency for Healthcare Research and Quality, 2011; D'Antonio, 2020).

A systematic review/meta-analysis of 15 studies (n = 888) found that, in cases not undergoing intervention, miscarriage occurred in 11.0% of fetuses, and incidence of intrauterine deaths, neonatal deaths, and perinatal deaths were 25.2%, 12.2% and 31.2%, respectively. In cases treated by laser surgery, the incidences of miscarriage, intrauterine deaths, neonatal deaths, and perinatal deaths were 19.6%, 27.4%, 7.4%, and 35.9%, respectively (Murgano, 2020).

A systematic review of 18 studies (n = 433) found three measures of survival rates (overall, double, and at least one) were similar, whether managed expectantly or treated with amnioreduction. Laser surgery had the highest survival rate (81%) compared with 68% for those managed expectantly and 54% for those undergoing amnioreduction (Khalil, 2016).

A systematic review of 34 studies (n = 3,868) of monochorionic twin pregnancies documented an increase in average survival of both twins from 35% to 65% ($P = .012$) and at least one twin from 70% to 88% ($P = .009$) during the past 25 years, attributing the change to the introduction of laser therapy (Ackerman, 2015).

A systematic review of 17 studies comparing the outcomes of monochorionic pregnancies treated with radiofrequency ablation (n = 320) or bipolar cord occlusion (n = 480) determined the co-twin death rates, live birth rates, and neonatal death rates were not significantly different between groups. The rate of preterm premature rupture of membranes was significantly lower in the radiofrequency ablation group (17.7% versus 28.2%, $P = .01$) (Gaerty, 2015).

Urinary tract obstruction

A systematic review/meta-analysis of 10 studies (n = 355) of fetuses with lower urinary tract obstruction found perinatal survival following vesico-amniotic shunt performed in the second trimester was higher than those cases treated conservatively (57.1% versus 38.8%, odds ratio 2.54, 95% confidence interval 1.14 to 5.67) (Saccone, 2020).

A review of 10 studies (n = 355) of fetuses with severe congenital urinary tract obstruction included nine analyzing the effects of vesico-amniotic shunt performed in the second trimester compared to the group conservatively treated. The shunt group had significantly higher survival (57.1% versus 38.8%) and post-natal (six to 24 months) renal function (Saccone, 2018). A review of nine studies (n = 246) of fetal lower urinary tract obstruction compared those treated with vesico-amniotic shunt to those treated conservatively. The shunt group had superior perinatal survival, but no differences were observed in six- to 12-month survival, two-year survival, or postnatal renal function (Nassr, 2017a).

Fetal tumors/cysts

A review of 92 non-randomized studies (n = 380) analyzed 324 observed and 56 aspirated cysts. Cysts that underwent ultrasound-guided aspiration had a significantly lower rate of postnatal surgery ($P < .001$) than those treated conservatively. The rate of prenatal torsion in simple cysts ≥ 40 mm was lower in aspirated cysts ($P = .03$) (Tyraskis, 2017).

A systematic review/meta-analysis of 34 studies (n = 954) showed that, in fetuses undergoing prenatal aspiration of the cyst, recurrence was 37.9%. Rates of ovarian torsion and intracystic hemorrhage diagnosed after birth were 10.8% and 12.8%, respectively, and 21.8% had surgery after birth (Bascietto, 2017).

A review of 59 studies (n = 70) of fetuses with pericardial teratoma compared prenatal treatment and non-intervention. Of those treated who were hydropic at intervention, 75.0% had a favorable outcome, compared to 30.8% in controls who developed hydrops (Nassr, 2017b).

A review of 20 fetal sacrococcygeal teratomas revealed survival rates of 30% after minimally invasive surgery, 45% after radiofrequency ablation or interstitial laser ablation, and 55% after open fetal surgery (Van Mieghem, 2014).

Congenital diaphragmatic hernia

In randomized controlled trials analyzed in the following systematic reviews, fetoscopic endoluminal tracheal occlusion improved fetal survival at birth but increased the risk for preterm delivery in fetuses with isolated congenital diaphragmatic hernia. Mild to severe tracheal injury occurred in up to 12% of cases. Fetoscopic endoluminal tracheal occlusion is usually reserved for the most severe cases at risk for pulmonary hypoplasia and death at birth. A lack of standardization in prenatal evaluation and postnatal management approaches may affect the external validity of trial results, but multidisciplinary management and access to extracorporeal membrane oxygenation appear to optimize postnatal outcomes. Data on long-term outcomes are needed.

In a systematic review and meta-analysis of four randomized controlled trials, fetoscopic endoluminal tracheal occlusion was associated with a higher survival rate in fetuses with severe, predominately left-sided congenital diaphragmatic hernia but not with more moderate cases. Fetoscopic endoluminal tracheal occlusion was associated with a higher risk of premature rupture of membranes and preterm delivery. There were no differences between cases and matched controls (expectant management) in terms of the need for supplemental oxygen at both birth and discharge or in the incidence of pulmonary hypertension. The optimal timing of balloon insertion could not be determined (Li, 2022).

A systematic review and meta-analysis of five studies ($n = 192$) and an individual participant analysis ($n = 150$) revealed a significant survival benefit when the procedure was provided in an integrated prenatal and postnatal setting compared to a nonintegrated setting (70.7% vs. 45.7%, $P = .003$). Increased availability of extracorporeal membrane oxygenation was a strong determinant of postnatal survival (odds ratio = 18.8, $P = .049$) (Sferra, 2022).

A systematic review of eight cohort studies and two randomized controlled trials ($n = 449$, of whom 228 survived to discharge) found tracheal complications of varying morbidity occurred in 6% of infants born alive and in 12% of those who survived to discharge. The spectrum of tracheal morbidities ranged from mild symptoms (e.g., effort-induced barking cough) to those requiring tracheostomy or tracheal stenting (Tho, 2023).

A reanalysis of data from the two Tracheal Occlusion To Accelerate Lung Growth trials on fetal surgery for congenital diaphragmatic hernia reported an absolute increase in the survival to discharge of 13% (95% confidence interval -1% to 28%, $P = .059$) and 25% (95% confidence interval 6% to 46%, $P = .0091$) for fetuses with moderate and severe pulmonary hypoplasia, respectively. Differences in outcomes between trials may be related to differences in local practices and underlying disease severity in study populations. The effect of gestational age at the time of balloon insertion on outcomes was uncertain (Van Calster, 2022; ClinicalTrials.gov identifiers NCT02875860, NCT01240057).

Thoracic lesions

Congenital thoracic malformations are a group of developmental disorders involving lung parenchyma, arterial supply, and venous drainage. Congenital pulmonary airway malformation, the most common form, and bronchopulmonary sequestration occur at different stages during fetal lung development. In the postnatal period, surgical resection is the treatment of choice for the symptomatic infant with respiratory distress. If there is a risk for fetal hydrops and postnatal treatment is not an option, congenital pulmonary airway malformation can be managed prenatally using corticosteroids, drainage, or fetal surgery to prevent fetal demise (Mehta, 2023).

A systematic review of 17 nonrandomized studies included 401 fetuses believed to have congenital cystic adenomatoid malformations. Three fetuses had open procedures and 54 had thoracoamniotic shunting to decompress the lung lesion. Two of the cohorts ($n = 13$) focused on treatment of bronchopulmonary sequestration. The review did not include literature for isolated pleural effusions or thoracocentesis as a treatment. The limited literature about open maternal-fetal surgeries and thoracoamniotic shunt placement reflects a wide range of differences in the spectrum of fetuses treated and their outcomes. Serial evaluations are essential to determining the clinical course, as there are no valid predictors of outcomes in this population. Trends

in management has evolved to treating only those with poor prognosis as indicated by fetal hydrops (Walsh, 2011).

Results of a systematic review found low level evidence supporting trans-amniotic needle decompression or thoracoamniotic shunting for improving survival when a fetus has a space-occupying cystic lung lesion and is determined to be high risk for hydrops based on imaging characteristics. Fetal lobectomy may be considered for the fetus who does not respond appropriately to a non-operative fetal intervention (e.g., maternal steroid therapy) and is less than 32 weeks of gestational age (Downard, 2017).

In 2024, we deleted several older references and added two indications to the coverage section:

- Thoracoamniotic shunt placement or decompression for macrocystic congenital cystic lung lesions and high risk for fetal hydrops (Downard, 2017).
- Fetal tracheal occlusion for isolated congenital diaphragmatic hernia and high risk for pulmonary hypoplasia (Li, 2022; Van Calster, 2022).

References

On November 30, 2023, we searched PubMed and the databases of the Cochrane Library, the U.K. National Health Services Centre for Reviews and Dissemination, the Agency for Healthcare Research and Quality, and the Centers for Medicare & Medicaid Services. Search terms were “fetal therapies” (MeSH), “fetal surgery,” “myelomeningocele,” “tumors,” “twin reversed arterial syndrome,” “twin-to-twin transfusion syndrome,” “urinary tract obstruction,” “cardiac anomaly,” “teratoma,” and “diaphragmatic hernia.” We included the best available evidence according to established evidence hierarchies (typically systematic reviews, meta-analyses, and full economic analyses, where available) and professional guidelines based on such evidence and clinical expertise.

Ackerman J, Peeters SH, Klumper FJ, Lopriore E, Middeldorp JM, Oepkes D. Twenty-five years of fetoscopic laser coagulation in twin-twin transfusion syndrome: A systematic review. *Fetal Diagn Ther*. 2015;38(4):241-253. Doi: 10.1159/000437053.

Adzick NS, Thom EA, Spong CY, et al. A randomized trial of prenatal versus postnatal repair of myelomeningocele. *N Engl J Med*. 2011;364(11):993-1004. Doi: 10.1056/NEJMoa1014379.

Agency for Healthcare Research and Quality. Maternal-fetal surgical procedures. <https://effectivehealthcare.ahrq.gov/products/fetal-surgery>. Published 2011. Last reviewed March, 2021.

American College of Obstetricians and Gynecologists. Maternal-fetal surgery for myelomeningocele. Committee opinion number 720. <https://www.acog.org/clinical/clinical-guidance/committee-opinion/articles/2017/09/maternal-fetal-surgery-for-myelomeningocele>. Published September, 2017. Reaffirmed 2023.

Araujo E Junior, Tonni G, Martins WP. Outcomes of infants followed-up at least 12 months after fetal open and endoscopic surgery for meningomyelocele: A systematic review and meta-analysis. *J Evid Based Med*. 2016(a);9(3):125-135. Doi: 10.1111/jebm.12207.

Araujo Júnior E, Tonni G, Chung M, Ruano R, Martins WP. Perinatal outcomes and intrauterine complications following fetal intervention for congenital heart disease: Systematic review and meta-analysis of observational studies. *Ultrasound Obstet Gynecol*. 2016(b);48(4):426-433. Doi:10.1002/uog.15867.

Bascietto F, Liberati M, Marrone L, et al. Outcome of fetal ovarian cysts diagnosed on prenatal ultrasound examination: Systematic review and meta-analysis. *Ultrasound Obstet Gynecol*. 2017;50(1):20-31. Doi: 10.1002/uog.16002.

Children's Hospital Colorado. Fetal abdominal cysts. <https://www.childrenscolorado.org/conditions-and-advice/conditions-and-symptoms/conditions/fetal-abdominal-cysts/>. Undated.

Children's Hospital of Philadelphia. Congenital diaphragmatic hernia (CDH). <https://www.chop.edu/conditions-diseases/congenital-diaphragmatic-hernia-cdh>. Undated. (a)

Children's Hospital of Philadelphia. Lower urinary tract obstruction (LUTO). <https://www.chop.edu/conditions-diseases/lower-urinary-tract-obstruction-luto>. Updated 2014.

Children's Hospital of Philadelphia. Sacrococcygeal teratoma (SCT). <https://www.chop.edu/conditions-diseases/sacroccocygeal-teratoma-sct>. Undated. (b)

Children's Hospital of Philadelphia. Twin reversed arterial perfusion sequence (TRAP sequence). <https://www.chop.edu/conditions-diseases/twin-reversed-arterial-perfusion-sequence-and-bipolar-cord-coagulation-for-acardiac-acephalic-twins>. Updated February 2022. (a)

Children's Hospital of Philadelphia. Twin-twin transfusion syndrome (TTTS). <https://www.chop.edu/treatments/selective-bipolar-cord-coagulation-procedure>. Updated February 2022. (b)

ClinicalTrials.gov. ClinicalTrials.gov identifier NCT00060606. Management of myelomeningocele study (MOMS). <https://www.clinicaltrials.gov/study/NCT00060606?term=NCT00060606&rank=1>. Last update posted July 7, 2020.

ClinicalTrials.gov. ClinicalTrials.gov identifier NCT01240057. Tracheal occlusion to accelerate lung growth trial for severe pulmonary hypoplasia (TOTAL). <https://www.clinicaltrials.gov/study/NCT01240057?term=NCT01240057&rank=1>. Last update posted May 4, 2021.

ClinicalTrials.gov. ClinicalTrials.gov identifier NCT02875860. Tracheal occlusion to accelerate lung growth trial (TOTAL). <https://www.clinicaltrials.gov/study/NCT02875860?term=NCT02875860&rank=1>. Last update posted June 23, 2022.

D'Antonio F, Beniloglu C, Sileo FG, et al. Perinatal outcomes of twin pregnancies affected by early twin-twin transfusion syndrome: A systematic review and meta-analysis. *Acta Obstet Gynecol Scand*. 2020;99(9):1121-1134. Doi: 10.1111/aogs.13840.

Diniz AMB, Manso PH, Santos MV, Rodrigues AJ, Sbragia L. A systematic review of benefits and risks of fetal surgery for congenital cardiac defects such as pulmonary valve stenosis and critical aortic stenosis. *Braz J Cardiovasc Surg*. 2023;38(3):398-404. Doi: 10.21470/1678-9741-2022-0273.

Downard CD, Calkins CM, Williams RF, et al. Treatment of congenital pulmonary airway malformations: A systematic review from the APSA outcomes and evidence based practice committee. *Pediatr Surg Int*. 2017;33(9):939-953. Doi: 10.1007/s00383-017-4098-z.

Gaerty K, Greer RM, Kumar S. Systematic review and metaanalysis of perinatal outcomes after radiofrequency ablation and bipolar cord occlusion in monochorionic pregnancies. *Am J Obstet Gynecol*. 2015;213(5):637-643. Doi: 10.1016/j.ajog.2015.04.035.

Gardiner H, Kovacevic A, Tulzer G, et al; Fetal Working Group of the AEPC. Natural history of 107 cases of fetal aortic stenosis from a European multicenter retrospective study. *Ultrasound Obstet Gynecol*. 2016;48(3):373-381. Doi: 10.1002/uog.15876.

Inversetti A, Van der Veeken L, Thompson D, et al. Neurodevelopmental outcome in children with spina bifida aperta repaired prenatally versus postnatally: A systematic review and meta-analysis. *Ultrasound Obstet Gynecol*. 2019;53(3):293-301. Doi: 10.1002/uog.20188.

Joyeux L, Engels AC, Russo FM, et al. Fetoscopic versus open repair for spina bifida aperta: A systematic review of outcomes. *Fetal Diagn Ther*. 2016;39(3):161-171. Doi: 10.1159/000443498.

Kabagambe SK, Jensen GW, Chen YJ, Vanover MA, Farmer DL. Fetal surgery for myelomeningocele: A systematic review and meta-analysis of outcomes in fetoscopic versus open repair. *Fetal Diagn Ther*. 2018;43(3):161-174. Doi: 10.1159/000479505.

Khalil A, Cooper E, Townsend R, Thilaganathan B. Evolution of stage 1 twin-to-twin transfusion syndrome (TTTS): Systematic review and meta-analysis. *Twin Res Hum Genet*. 2016;19(3):207-216. Doi: 10.1017/thg.2016.33.

Koehler SM, Knezevich M, Wagner A. The evolution of fetal surgery. *Journal of Fetal Surgery*. 2020;1(1). Open access pub website. <https://openaccesspub.org/jfs/article/548>.

Licci M, Guzman R, Soleman J. Maternal and obstetric complications in fetal surgery for prenatal myelomeningocele repair: a systematic review. *Neurosurg Focus*. 2019;47(4):E11. Doi: 10.3171/2019.7.FOCUS19470.

Li Q, Liu S, Ma X, Yu J. Fetal endoscopic tracheal occlusion for moderate and severe congenital diaphragmatic hernia: A systematic review and meta-analysis of randomized controlled trials. *Pediatr Surg Int*. 2022;38(9):1217-1226. Doi: 10.1007/s00383-022-05170-7.

Mazzola CA, Assassi N, Baird LC, et al. Congress of Neurological Surgeons systematic review and evidence-based guidelines for pediatric myelomeningocele: Executive summary. *Neurosurgery*. 2019;85(3):299-301. Doi: 10.1093/neuros/nyz261.

Maselli KM, Badillo A. Advances in fetal surgery. *Ann Transl Med*. 2016;4(20):394. Doi: 10.21037/atm.2016.10.34.

Mehta PA, Sharma G. Congenital pulmonary airway malformation. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. <https://www.ncbi.nlm.nih.gov/books/NBK551664/>. Updated August 7, 2023.

Mone F, Devaseelan P, Ong S. Intervention versus a conservative approach in the management of TRAP sequence: A systematic review. *J Perinat Med*. 2016;44(6):619-629. Doi: 10.1515/jpm-2015-0165.

Murgano D, Khalil A, Prefumo F, et al. Outcome of twin-to-twin transfusion syndrome in monochorionic monoamniotic twin pregnancies: A systematic review and meta-analysis. *Ultrasound Obstet Gynecol*. 2020;55(3):310-317. Doi: 10.1002/uog.21889.

Nassr AA, Shazly SAM, Abdelmagied AM, et al. Effectiveness of vesicoamniotic shunt in fetuses with congenital lower urinary tract obstruction: An updated systematic review and meta-analysis. *Ultrasound Obstet Gynecol*. 2017a;49(6):696-703. Doi: 10.1002/uog.15988.

Nassr AA, Hessami K, Zargarzadeh N, et al. Fetoscopic laser photocoagulation versus expectant management for stage I twin-to-twin transfusion syndrome: A systematic review and meta-analysis. *Prenat Diagn*. 2023;43(9):1229-1238. Doi: 10.1002/pd.6413.

Nassr AA, Shazly SA, Morris SA, et al. Prenatal management of fetal intrapericardial teratoma: A systematic review. *Prenat Diagn*. 2017b;37(9):849-863. Doi: 10.1002/pd.5113.

National Institute for Health and Care Excellence. Fetal cystoscopy for the diagnosis and treatment of lower urinary tract obstruction. <https://www.nice.org.uk/guidance/ipg205>. Published January 24, 2007.

National Institute for Health and Care Excellence. Fetal vesico-amniotic shunt for lower urinary tract outflow obstruction. <https://www.nice.org.uk/guidance/ipg202>. Published December 13, 2006a.

National Institute for Health and Care Excellence. Intrauterine laser ablation of placental vessels for the treatment of twin-to-twin transfusion syndrome. <https://www.nice.org.uk/guidance/ipg198/chapter/2-the-procedure>. Published December 13, 2006b.

National Institute for Health and Care Excellence. Percutaneous laser therapy for fetal tumours. <https://www.nice.org.uk/guidance/ipg180>. Published June 28, 2006c.

Rychik J, Khalek N, Gaynor W, et al. Fetal intrapericardial teratoma: natural history and management including successful in utero surgery. *Am J Obstet and Gynecol*. 2016;215(6):780.e1-780.e7. Doi: 10.1016/j.ajog.2016.08.010.

Saccone G, D'Alessandro P, Escolino M, et al. Antenatal intervention for congenital fetal lower urinary tract obstruction (LUTO): a systematic review and meta-analysis. *J Matern Fetal Neonatal Med*. 2018;1-161. Doi: 10.1080/14767058.2018.1555704.

Saccone G, D'Allessandro P, Escolino M, et al. Antenatal intervention for congenital fetal lower urinary tract obstruction (LUTO): Systematic review and meta-analysis. *J Matern Fetal Neonatal Med*. 2020;33(15):2664-2670. Doi: 10.1080/14767058.2018.1555704.

Sferra SR, Miller JL, Cortes MS, et al. Postnatal care setting and survival after fetoscopic tracheal occlusion for severe congenital diaphragmatic hernia: A systematic review and meta-analysis. *J Pediatr Surg*. 2022;57(12):819-825. Doi: 10.1016/j.jpedsurg.2022.05.011.

Tho ALW, Rath CP, Tan JKG, Rao SC. Prevalence of symptomatic tracheal morbidities after fetoscopic endoluminal tracheal occlusion: A systematic review and meta-analysis. *Arch Dis Child Fetal Neonatal Ed*. 2023. Doi: 10.1136/archdischild-2023-325525.

Tyraskis A, Badalis S, David AL, Eaton S, De Coppi P. A systematic review and meta-analysis on fetal ovarian cysts: Impact of size, appearance and prenatal aspiration. *Prenat Diagn*. 2017;37(10):951-958. Doi: 10.1002/pd.5143.

Van Calster B, Benachi A, Nicolaides KH, et al. The randomized tracheal occlusion to accelerate lung growth (total)-trials on fetal surgery for congenital diaphragmatic hernia: Reanalysis using pooled data. *Am J Obstet Gynecol*. 2022;226(4):560.e1-560.e24. Doi: 10.1016/j.ajog.2021.11.1351.

Van Mieghem T, Al-Ibrahim A, Deprest J, et al. Minimally invasive therapy for fetal sacrococcygeal teratoma: Case series and systematic review of the literature. *Ultrasound Obstet Gynecol*. 2014;43(6):611-619. Doi: 10.1002/uog.13315.

Vitucci A, Fratelli N, Fichera A, Sartori E, Prefumo F. Timing of intra-fetal laser therapy for twin reversed arterial perfusion (TRAP) sequence: Retrospective series and systematic review and meta-analysis. *Int J Gynaecol Obstet*. 2022;159(3):833-840. Doi: 10.1002/ijgo.14221.

Walsh WF, Chescheir NC, Gillam-Krakauer M, et al. Maternal-fetal surgical procedures. Technical Brief No. 5. Prepared by the Vanderbilt Evidence-based Practice Center under Contract No. 290-2007-10065. AHRQ Publication No. 10(11)-EHC059-EF. Rockville MD: Agency for Healthcare Research and Quality. https://www.ncbi.nlm.nih.gov/books/NBK54520/pdf/Bookshelf_NBK54520.pdf. Published April, 2011.

Worley G, Greenberg RG, Rocque BG, et al. . Neurosurgical procedures for children with myelomeningocele after fetal or postnatal surgery: A comparative effectiveness study. *Dev Med Child Neurol*. 2021;63(11):1294-1301. Doi: 10.1111/dmcn.14792.

Yoda H. Fetal and neonatal circulatory disorders in twin to twin transfusion syndrome (The secondary publication). *J Nippon Med Sch*. 2019;86(4):192-200. Doi: 10.1272/jnms.JNMS.2019_86-301.

Policy updates

1/2013: initial review date and clinical policy effective date: 6/2014

10/2019: Policy references updated.

2/2021: Policy references updated.

2/2022: Policy references updated.

2/2023: Policy references updated.

2/2024: Policy references updated. Coverage modified.