Recommendation and Guidelines for Perinatal Practice

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Delivery modes in case of fetal malformations

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Abstract: An estimated 276,000 babies die within 4 weeks of birth every year, worldwide, from congenital anomalies. Better quality ultrasound screening can increase the detection of these fetal malformations in the prenatal period. Prenatal counseling for the pregnant woman and her family, regarding the nature of the disease and prognosis is necessary. Options for management in prenatal, perinatal, intrapartum, neonatal, and childhood periods need to be thoroughly discussed, so that the family can make an informed decision. A multidisciplinary approach is usually needed once a decision has been made to optimize fetal outcome, to plan for the timing and location as well as the mode of delivery. In most of the cases, vaginal delivery can be attempted. An elective cesarean delivery should be reserved for maternal concern of dystocia, certain fetal conditions that cesarean delivery will optimize perinatal outcome, or if the parents have a psychosocial determination to have a live-born infant.

Keywords: Cesarean delivery; congenital anomaly; ethics; vaginal delivery.

Introduction

An estimated 276,000 babies die within 4 weeks of birth every year, worldwide, from congenital anomalies. The most common and severe congenital anomalies are heart defects, neural tube defects (NTDs), and Down syndrome (http://www.who.int/mediacentre/factsheets/fs370). Prenatal ultrasound can detect major structural fetal anomalies at 18–20 weeks of gestation in about 60% of cases. More fetal malformations are occasionally detectable later on [1]. Increasing availability of high-quality fetal ultrasound, coupled with a wider adoption of first trimester screening for chromosomal abnormalities has improved the chance of detecting fetal anomalies at an earlier gestational age [2]. Once a diagnosis of a fetal malformation is made by ultrasound, counseling of the pregnant woman is necessary. Depending on the gestational age and the nature of the anomaly, management options should be discussed [3]. Once a decision has been made to optimize the fetal outcome, a multidisciplinary approach is needed to plan for the timing and location as well as the mode of delivery. In most patients vaginal delivery can be attempted. An elective cesarean delivery should be reserved for when there is maternal concern of dystocia, certain fetal conditions that cesarean delivery will optimize perinatal outcome, or if the parents have a psychosocial determination to have a live-born infant.

For the previable fetus, termination of the pregnancy is an option that should be presented in a nondirective manner [3, 4]. Chervenak et al. developed an ethical comprehensive management strategy and justifications for third trimester pregnancies complicated by fetal anomalies [4, 5]. They suggested three categories for counseling:

1. Offer nonaggressive management and termination of pregnancy
2. Offer aggressive and nonaggressive management
3. Recommend aggressive management including delivery by cesarean delivery, when indicated.

Recommendations are based on beneficence-based obligations to the fetal patient in terms of classifications of fetal anomalies based on probability of antenatal diagnosis and degree of probability of outcomes. The clinical ethical concept of the fetus as a patient is explained by reference to the ethical principles of beneficence and respect for autonomy [5]. Nonaggressive fetal management is ethically justified when there is a very high probability about the diagnosis, and either (1) a very high probability of

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death as an outcome of the anomaly diagnosed or (2) survival with a very high probability of a severe and irreversible deficit of cognitive developmental capacity as a result of the anomaly diagnosed [5]. When the decision has been made to optimize the fetal outcome, the next steps should include a decision of timing and mode of delivery.

Women with the prenatal diagnosis of a fetal malformation are more likely than the general population to have cesarean delivery, depending on the nature of the fetal malformations [6]. However, consideration for the optimal route of delivery should include balancing benefits and the risks for both the pregnant woman and the fetal patient.

Kuller et al. [7] reviewed data on neonatal congenital malformations and reported that cesarean delivery may improve outcome for fetuses with certain malformations including isolated meningomyelocele (MMC), hydrocephalus with concomitant macrocephaly, anterior wall defects with extracorporeal liver, sacrococcygeal teratomas, hydrops, and alloimmune thrombocytopenia with low platelet count at term. Since then, further data on experiences on fetal malformations and delivery mode have been reported. A comprehensive listing of all fetal anomalies is beyond the scope of this paper. Our objective is to review recommendations on delivery modes for fetuses with common congenital malformations.

General consideration of delivery modes: cesarean vs. vaginal delivery

A cesarean delivery generally increases risks to the pregnant woman such as increased risks for infection, bleeding, organ injury, and especially risks in future pregnancies [8]. However, a cesarean delivery can also reduce potential birth trauma to the fetus with certain malformations as well as aid with timing and assisting with planned surgery such as the *ex-utero* intrapartum treatment (EXIT) procedure [9]. Therefore, fetal benefits of a cesarean delivery in cases of fetal malformations need to be carefully weighed against potential maternal risks. In addition, optimal timing of delivery and a cesarean delivery may be preferred in certain cases of fetal malformations where a multidisciplinary team needs to be assembled for neonatal evaluation, stabilization, and potential expeditious treatment. An uncomplicated vaginal delivery generally has decreased maternal risks when compared to a cesarean delivery. However, this equation is incomplete if one compares the delivery modes on an "intent to treat" basis to include the risks of instrumental vaginal delivery plus emergency cesarean delivery after a long labor [10]. Simpson [11] included "… both functional and structural fetal abnormalities …" in the main fetal reasons for abdominal delivery and added that "… efforts to decrease cesarean delivery for fetal indications in the current medicolegal environment will not be easy …".

In addition to potentially decreasing fetal risks and minimizing maternal risks with a scheduled cesarean delivery without labor, the possibility of prescheduling the birth allows for team preparation, particularly if multidisciplinary intervention is required immediately after the baby is born. These conflicting issues need to be discussed as early as possible once the fetal anomaly was diagnosed. One other issue that is often neglected needs to be considered. Parents may elect to have a cesarean delivery even if there is a dismal outcome to the fetus, to have the psychosocial benefit of having a live-born child.

Congenital heart disease

Congenital heart disease (CHD) constitutes the most frequent prenatally diagnosed group of congenital malformations [12]. Fetal cardiac medicine has evolved considerably over the past decades, predominantly in response to advances in imaging technology and innovations in therapies [13]. Most fetuses with cardiac malformations can safely be delivered vaginally without special considerations for timing or mode of delivery. However, in selective cases of cardiac malformations delivery at or near a tertiary center may be recommended for certain types of CHD, especially those where stabilization, team preparation, and multidisciplinary intervention is required immediately after the baby is born. No randomized trials have evaluated outcome based on the route of delivery for infants with severe CHD. The data that are available do not show any inherent advantage to cesarean section over vaginal birth [14, 15].

Therefore, for most cases of CHD, vaginal delivery rather than scheduled cesarean delivery can be attempted because there is usually no need for immediate cardiac intervention after delivery [16].

Fetal cardiac arrhythmias

Fetal cardiac arrhythmias constitute a special degree of CHD. Pregnant women carrying a fetus with fetal arrhythmias whose fetal heart rate during labor and delivery

cannot be monitored adequately to reassure fetal well-being may need to be delivered by cesarean section. In addition, fetuses with established compromise such as those with fetal hydrops and growth restriction, especially when they cannot tolerate labor, may benefit from being delivered by cesarean section instead of having to undergo long inductions [16].

Skeletal malformations dysplasia and limb reduction defects

Osteodysplasias or skeletal dysplasias include over 350 distinct conditions with many diagnosed prenatally by ultrasound. Some cases of fetal dysplasia include women who themselves may be affected [17]. In most cases of pregnancy of short-statured women, regardless if the fetus is at risk of skeletal dysplasia or not, a cesarean delivery may be indicated. The decision to proceed with cesarean section, and not trial of vaginal delivery, depends on whether the mother is affected by a long-trunk vs. short-trunk skeletal dysplasia [17]. Maternal osteogenesis imperfecta poses specific anesthesia challenges. The delivery plan should involve timing of delivery and the option of optimal anesthesia.

Multiple issues need to be addressed prior to delivery in women that have an average stature with a fetus with skeletal dysplasia. The fetus should be assessed for possible lethality vs. a fetus that has a skeletal disorder without lethality. A multidisciplinary approach is recommended to not only decide on the optimal mode of delivery but also on the timing and plan for neonatal care and resuscitation [18].

Microcephaly

Microcephaly, especially when associated with intracerebral calcifications, has recently received much attention due to its relationship with infections by the Zika virus during pregnancy [19]. The diagnosis of fetal microcephaly is usually made when the head circumference is below three standard deviations (SDs) of the mean by gestational age [20]. Many infants with microcephaly diagnosed during pregnancy and at birth have no intellectual disabilities. The delivery mode is usually not affected when the fetus has been diagnosed with isolated microcephaly, though additional findings may affect counseling to not do a cesarean delivery in certain circumstances, even when there are obstetric indications such as fetal distress or breech presentation.

Macrocephaly

Macrocephaly is defined as a head circumference exceeding 2–3 SDs above the mean by gestational age. A diagnosis of an isolated head circumference 2–3 SDs above the mean for gestational age does not appear to be a risk factor for abnormal neuropsychological development [21]. Cephalopelvic disproportion (CPD) with a large fetal head may be increased, and therefore cesarean delivery may be warranted specifically at term to prevent CPD.

Cephalocentesis is an invasive procedure aiming for two purposes. First is to reduce the size of the fetal head in a macrocephalic fetus so that vaginal delivery is possible. Second, is to interrupt a fetus with very dismal prognosis, such as a lobar holoprosencephaly. It should be considered as an alternative to cesarean section in selected cases of fetal hydrocephaly.

Urogenital malformations

Congenital malformations of the urogenital tract are among the most frequent prenatally identified fetal malformations. Obstructive uropathy accounts for the majority of cases [22]. The decision of delivery timing and modality requires a multidisciplinary team. Cesarean delivery is usually not indicated unless there is an extensive distention of the abdomen or bladder, which can cause significant tear of the woman's birth passage, should vaginal delivery be attempted without an adequate monitoring and intrapartum intervention, such as ultrasound guided fetal vesicocentesis.

Congenital diaphragmatic hernia

With broader availability of high-quality fetal anomaly screening program, congenital diaphragmatic hernia (CDH) is often diagnosed prenatally. Prenatal diagnosis of CDH allows for a systematic planning of fetal and neonatal management to optimize neonatal outcomes. For instance, fetal tracheal occlusion can be offered in high-risk CDH fetuses. Extracorporeal membrane oxygenation (ECMO) can be prepared at the time of birth, possibly on EXIT-to-ECMO basis. If EXIT-to-ECMO is planned, mode

and time of delivery may depend on availability and planning for ECMO. Frenckner et al. [23] reported a slightly better outcome with cesarean delivery in fetuses with CDH. They recommended further prospective studies to evaluate the optimal mode of delivery of fetuses diagnosed with diaphragmatic hernia in near-term or term infants [23].

Neural tube defects

NTDs are birth defects that affect the brain, spine, or spinal cord. The most common NTDs are spina bifida and anencephaly. The less common NTDs are encephaloceles, hydranencephaly, and iniencephaly. NTDs are common birth defects that affect approximately 1 in 1000 of live births [24]. Embryopathology of NTDs is failure of midline fusion of neural fold early in embryonic life. This incidence usually occurs during the first month after fertilization. Not only there is malformation of neuroectoderm (neural tissue and its skin cover), there can also be an abnormality in development of the corresponding mesoderm. This maldevelopment results in additional abnormalities of the axial skeletal and muscular systems such as meningomyelocele.

There were some observational studies dated back to 1990s suggesting that cesarean delivery may provide a better outcome for babies with MMC [25, 26]. Proponents for routine cesarean delivery for fetal MMC believe that cesarean delivery may reduce bacterial contamination of the exposed neural tissue. Planned cesarean delivery may also allow for a better preparation of the team, i.e. neonatologists and pediatric surgeons, should urgent primary closure is required. This led to an adoption of routine cesarean delivery protocols in many centers for pregnancies complicated with fetal MMC. The evidence supporting this recommendation is not strong as quality prenatal ultrasound was not widely available years ago. Babies who were born in tertiary care hospitals were more likely to be diagnosed with MMC prenatally. These babies were then delivered in the centers where postnatal surgical team is readily available. On the other hand, babies with MMC who were born vaginally at non-tertiary care centers were more likely undiagnosed cases. Therefore, the quality of immediate neonatal care may not be comparable to those delivered by cesarean section at tertiary care centers.

After these factors were corrected for in subsequent publications, cesarean section for MMC has not uniformly been found to provide a superior benefit in terms of mortality, infection, hospital stay, and short-term neurodevelopment [27]. There are no significant benefits in long-term neurodevelopmental outcomes after they were followed into the childhood period [28]. Many professional organizations nowadays no longer regard fetal MMC as an absolute indication for cesarean delivery [29]. Cesarean delivery may be reserved only in fetuses with MMC that 1) present in nonvertex position at the time of labor, 2) have hydrocephalus, or 3) the diameter of herniated sac is over 4–6 cm [30–32].

A landmark randomized controlled trial published by Scott Adzick in 2011 suggested several benefits to the fetus receiving *in-utero* repair of MMC [33]. Their primary outcome was a composite of fetal or neonatal death or the need for placement of a cerebrospinal fluid shunt by the age of 12 months. All of which are short- and long-term sequelae of MMC. This composite of adverse outcomes occurred in 68% of the infants in the prenatal surgery group and in 98% of those in the postnatal surgery group [relative risk, 0.70; 97.7% confidence interval (CI), 0.58–0.84; $P<0.001$]. Babies who received this *in-utero* repair tended to have better neuromotor outcomes than those who were managed conservatively. Maternal morbidity from the procedure is not negligible, and therefore it is being offered in only a limited number of specialized centers. Because thinning of uterine scar can be found in 35% of women after *in-utero* MMC repair, it is recommended that the baby should be delivered by cesarean section after this procedure has been performed earlier in pregnancy [33].

Abdominal wall defects

Gastroschisis and omphalocele are the most common congenital abdominal wall defects diagnosed prenatally. Gastroschisis is slightly less common than omphalocele, with the incidence of 1:10,000 and 1:7000 live births, respectively [34]. Omphalocele is more likely to have associated aneuploidies or physical malformation outside the gastrointestinal tract, compared to gastroschisis. Isolated omphalocele and gastroschisis diagnosed prenatally have a good prognosis after surgical correction [35].

Perinatal death from ventral defect results primarily from respiratory insufficiency (35%) or nonviable small bowel (19%) [35]. Survivors may suffer from prolonged parenteral nutrition and intensive care [36]. There are some thoughts that amniotic fluid can be toxic to the exposed bowel. This hypothesis is similar to the mechanism of progressive damage of the exposed neural tissue in fetuses

with open NTD. Earlier delivery has been attempted, but there is no proven benefit for this intervention to significantly reduce long-term childhood gastrointestinal morbidity or death [37].

Regarding route of delivery, there are hypothetical benefits of cesarean delivery for a fetus with isolated ventral wall defect. These include reduction of bowel contamination from vaginal flora, no compromise of mesenteric blood supply from pressure and twisting during uterine contraction and vaginal passing, and decreased chance of bowel avulsion during vaginal passing [38]. Scheduled cesarean delivery also allows for an ability to schedule for specialists (neonatologists and pediatric surgeons) availability at the time of birth. These potential benefits of scheduled cesarean delivery in a pregnancy complicated with isolated fetal ventral wall defects will outweigh its risks only when it can be shown to reduce neonatal morbidity and length of admission in neonatal intensive care unit (NICU) without compromising the welfare of the mother.

To date, there have been no randomized controlled trials comparing the neonatal and maternal outcomes according to the route of delivery for pregnancy complicated with isolated fetal abdominal wall defects. Segel et al. [39] have conducted a systematic review from 15 retrospective cohort studies, including a total of 805 fetuses with abdominal wall defects. They found no significant relationship between mode of delivery and the rate of primary fascial repair, duration of total parenteral feeding, neonatal sepsis, length of hospital stay, or death. The result from this meta-analysis, however, cannot be viewed as a solid guideline due to inherent confounding factors and heterogeneity of the retrospective studies that were included in the analysis. In addition, there are individual cases of fetal abdominal wall defects that both the fetus and the mother may benefit from cesarean section. This will be the case when the fetus is in nonvertex presentation or having an extremely large defect with significant liver herniation.

Fetal tumors

Fetal tumors have a prevalence of 1.7–13.5/100,000 births and represent a rare and heterogeneous group of abnormalities including tumors of the fetal face and neck such as fetal hygromas, fetal chest, liver, lung, kidney, adrenal gland, brain, pelvic cavity such as ovarian tumors, and sacrococcygeal teratomas [40, 41]. Even when there is a dismal prognosis such as a large intracranial teratoma, cesarean delivery is indicated to avoid maternal dystocia.

Head and neck tumors

Common tumors in the head and neck regions of the fetus include cystic hygroma, lymphangioma, goiter, and teratoma. More and more of these tumors can be diagnosed prenatally from routine ultrasound examination and adjuvant imaging, such as magnetic resonance imaging (MRI). If the size of the tumor is not too large, most of the babies can safely undergo vaginal delivery. Sizable solid tumor in the anterior compartment of the neck may prevent the fetus from fully flexion, and therefore vaginal birth is not possible, and may cause obstructed labor. In this case, cesarean delivery is indicated for the welfare of the mother [42].

Some cystic tumors in the head and neck region of the fetus can infiltrate into the oropharynx and impact the airway patency at the time of birth. Securing difficult airways can take time and in these cases an EXIT procedure may be indicated.

Ex-utero intrapartum treatment procedure

The term EXIT is a procedure first reported in 1997 [9] and involves the partial delivery of the baby, usually by cesarean delivery, while the partially delivered fetus is maintained on placental circulation with an intact umbilical cord. The EXIT procedure is usually done prior to the fetus' first breath to manage the fetal airway in fetal conditions, often fetal neck tumors, where airway obstruction is anticipated [9, 43].

The EXIT procedure requires exact timing as well as a multidisciplinary approach including obstetricians, pediatricians, neonatologists, anesthesiologists, radiologists, surgical subspecialists, and ethicists. While the EXIT procedure is more commonly utilized in cases of fetal neck tumors and obstructions, indications of the EXIT procedure have been expanded beyond neck tumors to aid in other interventions to enhance fetal ventilator support, or to support the fetus while other surgery is done, such as reversal of balloon tracheal occlusion in CDH, laryngeal atresia, eECMO, cervical lymphatic malformations, congenital high airway obstruction (CHAOS), prenatal repair of gastroschisis, and resection of lung and neck masses [9, 43–45].

Sacrococcygeal teratoma

Sacrococcygeal teratoma is one of the most common tumors arising in fetal period. This tumor is hypervascular, and fetuses can suffer from high output cardiac failure, anemia, and hydrops. Catastrophic bleeding can occur and currently vaginal delivery may be attempted with a tumor size of less than 5 cm [46].

Fetal malformations and genetic syndromes

Fetal congenital malformations, whether isolated or multiple, may be part of a genetic syndrome, sequence or association. More frequent chromosomal malformations that are associated with varying degrees of structural issues include Down (trisomy 21), Patau (trisomy 13), and Edward (trisomy 18) syndromes as well as Cri du chat 5p– syndrome. When fetal malformations are found in patients with genetic anomalies or syndromes, they need to be evaluated together with the genetic issue or syndrome when counseling patients about delivery mode and neonatal outcome [1].

The increased risk of neonatal death and neurologic anomalies after birth depend on the genetic anomaly and must be weighed against the potential of improving neonatal outcome with cesarean delivery and the futility of cesarean delivery in severe cases.

Conclusions

Our ability to diagnose fetuses with congenital anomalies has greatly increased over the past decades due to the increased availability of ultrasound. Counseling and planning of the delivery timing and modality has, therefore, become more poignant. Patients should be counseled respecting the ethical concepts of beneficence and respect for autonomy.

Once a decision has been made to optimize fetal outcome, a multidisciplinary approach is needed to plan for the timing and location as well as the mode of delivery. In most patients vaginal delivery can be attempted. An elective cesarean delivery should be reserved for when there is maternal concern of dystocia, if cesarean delivery will optimize fetal outcome, or if the parents have a psychosocial need to have a live-born infant.

References

[1] Gagnon A, Wilson RD, Allen VM, Audibert F, Blight C, Brock JA, et al. Evaluation of prenatally diagnosed structural congenital anomalies. J Obstet Gynaecol Can. 2009;31:875–81, 882–9.
[2] Stoll C, Dott B, Alembik Y, Roth MP. Evaluation of routine prenatal diagnosisby a registry of congenital anomalies. Prenatal Diag. 1995;15:791–800.
[3] Chervenak F, McCullough LB. Responsibly counselling women about the clinical management of pregnancies complicated by severe fetal anomalies. Med Ethics. 2012;38:397–8.
[4] Chervenak FA, McCullough LB. An ethically justified, clinically comprehensive management strategy for third-trimester pregnancies complicated by fetal anomalies. Obstet Gynecol. 1990;75(3 Pt 1):311–6.
[5] Chervenak FA, McCullough LB. Ethical dimensions of non-aggressive fetal management. Semin Fetal Neonatal Med. 2008;13:316–9.
[6] Case AP, Colpitts LR, Langlois PH, Scheuerle AE. Prenatal diagnosis and Cesarean section in a large, population-based birth defects registry. J Matern Fetal Neonatal Med. 2012;25:395–402.
[7] Kuller JA, Katz VL, Wells SR, Wright LN, McMahon MJ. Cesarean delivery for fetal malformations. Obstet Gynecol Surv. 1996;51:371–5.
[8] Gregory KD, Jackson S, Korst L, Fridman M. Cesarean versus vaginal delivery: whose risks? Whose benefits? Am J Perinatol. 2012;29:7–18.
[9] Liechty KW, Crombleholme TM, Flake AW, Morgan MA, Kurth CD, Hubbard AM, et al. Intrapartum airway management for giant fetal neck masses: the EXIT (ex utero intrapartum treatment) procedure. Am J Obstet Gynecol. 1997;177:870–4.
[10] Gee H. Caesarean section should be available on request: FOR: the mother's autonomy should be paramount. Br J Obstet Gynaecol. 2015;122:359.
[11] Simpson LL. When is primary cesarean appropriate: fetal indications. Semin Perinatol. 2012;36:328–35.
[12] Dolk H, Loane M, Garne E. The prevalence of congenital anomalies in Europe. Adv Exp Med Biol. 2010;686:349–64.
[13] Donofrio MT, Moon-Grady AJ, Hornberger LK, Copel JA, Sklansky MS, Abuhamad A, et al. Diagnosis and treatment of fetal cardiac disease: a scientific statement from the American Heart Association. Circulation. 2014;129:2183–242.
[14] Peterson AL, Quartermain MD, Ades A, Khalek N, Johnson MP, Rychik J. Impact of mode of delivery on markers of perinatal hemodynamics in infants with hypoplastic left heart syndrome. J Pediatr. 2011;159:64–9.
[15] Penny DJ, Shekerdemian LS. Management of the neonate with symptomatic congenital heart disease. Arch Dis Child Fetal Neonatal Ed. 2001;84:F141–5.
[16] Jowett VC, Sankaran S, Rollings SL, Hall R, Kyle PM, Sharland GK. Foetal congenital heart disease: obstetric management and time to first cardiac intervention in babies delivered at a tertiary centre. Cardiol Young. 2014;24:494–502.
[17] Allanson JE, Hall JG. Obstetric and gynecologic problems in women with chondrodystrophies. Obstet Gynecol. 1986;67:74–78.
[18] Krakow D. Lachman RS, Rimoin DS. Guidelines for the prenatal diagnosis of fetal skeletal dysplasias. Genet Med. 2009;11:127–33.

[19] Oliveira Melo AS, Malinger G, Ximenes R, Szejnfeld PO, Alves Sampaio S, Bispo de Filippis AM. Zika virus intrauterine infection causes fetal brain abnormality and microcephaly: tip of the iceberg? Ultrasound Obstet Gynecol. 2016;47:6–7.
[20] Chervenak FA, Jeanty P, Cantraine F, Chitkara U, Venus I, Berkowitz RL, et al. The diagnosis of fetal microcephaly. Am J Obstet Gynecol. 1984;149:512–7.
[21] Biran-Gol Y, Malinger G, Cohen HM. Davidovitch HD. Lev D. Lerman-Sagie T, SchweigerA. Developmental outcome of isolated fetal macrocephaly. Ultrasound Obstet Gynecol. 2010;36:147–53.
[22] Hindryckx A, De Catte L. Prenatal diagnosis of congenital renal and urinary tract malformations. Facts Views Vis Obgyn. 2011;3:165–74.
[23] Frenckner BP, Lally PA, Hintz SR, Lally KP; Congenital Diaphragmatic Hernia Study Group. Prenatal diagnosis of congenital diaphragmatic hernia: how should the babies be delivered?J Pediatr Surg. 2007;42:1533–8.
[24] Greenberg F, James LM, Oakley GP, Jr. Estimates of birth prevalence rates of spina bifida in the United States from computer-generated maps. Am J Obstet Gynecol. 1983;145:570–3.
[25] Luthy DA, Wardinsky T, Shurtleff DB, Hollenbach KA, Hickok DE, Nyberg DA, et al. Cesarean section before the onset of labor and subsequent motor function in infants with meningomyelocele diagnosed antenatally. N Engl J Med. 1991;324:662–6.
[26] Chervenak FA, Duncan C, Ment LR, Tortora M, McClure M, Hobbins JC. Perinatal management of meningomyelocele. Obstet Gynecol. 1984;63:376–80.
[27] Bensen JT, Dillard RG, Burton BK. Open spina bifida: does cesarean section delivery improve prognosis? Obstet Gynecol. 1988;71:532–4.
[28] Merrill DC, Goodwin P, Burson JM, Sato Y, Williamson R, Weiner CP. The optimal route of delivery for fetal meningomyelocele. Am J Obstet Gynecol. 1998;179:235–40.
[29] Wilson RD, Committee SG, Wilson RD, Audibert F, Brock JA, Campagnolo C, et al. Prenatal screening, diagnosis, and pregnancy management of fetal neural tube defects. J Obstet Gynaecol Can. 2014;36:927–42.
[30] Cochrane D, Aronyk K, Sawatzky B, Wilson D, Steinbok P. The effects of labor and delivery on spinal cord function and ambulation in patients with meningomyelocele. Childs Nerv Syst. 1991;7:312–5.
[31] Hadi HA, Loy RA, Long EM, Jr., Martin SA, Devoe LD. Outcome of fetal meningomyelocele after vaginal delivery. J Reprod Med 1987;32:597–600.
[32] Anteby EY, Yagel S. Route of delivery of fetuses with structural anomalies. Eur J Obstet Gynecol Reprod Biol. 2003;106:5–9.
[33] Adzick NS, Thom EA, Spong CY, Brock JW 3rd, Burrows PK, Johnson MP, et al. A randomized trial of prenatal versus postnatal repair of myelomeningocele. N Engl J Med. 2011;364:993–1004.
[34] Paidas MJ, Crombleholme TM, Robertson FM. Prenatal diagnosis and management. Parry S, Marder SJ. Delivery and obstetrical issues. In: Rychik J, Wernovsky G, editors. Hypoplastic left heart syndrome. New York, NY: Springer; 2003. p. 29–37.
[35] Swartz KR, Harrison MW, Campbell JR, Campbell TJ. Selective management of gastroschisis. Ann Surg. 1986;203:214–8.
[36] Bradnock TJ, Marven S, Owen A, Johnson P, Kurinczuk JJ, Draper ES, et al. Gastroschisis: one year outcomes from national cohort study. Br Med J. 2011;343:d6749.
[37] Grant NH, Dorling J, Thornton JG. Elective preterm birth for fetal gastroschisis. The Cochrane Database Syst Rev. 2013;6:CD009394.
[38] Sakala EP, Erhard LN, White JJ. Elective Cesarean section improves outcomes of neonates with gastroschisis. Am J Obstet Gynecol. 1993;169:1050–3.
[39] Segel SY, Marder SJ, Parry S, Macones GA. Fetal abdominal wall defects and mode of delivery: a systematic review. Obstet Gynecol. 2001;98:867–73.
[40] Kurjak A, Zalud I, Jurković D, Alfirević Z, Tomić K. Ultrasound diagnosis and evaluation of fetal tumors. J Perinat Med. 1989;17:173–93.
[41] Cho JY, Lee YH. Fetal tumors: prenatal ultrasonographic findings and clinical characteristics. Ultrasonography. 2014;33:240–51.
[42] Wataganara T, Ngerncham S, Kitsommart R, Fuangtharnthip P. Fetal neck myofibroma. J Med Assoc Thai. 2007;90:376–80.
[43] Moldenhauer JS. Ex utero intrapartum therapy. Semin Pediatr Surg. 2013;22:44–9.
[44] Pivetti V, Cavigioli F, Lista G, Napolitano M, Rustico M, Paganelli A, et al. Cesarean section plus delayed cord clamping approach in the perinatal management of congenital high airway obstruction syndrome (CHAOS): a case report. J Neonatal Perinatal Med. 2014;7:237–9.
[45] Lazar DA, Olutoye OO, Moise KJ Jr, Ivey RT, Johnson A, Ayres N, et al. Ex-utero intrapartum treatment procedure for giant neck masses–fetal and maternal outcomes. J Pediatr Surg. 2011;46:817–22.
[46] Gross SJ, Benzie RJ, Sermer M, Skidmore MB, Wilson SR. Sacrococcygeal teratoma: prenatal diagnosis and management. Am J Obstet Gynecol. 1987;156:393–6.

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