American Pediatric Surgical Association

Prenatal Counseling Series

Myelomeningocele

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Saving Lifetimes™

from the
Fetal Diagnosis and Treatment Committee

Authors: Christina M. Theodorou, MD, and
Darrell Cass, MD

Edited under the leadership of
Ahmed I. Marwan, MD and the 2021 APSA
FD&T Committee

Overview

- Myelomeningocele (MMC), an open neural tube defect with protrusion of the spinal cord, is the most severe form of spina bifida
- Overall, myelomeningocele occurs in nearly 1 in 2000 live births[1]
- Damage to the exposed developing spinal cord accrues through gestation
- MMC most commonly occurs in the lumbosacral spine[2]
- Spinal cord damage has numerous sequelae for the child throughout life:
  - Lower extremity paralysis or loss of motor function
  - Hindbrain herniation, with resulting hydrocephalus
  - Cognitive impairment
  - Neurogenic bowel and bladder dysfunction
  - Musculoskeletal anomalies
  - Sexual dysfunction
- Higher spinal cord lesions are often more severe due to the distal neurologic dysfunction

Initial Prenatal Evaluation and Diagnosis: Imaging Studies to Obtain and Timing Laboratory Testing

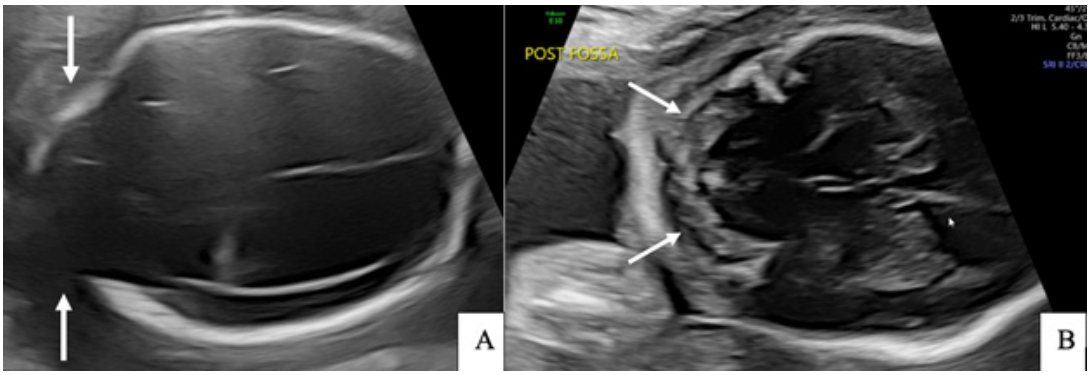
- Maternal serum AFP (alpha-fetoprotein) may be high
- Amniotic fluid should be assessed for AFP and AChE (acetylcholinesterase) levels

Imaging: Ultrasound[3]

Detailed fetal ultrasound if there is suspicion for MMC on routine screening should be obtained at 18-22 weeks

- Ultrasound – Fetal Spine
  - The fetal spine should be examined to locate the conus medullaris, which can be used to quantify the spinal level of any osseous lesion
  - Evaluate for the presence and dimensions of a sac around the MMC
    - Large defects may affect surgical planning
  - Components of the sac should be identified, including the neural placode
  - The thickness of the sac should be evaluated
  - A full spinal evaluation should be done to determine if other anomalies are present, such as kyphosis, scoliosis, or a cervical spine syrinx

- Ultrasound – Fetal Brain
  - The cerebral ventricles should be evaluated and sized
    - Ventricular diameter > 10 mm is considered ventriculomegaly
  - The cerebellum and cisterna magna should be evaluated for evidence of hindbrain herniation
    - "Banana sign": crescent-shaped cerebellum may be noted
    - "Lemon sign": frontal bone concavity near the coronal sutures of the fetal skull may be seen
  - Intraventricular or germinal matrix hemorrhages should be noted
- Ultrasound – Extremities
  - Abnormalities such as talipes (club foot) or rocker bottom foot should be noted
  - The presence of flexion and extension at all joints should be evaluated

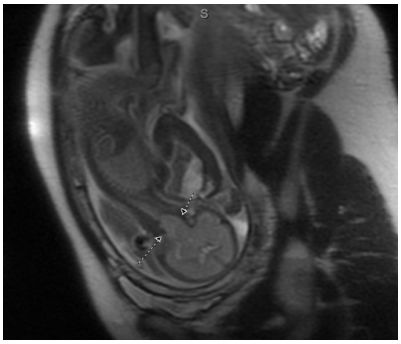


Fetal ultrasound showing "lemon sign" (frontal bone concavity) in image A and "banana sign" (crescent-shaped cerebellum) in image B, marked by arrows. Images courtesy of Dr. Ramesh Papanna, MD, University of Texas Health.

Imaging: Fetal MRI[4]

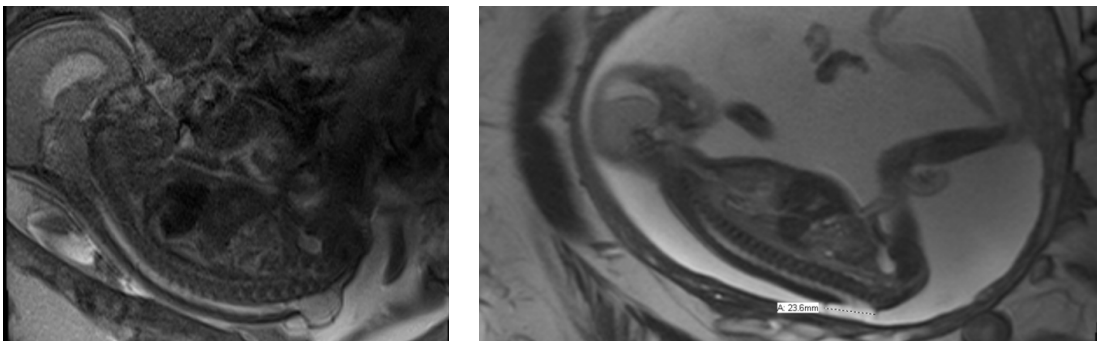
Fetal MRI is needed to obtain more detailed information about any findings noted on US. Fetal MRI should ideally be performed at a fetal center to obtain an adequate study.

- Fetal MRI – Fetal Brain
  - The fetal MRI is key in assessment of hindbrain herniation
    - Additional details such as gray matter heterotopia, intraventricular hemorrhage, and callosal dysgenesis may be evident on MRI
    - Degree and cervical level of hindbrain herniation may be determined
  - The presence of ventriculomegaly should be assessed



Fetal MRI showing hindbrain herniation. Image courtesy of Dr. Payam Saadai, UC Davis Medical Center.

- Fetal MRI – Fetal Spine
  - Presence of an open spinal defect should be evaluated, with elevation of the neural placode to distinguish MMC from myeloschisis
  - Any spinal kyphosis or scoliosis or syrinx should be noted



Fetal MRI showing lumbosacral myelomeningocele. Images courtesy of Dr. Payam Saadai, UC Davis Medical Center.

Imaging: Fetal Echocardiography

- Fetal echocardiogram should be obtained to evaluate for congenital heart disease[5]

Differential Diagnosis of MMC

- Sacrococcygeal teratoma
- Sacral agenesis
- Segmental spinal dysgenesis

Key Points for Prenatal Counseling

- Highly variable severity of disease
- Potential interventions, timing of interventions, including postnatal
- Potential sequelae
- Early referral to a fetal surgery center, ideally between 18-24 weeks gestation

MMC Lesion Level

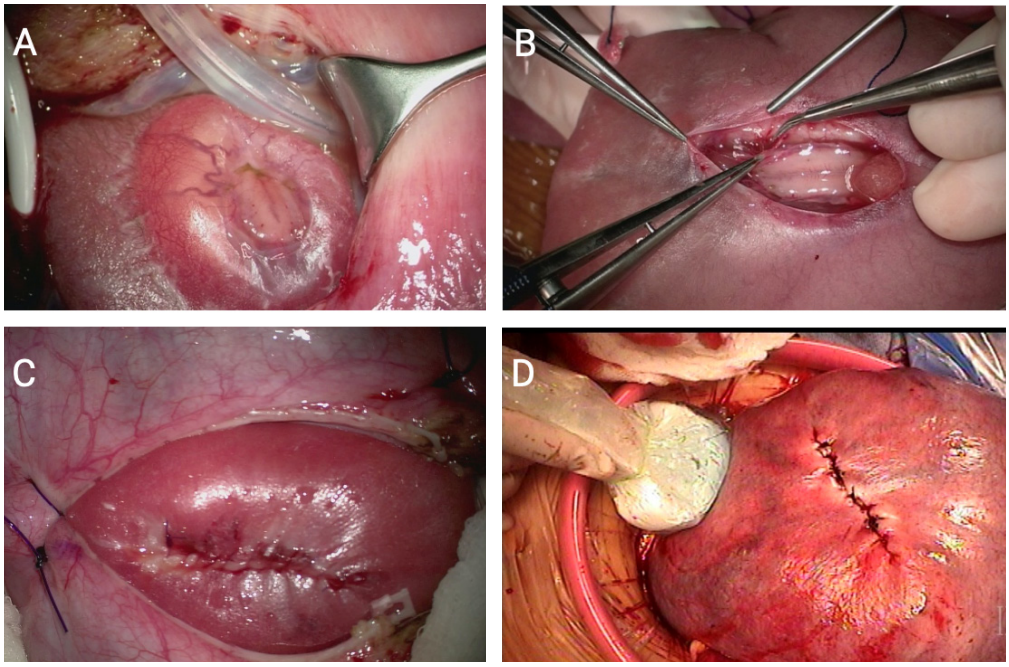
- In the Management of Myelomeningocele Study(MOMS), the most common anatomic lesion level was at L3-L4
- Although lumbosacral MMC is the most common lesion, MMC may occur anywhere along the spine

Fetal Intervention

- Fetal MMC repair has been shown to be superior to postnatal MMC repair, resulting in lower rates of hydrocephalus requiring ventriculoperitoneal shunting, and improved distal motor function.
- Importantly, the landmark MOMS trial established fetal MMC repair as the standard of care.
  - By 30 months of age, 45% of children who underwent fetal MMC repair were able to walk independently compared to only 24% of children who underwent postnatal MMC repair.
- There are two main types of fetal MMC repair: open and fetoscopic.
  - In open fetal MMC repair, the fetal back is delivered via maternal laparotomy and hysterotomy and the MMC defect is repaired.
  - Fetoscopic MMC repair is a minimally invasive alternative, using laparoscopic instruments to perform the repair. More commonly, fetoscopic MMC repair is performed via maternal laparotomy with fetoscopy to perform the fetal MMC repair. Some centers perform laparoscopic maternal abdominal access followed by fetoscopic MMC repair.
  - There is technical variability between fetal centers with regards to the approach chosen and the details of the repair.
- Eligibility for fetal surgery: Inclusion criteria for the MOMS trial were as follows:

INCLUSION	EXCLUSION
• MMC lesion at any level T1-S1 with hindbrain herniation • Maternal age ≥18 years • Gestational age 19w0d-25w6d gestation • Normal karyotype	• Multifetal pregnancy • Maternal comorbidities including: insulin-dependent diabetes; BMI ≥ 35; history of cervical insufficiency, placenta previa or placental abruption; cervix length <20 mm on ultrasound; previous spontaneous singleton delivery before 37 weeks; maternal HIV, Hepatitis B, or Hepatitis C; uterine anomalies such as large or multiple fibroids, Müllerian duct anomaly; maternal-fetal Rh isoimmunization or Kell sensitization; history of neonatal alloimmune thrombocytopenia • Other maternal medical condition which is a contraindication to surgery or general anesthesia, including any patients with previous hysterotomy in the active segment of the uterus • Fetal factors: fetal anomaly not related to MMC; fetal kyphosis ≥ 30 degrees • Lack of psychosocial support • Non-resident of the US

- Expanded eligibility criteria: Some institutions have expanded the upper BMI limit to 40, and have found no increases in adverse maternal or fetal outcomes.[6,7]
- Post-intervention monitoring
  - Following fetal MMC repair, mothers are admitted to the hospital for monitoring for preterm labor
  - After discharge, mothers are monitored closely with frequent (often weekly) ultrasound examinations of the fetus to assess well-being
  - Modified bedrest and restricted activity are recommended through delivery
  - The baby is subsequently delivered by Cesarean section at 37 weeks gestation if an open approach is used
- Potential complications of fetal intervention
  - Preterm delivery is the most common complication, occurring in almost 80% of patients in the MOMS trial, at an average gestational age of 34 weeks
  - Patients are at risk for subsequent complications of prematurity
  - Additional risks include chorioamniotic membrane separation, and fetal or neonatal death, which is rare (< 5% of cases).[2]
  - A systematic review of the literature on these two approaches found no differences in perinatal mortality, ventriculoperitoneal shunt placement, or postnatal motor function, but fetoscopic repair was associated with higher rates of premature rupture of membranes, MMC repair site dehiscence, and cerebrospinal fluid leak
  - Fetoscopic MMC repair does not require a large uterine incision, decreasing the mother's risk of future uterine rupture, and retaining the ability for potential future vaginal deliveries
- Maternal complications: Although fetal surgery is relatively safe for the mother, it is still a major abdominal surgery. The primary risk to be counseled on is the need for future deliveries to occur via Cesarean section due to a 9.6% risk of uterine rupture with vaginal delivery.[8]



Fetal myelomeningocele defect (A) seen during fetal repair with dissection of the dura (B). After fetal skin closure (C), the uterus is then closed (D). Images A-C courtesy of Dr. Payam Saadai, UC Davis Medical Center and Image D courtesy of Dr. Ahmed Marwan, MD.

Postnatal Intervention

- For patients not eligible for fetal MMC repair, or for families who choose to not undergo fetal repair, postnatal repair of the MMC defect is performed within 48-72 hours after birth. Early repair is necessary to prevent infection which can result in meningitis.
- Some patients who undergo fetal MMC repair require revision of the repair due to wound dehiscence or persistent cerebrospinal fluid leak.

Follow-up and Development

- Patients with MMC require lifelong multidisciplinary care, which may include the following, from diagnosis and beyond:
  - Maternal-Fetal Medicine
  - Neonatology
  - Neurosurgery
  - Pediatric Surgery
  - Physical Medicine & Rehabilitation
  - Pediatrics
  - Urology
  - Gastroenterology
  - Orthopedic Surgery
  - Psychology or Psychiatry
  - Social Work

- General Timeline of Follow up: In addition to regular care by the patient's pediatrician, frequent follow-up with multiple subspecialists is imperative.9 General guidelines are listed below.
  - **Neurosurgery:** every 3-4 months (age 0-1), every 6 months (age 1-2), every 6-12 months (age 3-5), yearly (age 6 and above)
  - **Orthopedic Surgery:** every 3 months (age 0-1), as needed thereafter to evaluate and treat for scoliosis, or other spinal deformities
  - **Urology:** by age 3 months, obtain renal/bladder ultrasound, urodynamics, serum creatinine; obtain follow-up ultrasounds every 6 months until age 2, then yearly. Obtain follow-up urodynamics yearly through age 3. Yearly creatinine checks are recommended starting at age 6
  - **Pediatric Surgery / Gastroenterology:** initiate bowel management program as needed for bowel dysfunction
- Potential sequelae, long-term outcomes:
  - Lower extremity paralysis or loss of motor function[2,10]
  - Hindbrain herniation, with resulting hydrocephalus[2,10]
  - Possible cognitive impairment[11]
  - Neurogenic bowel and bladder dysfunction[12,13]
  - Musculoskeletal anomalies[14]
  - Male sexual dysfunction[15]
  - Latex sensitivity

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