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MYELOMENINGOCELE A COMPARISON THE POST OPERATIVE COMPLICATIONS B/W INFANTS WITH PARAPLEGIA AND THESE WITH VARIABLE DEGREE OF LOWER LIMBSWEAKNESS ASTUDY OF 100 CASES 2013

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ABSTRACTE

BACKGROUND: Myelomeningocele is a complex malformation of spinal cord, nerves roots, meninges, vertebral body and skin .this neural tube defect is common congenital anomaly and is typically referred to as spina bifida. This condition result from failure of neural tube to close in developing fetus. Medical, surgical and rehabilitation issues arise in the patients with MMC. **Aim of this study**: was to determine the deference between the post operative complications in infants with paraplegia and these of variable degree of weakness and some aspects of the epidemiology of MMC in our country among. admission at Al Kademia teaching hospital and neurosurgical hospital in Baghdad. **Patient and method**: A prospective study on 100 cases of MMC that were admitted into Al Kadymia and neurosurgical teaching hospitals in Baghdad during the period September 2012 thruogh September 2013.Data collected for infants and mothers. **Results**: female predominance (female:male is 2.3:1). All of infants of socioeconomic poor families. Fifty nine of infants of consanguineous marriage 41% of non consanguineous marriage .Regarding the site commonest site was lumar spine 50%. Postoperative complications: Infection was common in nonmoving infants 30%. CSF leak common in nonmoving 20%. Postop. Ilius in 30% and neurological deterioration common in nonmoving infants 40%. Primary HCP occure in 69% while Secondary HCP in78%. Post op.meningitis complicated 25% of cases the majority in nonmoving 88%. **Conclusion and Recommendation:** The incidence of MMC appeare to be non-declining in Iraq, complications more common in paraplegic infants. multidisciplinary team is required and minimal invasive surgical techniques are required.

Chapter 1

INTRODUCTION

Myelomeningocele (MMC) is a nonlethal form of neural tube defect (NTD.)that results from failure of the neural tube to fuse during early embryogenesis. The lesion is characterized by protrusion of the meninges through a midline bony defect of the spine, a sac containing cerebrospinal fluid and dysplastic neural tissue not covered by skin.

MMC represents an important congenital defect of the brain and spinal cord that affects approximately one in 2,000 live births and about 23% of pregnancies that end in elective abortion .[1,2]

MMC leads to lifelong and significant physical disabilities including paraplegia, hydrocephalus, bladder and fecal incontinence, sexual dysfunction, skeletal deformation and mental impairment.[3] The mortality rate, which can be as high as 47% on long-term follow up, is principally attributable to the hindbrain herniation observed in Chiari malformation and to the renal failure observed in neurogenic bladder dysfunction.[4] The cost of treating these patients represents a significant impact on the public health system.

Pathogenesis of Neurological Deficit

Several theories attempt to explain the neurologic defects associated with an open spinal cord defect. The neurologic injury may result from a “two-hit” phenomenon.[5] The first hit is the original defect in neurulation that creates MMC, and the second hit is the secondary trauma to the spinal cord that results from its exposure to the intra-uterine environment, such as the amniotic fluid, and from direct trauma in the gestational period, or during labor or delivery. Support for the two-hit hypothesis of spinal cord damage comes from sonographic examinations. Studies have shown leg movements during prenatal ultrasonographic observation and abnormal postnatal leg movements.[6,7] These movements in the prenatal period could be secondary to spinal arc reflexes or could come from the cerebrum through an intact spinal cord that is damaged secondarily during gestation.

Other support for the theory consists of the neurologic results followingacesarean section prior to labor. Luthy et al.[8] reported 160 cases of infants with MMC and compared their results based on delivery via vaginal or cesarean section routes both prior to the onset of labor and after labor onset. Delivery by cesarean section before the onset of labor resulted in better motor function at 2 years of age. They also observed that delivery by cesarean section after

onset of labor but before rupture of membranes resulted in better motor function than cesarean section performed after onset of labor and after rupture of membranes. They conclude that the loss of amniotic fluid with labor, after membrane rupture, may lead to traumatic injury of nerves.[11]

Diagnosis of Myelomeningocele

Prenatal diagnosis of MMC is possible before the twelfth postmenstrual week by noting irregularities on ultrasound of the bony spine or a bulging within the posterior contour of the fetal back in the sagittal view. Meticulous ultrasonography in the axial plane shows the absence of the posterior arches of the vertebrae, with protrusion of a fluid-filled sac. The neural placode, which is scarred in the inner side of the sac, is lifted out of the spinal canal. On coronal section, the affected bony segment shows a divergent configuration instead of the typical parallel lines of the normal vertebral arches.[9] The vertebral level can be assessed in a sagittal plane; the last rib corresponds to T12, the top of the iliac wing to L5/S1.Kollias et al.[10], using this method, reported that the ultrasonographic level correlates with the anatomical level in 64% of the cases.

The diagnostic sensitivities for prenatal sonographic detection of MMC are reported to be 80% and 90% when the examination is performed by a highly qualified sonographer who is carefully evaluating the spine (Fig. 1.1).[11,12] In contrast, the sensitivity for detection of a spinal lesion is lower than 50% when ultrasound is performed in a low-risk population, by an inexperienced sonographer, or using less advanced equipment.[10,13]

Indirect signs of MMC are a consequence of the Chiari II malformation. The major features include inferior displacement of the medulla and the fourth ventricle into the upper cervical canal; elongation and thinning of the upper medulla and lower pons; and inferior displacement of the cerebellum (Fig. 1.2) through the foramen magnum (“banana” sign). Ventriculomegaly may result from the hindbrain malformation blocking the flow of cerebrospinal fluid.[13] Thechanges in the posterior fossa and the hindbrain herniation into the foramen magnum may be seen by ultrafast magnetic resonance imaging (MRI) in the sagittal plane. Ultrasound using axial views is an inadequate substitute for MRI in the evaluation of hindbrain herniation.[14] However, both methods are equally accurate to determine the level of the lesion in fetuses with MMC (Fig. 1.2)[15]

Fig1.1U/S of fetus 20 weeks of gestation; revealing the myelomeningocele and after birth.[15]

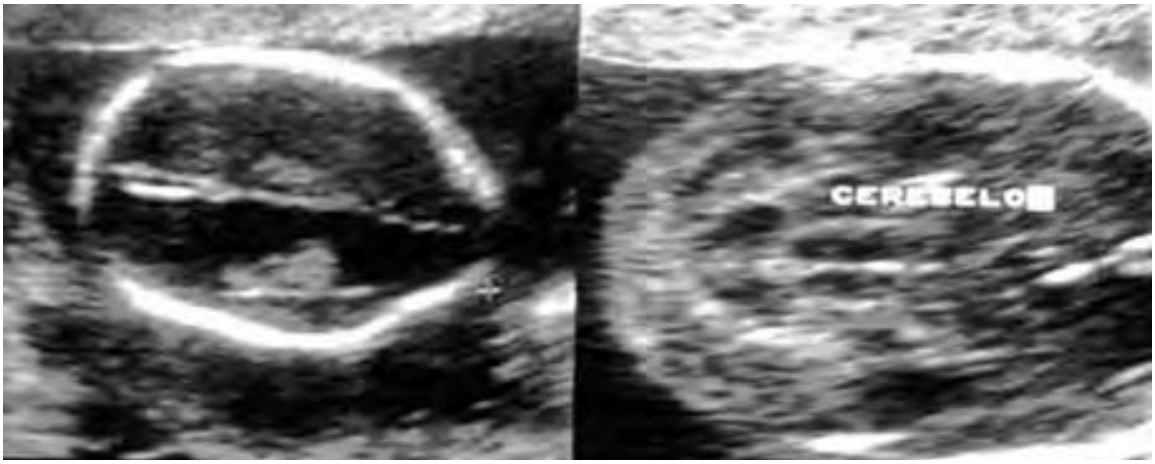


Fig. 1.2Ultrasound of a fetus at 23 weeks gestation, revealing the lemon and the banana sign[15]

Rationale for Surgery

Almost all children born with MMC have an associated Chiari II malformation, and approximately 85-90% of such babies have hydrocephalus at birth or develop it subsequently, thus requiring a shunt to drain the excess cerebrospinal fluid from the brain into the abdomen, where it is absorbed. Twocommon problems with shunts are malfunction and infection, and most children with hydrocephalus will require multiple shunt revisions. Shunt dependence carries with it a 1% per year mortality risk.[16] Symptoms related to Chiari II malformation are determined by the degree of descent of the hindbrain and cerebellum down the cervical spine, and include difficulty swallowing, inspiratory stridor, weak cry and insufficient breathing; in severe cases it may lead to death.[17]

The level of MMC is an important factor for prediction of the capacity to walk. Patients with lesions at sacral levels are able to ambulate 100% of the time in 93% of cases; 91% of young adults with L5 lesion ambulate 75-100% of the time. However, no patient with a lesion at the

level of L3 or above can ambulate most of time without using a wheelchair.[18] Ninety percent of patients with thoracic lesion, 45% with lumbar lesion and 17% with sacral lesions are mobile with the use of crutches or wheelchairs.[19]

Most patients with MMC require some form of intermittent catheterization to control urination, with 85% of these patients able to keep dry. Thirty-eight percent of patients use a bowel program and 52% report social continence.[18] About 84% of children with neuropathic bladders have abnormal bowel control and sever chronic constipation .[20]

Young people with MMC are found to be at greater risk of social isolation, depressive mood, lower self-esteem and suicidal ideation. The quality of their social life is determined by the degree of functional loss (ambulation difficulties, urinary and fecal incontinence).[21]

In 1997, direct closure of MMC was performed by hystercotomy at Vanderbilt University (VU).[23] and also at The Children's Hospital of Philadelphia (TCHP).[24] Opening the uterus for fetal surgery was then a great challenge, and initially was only indicated in fetuses with a high risk of prenatal death. On the contrary, MMC has significant prenatal and postnatal morbidity but the risk of intrauterine death is low. New knowledge of mechanical materials,tocolytic and anesthetic drugs and fetal monitoring were important factors for this management.

Despite different protocols of inclusion and exclusion criteria for surgical candidacy used by these two institutions, more than 200 surgeries have been done, with significant results obtained from their studies.

The most important benefit has been the reduction and sometimes complete reversal of the hindbrain herniation as seen by magnetic resonance imaging.[25] Observation of 104 cases of open fetal surgery from both institutions, followed up for at least one year, revealed that the incidence of shunting occurred in 54% of the cases, compared with 86% in a historical group obtained from The Children's Hospital of Philadelphia, and also that shunting was less common when the surgery was performed prior to 26 weeks gestation (42.7%).[26,27] Bruner et al.[28] compared 29 cases of fetal surgery with those of historical controls at Vanderbilt University and observed a decrease in the shunt rate (59% vs. 91%), as well as a decreased incidence of hindbrain herniation (38% vs. 95%) and a decreased incidence of clubfoot (28% vs. 70%).

Despite excellent results in preventing hindbrain herniation, fetal surgery for MMC did not show the same outcome in improving sensorimotor function. Tubbs[29] compared 37 patients who underwent intrauterine procedures at VU with conventionally treated patients at the University of Alabama and, in both groups the average level of leg function roughly approximated the upper level of lesion. It appears that intrauterine correction has little effect on leg function.[29] Johnson et al.[9] questioned the selection criteria of indication at VU. At TCHP the movement of legs and feet observed on ultrasound was an important element toselect fetuses for surgery. In their series, 57% had better than predicted leg function at birth in cases of thoracic and lumbar lesion.[9,30] No improvement in functional bladder outcome was observed at a short follow-up after 1 year of age.

Morbidity and perinatal mortality have occurred in cases of open fetal surgery for MMC. The maternal morbidity reported at VU was due to blood transfusion in the postoperative period (2.2%) pulmonary edema (5.1%) bowel obstruction at 33 weeks (0.5%) and uterine dehiscence or rupture from hysterotmy (2.2%). No maternal deaths were noted.[32] Perinatal mortality occurred in 4% of cases at VU and 6% at TCHP and was related to prematurity and infection. In all cases observed, prematurity was the most frequent problem in open fetal surgery, the mean gestational age at delivery being 34 weeks.[1]

There are controversies about the real benefits of intrauterine repair of MMC. It is important to consider the effects in a balance where on the one side there is a reduction of MMC defects and on the other side the risk of morbidity due to the surgery and prematurity. Long-term data of the patients submitted to prenatal repair are needed for better comprehension of its real benefits. An initiative called Management of Myelomeningocele Study (MOMS trial) was created in 2002 and consists of a multicentered and randomized trial for a period of 5 years. Three centers have been selected for fetal surgery: Vanderbilt University, The Children's Hospital of Philadelphia and University of California, San Francisco. 100 patients will undergo fetal surgery and 100 patients will be selected to form the control group. George Washington University will collect the data of surgery and follow-up.

Selection of the Patients

The selection criteria for patients to undergo open fetal surgery conform to those of the MOMS trial[33]

Inclusion criteria

1. Gestational age between 19 to 25 weeks and 6 days
2. Maternal age ≥ 18 years
3. Normal fetal karyotype
4. Defect between T1 and S1
5. Atrium < 18 mm
6. Hindbrain herniation seen by magnetic resonance imaging
7. Signed informed consent form

Exclusion criteria

1. Multifetal pregnancy
2. Insulin-dependent pregestational diabetes
3. Obesity
4. Fetal kyphosis ≥ 30 degrees
5. Fetal anomaly not related to the myelomeningocele
6. Preterm labor in the current pregnancy
7. Short cervix < 20 mm
8. History of spontaneous delivery < 37 weeks
9. Placenta previa
10. Maternal HIV, hepatitis B and C
11. Uterine anomaly
12. Alloimmunization

Examination of the Baby Born with a Myelomeningocele

The examination of the lesion includes noting its circumference, shape, the placode, skin integrity, and the extent of the cutaneous and epithelialized layers (Fig 1.3). The spinal column is examined for evidence of early scoliosis, kyphosis, and visible and palpable prominent laminae at the lateral margin of the lesion. Orthopedic deformities of hips, knees, ankles, and feet are noted and give further clues of the functional neurologic level. Early orthopedic consultation may be needed for evaluation of foot deformities and possible early casting. The presence of dysmorphic features may indicate a syndromic cause of MMC.[34]

It is crucial to evaluate the neurological function and determine the level of spinal involvement. Progressive spinal neurological deficit in patients suffering from spina bifida is a very common clinical phenomenon. The patient's neurological status should be carefully

followed, paying particular attention to the spinal level of neurological function. Various scoring systems have been applied in this field for children with spina bifida.[35-36] The Spina Bifida Neurological Scale (SBNS) is a commonly used scoring system and is very useful in both theevaluation of patients' clinical status and the quantitative analysis of chronologic ages in their neurological status.[35] This scale is based on motor function, reflexes, bladder and bowel function. The scoring system can be applied to neonates and infants and may be used to foresee their daily activities in thefuture (Tables 1.1, 1.2, 1.3).[35]

The most common and important clinical problems related to the primary lesion in spina bifida patients are

1. Standing.
2. Ambulation.
3. Voluntary control of bladder and bowel function.

These functions are linked with the level of spinal involvement. Consequently, the assessment of residual function is through the assessment of motor function, reflexes, and bladder and bowel function. Impairment of sensation is also a major symptom of spina bifida, but its assessment is difficult in newborns and infants.

The motor examination can be conducted with pinpricks over the baby's torso or upper extremities. A newborn with a lesion at T12 or above has flail legs. Hip flexion requires L1 to L3 function while knee extension involves L2 to L4 function. Knee flexion signifies a L5 to S1 function. Plantar flexion demands function at S1-2.[37]

Spontaneous movements are best assessed by suspending the infant in the prone position and examining for spontaneous movements of the feet, legs, and hips.[38] All stimulation is best restricted to the shoulders since stimulation of paralysed lower limbs and trunk may result in reflex movements, giving a false impression.

Reflex testing is important as an intact reflex arch confirms both afferent (sensory) and efferent (motor) neural function. Commonly evaluated reflexes include the patellar tendon reflex (femoral nerve, L2-4), Achilles tendon reflex (tibial nerve, S1-2), and anal reflex (pudendal nerve, S3-4).[35]

The sensory level can be determined by the stimulation of the distal to proximal dermatomal segments with pinpricks. The sensory level is usually one or two segments higher than the

anticipated motor level.[37]

Judgment of the functional level of the lesion makes certain the reasonable estimates of potential future capacities. Most patients with lesions below S1 have the ability to walk without an aid. Infants with lesions above L2 often depend on a wheelchair for the majority of activities. Patients with intermediate lesions show similar degrees of wheelchair dependency (L3) or will be primarily ambulatory with braces or other devices (L4, L5).[39] Variability is possible between subsequent ambulatory status and apparent neurological segmental level with midlumbar lesions.[26] Good strength of iliopsoas (hip flexion) and quadriceps (knee extension) is important for predicting ambulatory potential. Segmental level is also necessary in determining the scoliosis development. Most patients with lesions above L2 exhibit significant scoliosis, while it is not very common in patients with lesions below S1.[39]

The bladder problems connected with spina bifida are almost always of the lower motor neuron type with neurological flaccidity of the bladder due to a lesion of the sacral portion (S2-4) of the cord of cauda equina. Thus, bladder and bowel control evaluation measures the spinal levels below those evaluated by motor function testing. Until infants and neonates develop voluntary voiding, the voiding status cannot be clinically evaluated.[35]

Sphincter function is evaluated through observation of the anal tone and observing whether urine dribbles continuously from the urethra. Infants with a positive anocutaneous reflex have a better prognosis for urinary continence.[41]

Anal and urethral mucosae may prolapse in severely paralyzed cases.[41,42] Very early diaper dermatitis may also be a sign of incontinence.

Table 1.1 Scoring scale for motor function.

Functioning Nonfunctioning	C-Th L2	L1	L2 L3	L3 L4	L4 L5	L5 S1	S1 S2
Hip							
Flexion	–		±	+	+	+	+
Extension	–		–	–	–	–	±
Adduction	–		±	+	+	+	+
Abduction	–		–	–	–	+	+
Knee							
Extension	–		±	+	+	+	+
Flexion	–		–	–	–	±	+
Ankle							
Dorsiflexion	–		–	–	±	+	+
Plantarflexion	–		–	–	–	–	±
Inversion	–		–	–	±	+	+
Eversion	–		–	–	–	–	–
SBNS motor (worse side)	1		2	3	4	5	6

–, complete paresis; ±, incomplete paresis; +, intact; *SBNS*, Spina bifida neurological scale

Table 1.2 Scoring scale for preserved reflexes.

Functioning	C-Th ~L2	L3	L4	L5	S1	S2	S3
Nonfunctioning	L3	L4	L5	S1	S2	S3	S4
Patellar reflex	–	±	+	+	+	+	+
Achilles reflex	–	–	–	±	+	+	+
Anal reflex	–	–	–	–	–	±	±
SBNS reflex (worse side)	1	2		3		4	

–, absent; ±, diminished; +, intact

Table 1.3 Scoring scale for bladder and bowel function.

Functioning	C. Th L. S1	S2				S3		
Nonfunctioning	S2	S3				S4		
Bladder control	–	–	±	+	±	+	+	+
Bowel control	–	±	–	±	+	±	+	+
SBNS								
BB control	1	2	3	4	5			

–, uncontrollable; ±, partially controllable; +, controllable; *BB*, Blader and bowel function scale

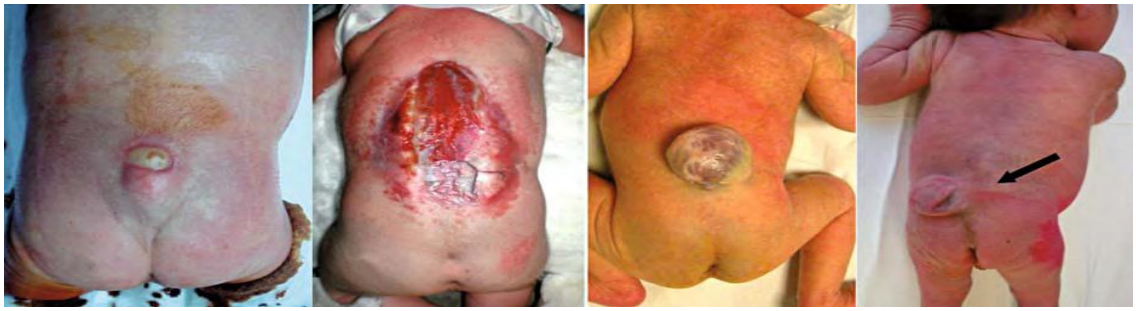


Fig. 1.3 A-D **A detailed examination of the lesion is needed for the further treatment.** A **a small contaminated and infected myelomeningocele.** B **a huge difficult-to-close defect.**C **a typical midline myelomeningocele. D asymmetrically localized myelomeningocele typical for hemimyelomeningocele**[34]

Basis for Differential Diagnosis: Classification of Spinal Dysraphisms

For lack of clear genetic correlation, the malformations of the spine and cord are classified according to the assumed embryological sequence, and to the pathological-radiological findings.

Abnormal development of the notochordal process leads to notochordal dysraphism. A persistent communication of the notochordal canal with the ventral endoderm results in the rare neuroenteric canals and/or neuroenteric cysts. Duplication of the notochord leads to a tentative duplication of the spine and a partial duplication of the cord, and results in the diastematomyelia (which rarely may be associated with a MMC). The skin is intact but a characteristic patch of hair is commonly present.[45]

Failed closure of the spinal cord causes the open spinal dysraphism and its topographic variants: spinal MMC, Chiari III and exencephaly-anencephaly. Spinal MMC occurs frequently at the lumbosacral level, but also at the thoracic and cervical levels (often confused with non-terminal myelocystoceles). It is usually isolated but may sometimes be found in association with diplomyelia (hemi-myelomeningocele), lipomas, and epidermoid/dermoid cysts. It is essentially always associated with the Chiari II malformation of the hindbrain in a small posterior fossa. It may occur as a familial disorder, and can be prevented by the administration of folic acid.[35]

The neural tube may close properly but remain attached to the skin, whichthen is pulled upward into the spinal canal during the relative upward ascent of the cord. The resulting dermal tract/dermal cyst abnormality extends from the skin to the neural tube across the neural arches/ligaments and the meninges. The tract/cyst becomes progressively filled with dermal secretions and expands; as it is open to the environment, in two-thirds of cases it becomes infected. Usually lumbosacral, it may be observed anywhere along the dorsal midline, especially at the cervico-thoracic junction and in the posterior fossa. Except for the dermal pit the skin is intact but may present a flat angioma with some hair. The nasal dermal tract is different: the skin is pulled in by the anterobasal dura of the foramen caecum instead, and does not extend to the nervous tissue.[34,40]

The lipomyelomeningocele (LMMC, or spinal lipoma) is assumed to result from the accidental trapping of mesenchymal cells in the central canal at the time of the separation from the skin, with a subsequent lipomatous dysplasia. Actually the process may be more complex, as the lipomatous mass is often multitissular. The lipoma is typically sacral at the level of the low lying caudal cord, and always involves the posterior aspect of the cord. It is typically continuous with the subcutaneous fat through a bony defect of the neural arches, and it blends with the adjacent dura. The cerebrospinal fluid (CSF) - filled meningeal sac may bulge through the bone defect, often asymmetrically. The cord remains low, tethered to the lipoma. A syringomyelia may develop. A Chiari II malformation is never associated with a LMMC (the neural tube is not open).The subcutaneous fat is often thickened; the skin covering is intact but a flat cutaneous angioma is typically present. In other topographic variants, the lipoma may be found in the cord above the conus, or below it in the filum terminale; usually it is then strictly subpial, although it may sometimes be attached to the dorsal dura[12,50].

The "simple" meningocele is a rare malformation of unknown mechanism. It is a CSF-filled meningeal sac, always covered with skin (sometimes dystrophic) but not by fat. By definition it should not contain neural elements, but it may contain some secondarily herniated neural tissue, dystrophic filum or nerve roots. The conus is in a normal location. A Chiari II malformation is never associated but because of a hydrodynamic imbalance with exaggerated compliance of the dural sac, a Chiari I deformity and hydrosyringomyelia may develop.[44,48]

The uncommon myelocystocele is typically terminal (sacral), but it may be found anywhere along the spine (non-terminal myelocystocele). It is often confused with classical spinal MMC. Its mechanism is unknown. It corresponds to ahydromyelic sac protruding out of the cord into a bulging dorsal meningeal sac. The skin is intact, the subcutaneous fat is present. There is no Chiari II malformation, but for hydrodynamic reasons a Chiari I deformity may develop. It may be associated with pelvic and abdominal malformations.

The anterior sacral meningocele may be simple and isolated, or associated with a tethered cord, a lipoma, or a dermoid/teratoma (Currarino triad). It is extruded anteriorly within the posterior pelvic cavity through an anterior sacral defect. This is typically associated with a "scimitar" sacral deformity. It is never associated with a Chiari II malformation.

Imaging Tools

The optimal modalities with which to investigate MMC and the Chiari II malformation are magnetic resonance (MR) imaging above all, computed tomography (CT) for the bony abnormalities, and ultrasonography (US) for a non-invasive bedside evaluation of pathology in an infant or a fetus. However, at birth, the diagnosis is a clinical one, and assessing cardiac or urologic anomalies is more important than assessing the malformation itself.

MR imaging produces a good depiction of the spinal and cranial morphological abnormalities, and a precise identification of the normal and dysplastic tissues. Generally assumed to be more innocuous than CT (no ionizing radiation), MR is, however, not fully non-invasive in the young child as sedation or general anesthesia are needed.Specifically in a newborn with MMC, itis important toexamine the infant lying on the side, to avoid compression of the meningeal sac.The quality of imaging may be suboptimal as compared to that in older children because of the high water and low myelin content in the neonate, and because of the small size of the subjects. On the contrary, from the age of a few months MR imaging yields spectacular results with which the repaired MMC, the dysplasia of the

hindbrain and its sinovenous surroundings, and the midbrain and forebrain dysplasia can be assessed. Hydrocephalus also can be precisely evaluated. Coronal imaging of the scoliotic bony spine may also be helpful. In utero, MR is extremely useful as complement to US for the diagnosis of MMC/Chiari II. It can performed in utero, at or even before 20 weeks; i.e., well before the limit of legal termination in most countries, and before the limit of fetal surgery at 25 weeks. It depicts the level and extent of the spinal defect and better than US, the Chiari IImalformation, the ventriculomegaly and the dysplastic hemispheres, which are important features if fetal surgery is contemplated.

CT can be useful to evaluate the spine and the skull anomalies, using low dose imaging, but it is not really useful for analysing the malformation itself. It is obviously not used for diagnosis in utero. It is a simple way to follow-up shunted hydrocephalus however, if MR is not readily available. A comment must be made about latex allergy, which is a problem particular to the children with MMC/Chiari II. Up to two-thirds of patients may be affected. This high incidence is thought to be related to the repetition of surgical interventions.[43,44] Consequently, every care should be taken to avoid the use of and any contact with latex gloves while preparing the patients for sedation, anesthesia, or placement of a venous line. The technicians, physicians and nurses involved in pediatric imaging should be well aware of the risks, and ideally, given the relatively large number of MMC patients, any pediatric radiology setting should be kept latex free.

Prenatal Imaging

In addition to biology, prenatal imaging is extremely important for the diagnosis of NTDs, for several reasons. The first is that it makes the morphologic diagnosis clear. The second is that it identifies the features that help to prognosticate the disorder (level and extent of the defect, mobility of the lower limbs, severity of the posterior fossa changes, and degree of ventriculomegaly/hydrocephalus). The third reason is that, together with the personal, affective, familial, religious and legal contexts, it helps in decision-making: to do nothing or, on the contrary, terminate the pregnancy; to prepare for delivery by caesarean section, and for early perinatal care; to perform fetal surgery where available. Early fetal surgery (before 25 weeks) is performed in a few, highly specialized centers. It is not free of complications (rethetering, epidermoids, and increased perinatal mortality[45]). However, it has led to rapid reversal (within three weeks) of the Chiari II malformation.[46-47] Hydrocephalus is less common, and develops later. patients with a ventricular size less than 14 mm at the atrium

and a defect at or below L4 are less likely to require eventual ventriculo- peritoneal shunting[48,49] When leg motion is present, it seems to grant a somewhat better long-termneurological function compared with that expected in conventionally treated patients[45,50-51], presumably by avoiding the noxious effect of prolonged contact of the neural placode with the amniotic fluid.[45,52] Early imaging is therefore of utmost importance in making such significant choices. It is easily done with U/S, and it may take more effort with MR imaging (small fetal size, fetal/ maternal motion). U/S is sufficient for the diagnosis of MMC itself, but MR is more useful for a global assessment of the CNS. MR can be performed, and be fully diagnostic as early as 18 gestational weeks; i.e. well before the end of the surgical window (25 weeks), and before the end of the legal period for termination in most countries.

Prenatal Diagnosis

Ultrasound is a good screening method, best imaging clue:

1. Spine defect.
2. Chiari II: “lemon”, “banana” signs (as early as 12 weeks).
3. Ventriculomegaly.

Fetal MRI is a complementary technique.

Neonatal Imaging and Post-surgical Follow-up

MMC is usually diagnosed by prenatal ultrasound or MR. When continuation of pregnancy is chosen, an elective caesarean delivery is planned. Unexpected MMC are uncommon, and concern mostly low, small, non-bulging myeloceles. Optimally, the delivery should be scheduled in a center where a neurosurgeon specialized in the care of children is available. At birth, the diagnosis of MMC is confirmed by visual examination, and imaging the MMC is, as a rule, unnecessary. On the contrary, imaging studies are mandatory to assess associated conditions, such as pulmonary or cardiac abnormalities, which might affect prognosis and hence the decision to go to surgery. Cranial and renal sonograms are also important, but need not delay surgical intervention; they can be performed after surgery. Spinal films are not essential. The timing of surgery, usually in the first 48 hours after birth, is important because an increased infection rate is associated with delayed surgery.[53] The MMC is usually located in the lumbosacral area. In rare instances, it may be located higher; it is not clear whether the mechanism of the high spinal MMC is the same as that of the lowMMC. Cervical MMC seem to have a better long-term neurological prognosis than low spinal MMC.[54,55] The

information, however, is compounded by the fact that there may be some confusion in the literature between true MMC and nonterminal myelocystocele[56], which seems to carry a poor motor prognosis.[57] If the neonate presents with brainstem-related clinical features, it is important to carefully investigate the anatomic status of the cranio-vertebral junction (bone, dura, venous sinuses and effluents) and of the lower hindbrain with MR. As part of the brainstem dysfunction can be related to degenerative, rather than dysplastic lesions, an early decompressive surgery may be indicated to correct them.[58]

Non-CNS Investigations

Clinically, apart from the known limb paresis and CNS anomalies, patients with myelomeningoceles are at risk of renal failure in adolescence or adult life, secondary to neuropathic bladder-sphincter dysfunction. Sometimes the urodynamic changes may precede the neurological deficit related to cord tethering or progressive hydrosyringomyelia. In MMC, detrusor sphincter dyssynergia creates the functional obstruction urinary tract dilatation and high-pressure vesico-ureteral reflux in 50% of affected patients. Incomplete bladder emptying adds recurrent urinary tract infections. Urodynamic studies in children with MMC assess the detrusor muscle and urethral sphincter functions during bladder filling and emptying, and better identify the disorder as incontinence or obstruction. A voiding cysto-urethrogram should be performed simultaneously to assess the degree of vesico-ureteral reflux. In the first years of life U/S evaluation of the renal parenchyma isimportant as these children are at high risk of infection[59, 60]

U/S Imaging

The U/S in MMC/Chiari II malformation is obviously limited to the newborn and young infant, when the cranial and spinal acoustic windows are still accessible

Cranial U/S

U/S is a safe investigating modality that can be used bedside. The primary indication for performing cranial sonography in the newborn with a neural tubedefect is to determine the ventricular size. Hydrocephalus that is associated with MMC is commonly mild in utero, and tends to becomes more severe after birth and especially after the surgical closure of the MMC, presumably because surgery reduces the compliance of the dural sac and interrupts the CSF leakage. It may also result from the association of multiple anatomical causes, such as compression of the aqueduct by the upwardly herniated cerebellum, the compression of the fourth ventricle or the obstruction of its outlet, and the crowding of the posterior fossa and

foramen magnum. Beside hydrocephalus, the forebrain often presents a characteristic ventriculomegaly with small pointed frontal horns and disproportionately large posterior atria (colpocephaly). This is typically associated with a dysplastic corpus callosum and it points to a developmental defect of the white matter. The coronal images may demonstrate widening of the interhemispheric fissure and gyral interdigitation. The third ventricle is often expanded and the large massa intermedia may be noted filling the ventricle in the coronal images. The fourth ventricle is not often visualized because it is compressed, elongated and displaced toward the upper spinal canal. The posterior fossa and cerebellum are small.[61-62]

Cranial Sonographic Findings in Chiari II Malformation

1. Inferomedial pointing of frontal horns, colpo-cephalic atria.
2. Partial absence of corpus callosum and septum pellucidum.
3. Prominent interhemispheric fissure.
4. Large massa intermedia.
5. Effaced fourth ventricle

Spinal U/S

U/S is not needed on the exposed neural placode but occasionally, if the placode is well epithelialized it may be helpful to tell the difference between a MMC and a meningocele or a lipomyelomeningocele. Nerve roots can be seen extending between the sac and dysraphic spinal canal in the MMC, whereas meningocele appears as an empty sac, or a sac containing only strands of thin, randomly oriented lacelike membranes.[63] Scanning over the sac must be performed gently and carefully, so as not to disrupt or contaminate it, and when no skin is covering the defect, a plastic wrap or drape may be used.[62] If ultrasound is performed in the neonate before surgery the remainder of the cord should be imaged in search of associated anomalies: hydrosyringomyelia, lipoma, etc.[64-65] The cervical canal in the newborn can be imaged by U/S through the posterior aspect of the neck. In contrast to the free cisterns seen in normal newborns, the newborn with MMC will typically demonstrate echogenic soft tissue dorsal to the upper cervical cord, and the cord oscillation is dampened when the herniation is severe.[66]

CT imaging has no place at this stage as the information needed can be easily obtained from U/S or from MR when it is performed.

MR imaging may be requested when the clinical features or the dysraphism are atypical, or

when it is difficult to make a surgical decision. MR imaging is the procedure of choice that provides the most detailed picture of the spinal malformation and of the associated intracranial abnormalities. When the MMC is bulging, the patient should be lying on the side to avoid the discomfort of compressing the sac and increasing the CSF pressure. Multiplanar T1 and T2 weighted sequences should be used for the spine and the brain; given the diagnostic importance of fat tissue, sequences without fat saturation should always be obtained. No contrast agent is needed at this stage.[67]

Early Post-Surgical Imaging

Schematically stated, surgery of the MMC consists of the dissection of the neural placode from the surrounding ectoderm, reconstitution of a neural tube, and closure of the dural sac and of the more superficial layers, including the skin. If there is no surgical complication, there is no need for post-surgical imaging. Should it be performed, it is to check that a satisfactory anatomical result has been obtained.

The viscera should be imaged (typically by U/S) in the early post-surgical period because surgery has to be performed quickly after birth to avoid infectious complications. It is also the time when hydrocephalus develops because the closure of the MMC reduces the compliance of the meninges and stops the leakage of the CSF. A close surveillance therefore should be kept during the subsequent weeks. In infants, the ventricles may dilate before any significant increase in head circumference appears. Transcranial US performed every few days is the easiest, most efficient and least invasive way to detect this dilation. If the hydrocephalic process is confirmed (increasing size of the ventricles between two examinations), the choice for surgical treatment is between shunt placement and endoscopic third ventriculostomy (ETV).[67] MR best appreciates the status of the third ventricular floor and interpeduncular cistern. In a case where cerebellar descent into the cervical canal compromises the function of the medulla, upper cord and low cranial nerves, MR with MR venography again is most appropriate to evaluate the anatomy, especially venous, of the surroundings structures of the cranio-vertebral junction.[68]

Post-Surgical Complications

Following MMC repair, infants typically have neurological deficits that are stable: sensory-motor deficits of the lower limbs, bowel and bladder incontinence, brainstem, upper cord and low cranial nerve dysfunction, psycho-intellectual delay. If further neurological deterioration develops, scoliosis worsens quickly, a discrepancy appears between the neurological level

and the level of the MMC or a gross asymmetry of the neurologic function of the lower limbs develops, MR of the spine is indicated. There are diverse mechanisms proposed to explain a clinical worsening, including re-tethering of the cord, constriction of the dural sac, focal compression from an (epi)dermoid cyst or an arachnoid loculation, and evolving hydrosyringomyelia and/or hydrocephalus.[69.70]

Years ago, great efforts were made to prevent the so-called cord re-tethering, and correlatively to show whether the cord was free or not, by conventional imaging, by performing MR in the supine position, or by studying the cord motion by phase contrast imaging.[68-69] This did not prove to be very productive, and today it is widely accepted that the cord remains tethered at the surgical site in every child with repaired MMC[70], whereas only 10-30% of patients will deteriorate neurologically. Causes other than re-tethering therefore should be considered to explain this deterioration.

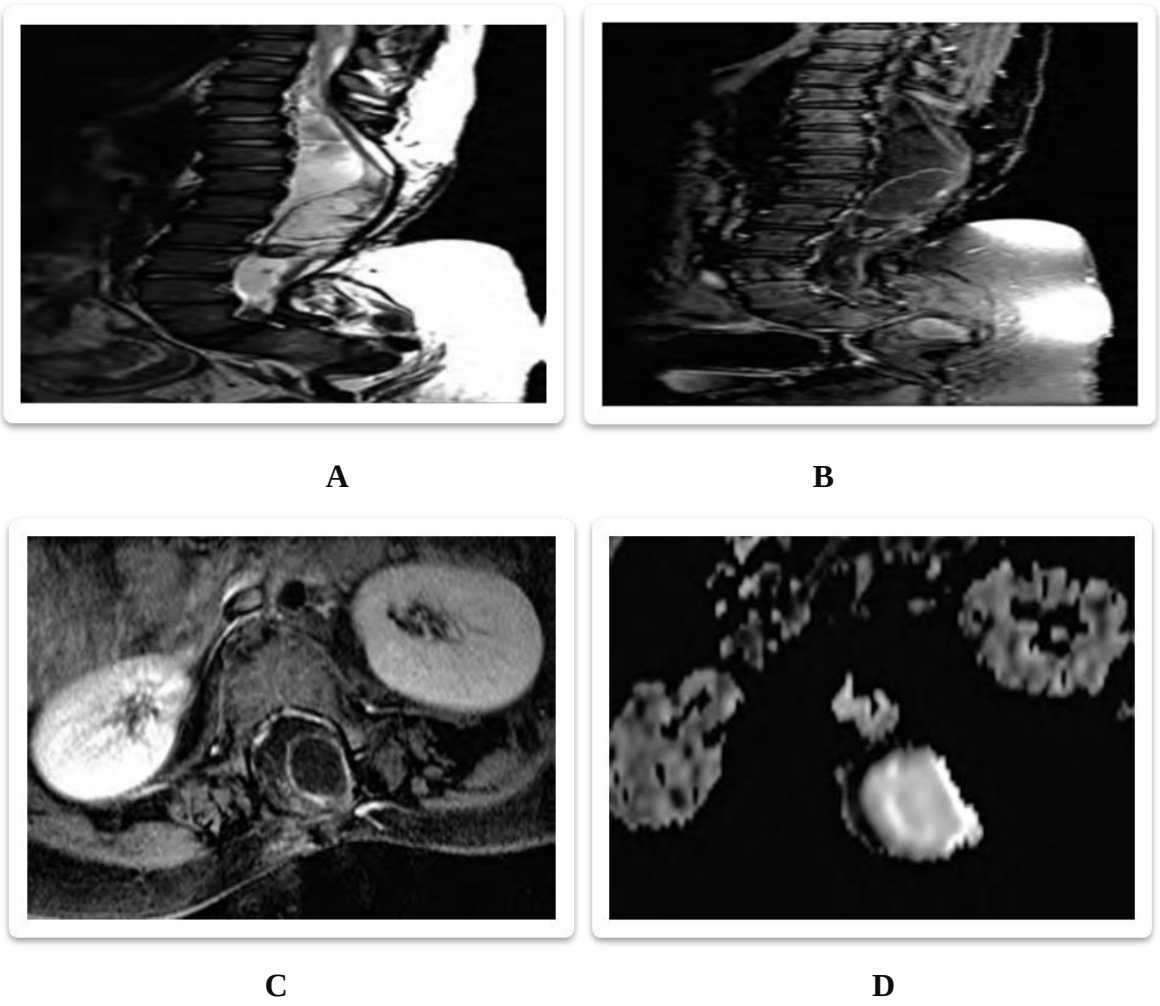
Compression of the reconstructed distal cord may be due to a post-surgical dural constriction: progressive sclerosis at and around the reconstituted dural sacmay result in progressive narrowing of the spaces around the cord and, either directly because of the acquired stenosis or indirectly because of a vascular involvement, generate a progressive myelopathy. This dural stenosis can easily be recognized with MR, without or with intravenous contrast.[72]

Another possible meningeal cause for compression is an arachnoid cyst or loculation. Spinal arachnoid cysts have been reported to be relatively common in MMC patients[71], particularly when positive contrast myelogram or myelo-CT were performed. They can become compressive with time, at any level within the spinal canal. In addition, surgery at and around the MMC, with the attempted reconstruction of a pia-covered neural tube and of a closed dural canal, may result in the development of arachnoid loculations that can also expand and become compressive with time. This has also been observed after decompression of the cranio-cervical junction.[72] Either developmental or acquired, these arachnoid cysts contain pure CSF and are difficult to diagnose on MR. The best clue is the local mass effect they exert on the cord and/or the roots: displacement and compression. They do not enhance with contrast.

A third cause for compression of the cord and roots is a developing (epi)dermoid cyst (Fig. 1.4).It may develop as an intrinsic association with the MMC, or it may result from inclusion of a skin fragment in the wound at the time of surgery. This especially seems to occur in the

context of fetal MMC surgery.[73] Developmental or acquired, (epi)dermoid cysts accumulate desquamation and secretion products, expand slowly and may compress the cord. The diagnosis may be missed on T1 and T2 weighted imaging, even with contrast, because the signal of the cysts may be close to that of the CSF; the use of FLAIR or diffusion sequences (Fig. 1.4d) is necessary to locate and recognize them.[73,74]

Finally, major causes of neurological deterioration of MMC patients are expanding hydrosyringomyelia and hydrocephalus, singly or in association. Both are easily diagnosed on MR, and even on CT. As they are not related in any way to the surgery, but both typical complications of the Chiari II malformation.[75]



A **B**

C **D**

Fig. 1.4 A-D Repaired thoraco-lumbar MMC. The cord remains tethered to the dorsal dural sac. A **two masses are demonstrated, one with high, the other below with low T2 signals.** B, C **both masses enhance (T1FS C+ sagittal and axial), the largest one at the periphery only.** D **axial diffusion imaging shows restriction in the larger mass, consistent with an epidermoid cyst.[73,74]**

The Long-Term Complications of MMC/Chiari II

Hydrocephalus

Hydrocephalus is common in MMC/Chiari II, presumably related toposterior fossa crowding and aqueductal compression. As it typically develops shortly after the surgical MMC closure in the neonatal period (that reduces the compliance of the meninges and stops the CSF leakage), it is usually dealt with in the first weeks or months after MMC repair. The early surveillance is done with U/S; it has to bedone with CT or MR after closure of the fontanels. Like any patient with chronic hydrocephalus, the child is exposed to late complications, and to repeated imaging. Therefore, one should be aware of the normal appearance of the brain in this context. CT is commonly used, and is efficient; due to the potential hazard of ionizing radiation, MR would be the modality of choice, but in young children, it requires sedation or general anaesthetic, more than CT. The use of the ultrafast MR T2 weighted sequences used in fetal imaging has been advocated to avoid sedation, but although they show the size and morphology of the brain and ventricles, the resulting images are less than optimal, with a poor signal specificity. Therefore CT still is considered necessary in many centers, especially since good axial and coronal reformats may be obtained. Whatever the modality used, current studies should always be compared with previous ones.[75,76]

The large majority of children and adolescents with chronic Chiari II have been classically treated with a ventriculo-peritoneal (VP) shunt. The morphological appearance of the brain is characteristic on axial image in those children. The shunted ventricles are commonly larger posteriorly than anteriorly. When the cerebral mantle is deficient, the collapse of the shunted ventricles results in a significant widening of the subarachnoid spaces. This is usually not apparent over the convexity because the often major thickening of the calvarium effaces the subarachnoid spaces (Figs. 1.5). However, it is conspicuous in the region of the posterior midline where a short dysplastic corpus callosum, a deficient cerebral mantle postero-medially, and a large pericerebellar cistern between the laterally displaced temporal lobes and the hypoplastic tentorium act to exaggerate it (Figs. 1.6). On the floor of this dilated cistern, the towering cerebellum is seen. The elongated midbrain with tectal beaking is seen in front of it. The posterior fossa is usually crowded, with a deformed folial pattern of the cerebellar hemispheres, a buried vermis, wrapping of the brainstem by the cerebellum, and the herniated hindbrain filling the large foramen magnum.[77,78]

When the shunt is not paten and when the child presents with hydrocephalus, the lateral

ventricles become prominent, effacing the subarachnoid spaces. Periventricular interstitial edema is uncommon. Rarely, the fourth ventricle may be trapped and therefore become prominent. Then the risks of compression of the brainstem in an already packed posterior fossa are high. Disconnection of the shunt may sometimes be demonstrated on appropriately windowed images of the softtissue of the upper neck. The lower segments of the device are routinely examined with plain films. In case of peritoneal encystment, abdominal U/S is indicated.[78]

Findings are the same on axial MR images if MR is used. A better description of the various brain dysplasias is obtained from the sagittal and coronal planes. Increasingly in recent years, endoscopic third ventriculostomy (ETV) has been performed in infants[67] This requires a precise presurgical MR assessment of the anterior third ventricle and of the interpeduncular cistern to plan the procedure as, depending on the severity of the Chiari II malformation, the cistern may be effaced or packed with cerebellar tissue. Typically after the procedure the ventricles remain much larger than after placement of a VP shunt[74], and the diagnosis of developing chronic hydrocephalus may be difficult to make on imaging alone. Careful comparison with previous studies may help, together with the assessment of the clinical features.[67,69]

Finally, a VP shunt may be removed and replaced by an ETV. Again, a presurgical assessment is needed, and the lateral ventricles are expected to remain large after the procedure, more than after the VP shunt placement.

Rarely, other complications of shunted hydrocephalus may occur. The morphological abnormalities behind the “slit ventricle syndrome” are difficult to assess, as the CSF pressure increase develops in an essentially non-expandable ventricle. Rare conditions such as subdural collections and infections need the appropriate imaging[70,72]

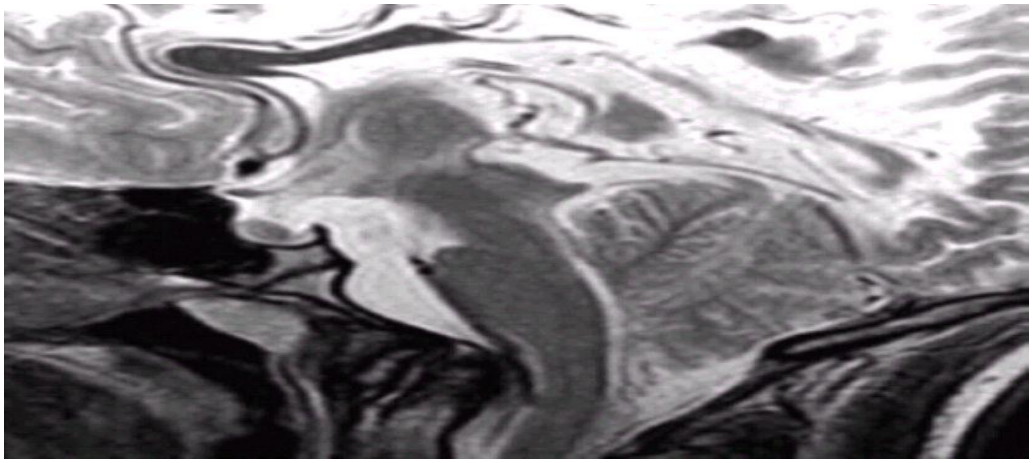


Fig. 1.5 Chiari II, posterior fossa. Sagittal T2w. Scalloping of the clivus, small posterior fossa and tentorium, descent of the brainstem and cerebellum, effaced fourth ventricle, verticalized primary fissure, and atrophy of lower cerebellum. Note also tectal beaking, large massa intermedia, low and small anterior commissure, dysplastic posterior corpus callosum[77]

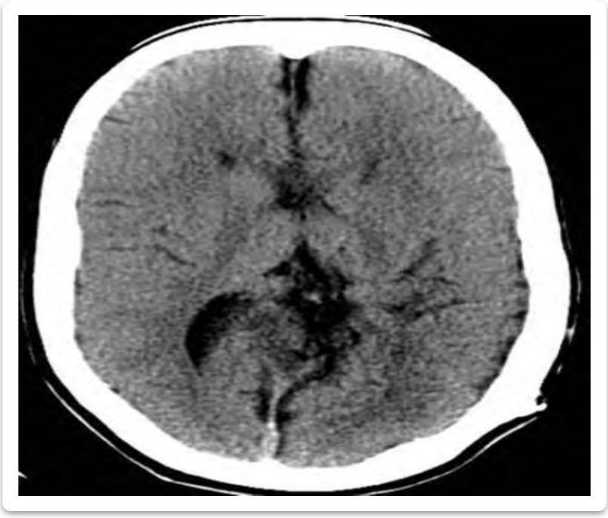


Fig. 1.6 Chiari II, follow-up of hydrocephalus. Characteristic CT appearance. Small ventricles, mild enlargement of the ambient cistern, related to the dysplasia of posterior medial hemisphere[78]

Hydrosyringomyelia

Pathology studies of the cord have shown that the central canal of the cord remains dilated in patients with MMC.[75] A prominent central canal is therefore commonly seen on MR images of patients with MMC, the incidence being evaluated in 40-95% of cases. The dilation sometimes becomes significant and appears as a real hydrosyringomyelia, either focal, segmental or diffuse. Short segments of hydromyelia may be seen just below the Chiari II

malformation in the cervical cord, or just above the MMC in the terminal cord; they are typically asymptomatic. It is uncertain how they form. In general, hydrosyringomyelia, usually associated with Chiari I deformities, can be explained by a hydrodynamic imbalance of the CSF above and below the obstructed foramen magnum. A similar mechanism might be involved in Chiari II malformation.[77,79]

However, the persistent patency of the central ependymal canal and its communication with the cerebral ventricles through the obex might explain the classical association of hydrosyringomyelia with hydrocephalus in the MMC patients.[76,77,78,79] This is the explanation of the clinical rule that hydroce- phalus should be ruled out and the VP shunt patency should be checked when hydrosyringomyelia develops in a MMC/Chiari II patient.

Hydrosyringomyelia should be considered when a patient presents with a secondary neurological deterioration, such as a new spasticity. Classically, scoliosis also is considered a manifestation of hydrosyringomyelia, but this assumption has recently been challenged.[80] Although axial CT of the spine can show the cystic appearance of the cord, MR is the modality of choice, mostly T2 weighted sagittal and axial planes.[81] It demonstrates the enlarged cord effacing the subarachnoid spaces around it, the elongated CSF-filled expanding cyst within the cord and its level and extent cranially and caudally. The usual horizontal septations are thought to represent more resistant planes of decussation. MR should be extended to the brain to look for hydrocephalus, or for a trapped fourth ventricle with signs of compression of the brainstem. The classical syringobulbia (rupture of the dilated central canal and CSF leakage forming a syrinx in the medulla) is, at most, exceptional, and it is the Chiari II malformation, rather than this hypothetical syringobulbia, that usually explains the occasional development of low brainstem symptoms.[76,78,79]

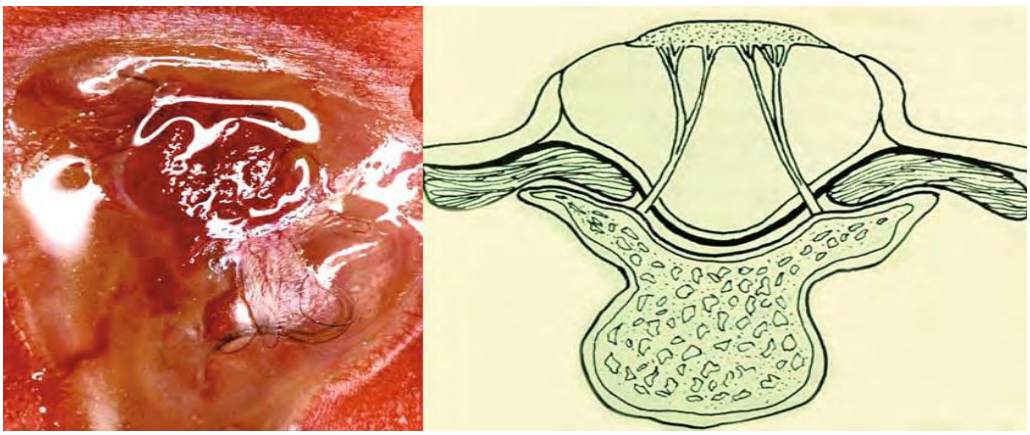
Myelomeningocele Primary Repair Surgical Technique

Introduction

A clear understanding of the pathologic anatomy of the spinal malformation is a fundamental prerequisite of the pre-operative work-up in spina bifida patients.[82] The malformed spinal cord or primitive neural plaque (placode) presents as a flat tongue of neural tissue with its borders merging into the contiguous malformed meningeal coverings. As an effect of the failed neurulation process, both ventral and dorsal spinal roots exit from the ventral aspect of the placode, the dorsal roots exiting laterally to the ventral ones, and corresponding to the boundary between the placode and the arachnoid membrane (junctional zone). The presence

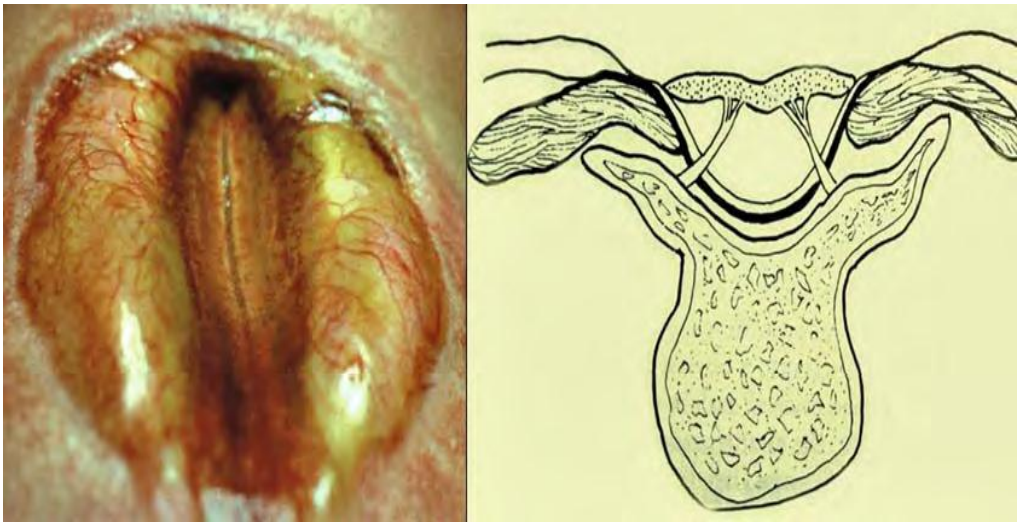
of an intact subarachnoid space ventral to the placode confirms the lesion as a myelomeningocele (MMC) (Fig. 1.7), whereas its absence confirms it to be a myelocele, which more closely resembles the deranged anatomy of failed neurulation (Fig. 1.8).[82,83]

The residual function of the placode has been much debated.[83] Spontane-ous movements are present in many myelodysplastic newborns, as well as in response to intraoperative electrical stimulation of the placode.[84] Likewise, somatosensory evoked potentials can be elicited within the placode by means of peripheral nerve stimulation. Cortical evoked responses can be recorded after placode electrical stimulation.[83] Furthermore, even in the absence of cortical control, the placode may still maintain intact local spinal reflexes that may contribute to bowel and bladder function.[85] All of the above considerations make it plausible that some residual functional neural elements are still present in the placode; these consequently deserve special attention and care. From a practical point of view the placode must be handled with care to minimize the risk of harming that residual functional nervous tissue, and be protected from dehydration by covering it with a gauze dressing soaked in a sterile saline solution. The application of a plastic wrap over the gauze will help to keep the placode adequately moistened.[86,87] The usefulness of systemic antibiotic therapy to prevent cerebrospinal fluid (CSF) infection is debated; conversely, local antibiotics or iodine-containing medications are to be avoided for their potentially adverse effect on the placode.[86, 87]



A **B**

Fig. 1.7 A,B Clinical appearance of a lumbar myelomeningocele A **and schematic drawing** B **of the malformation, demonstrating the relationship of the placode with the subarachnoid space and cutaneous layers, and the exit and course of the spinal roots within the malformed sac[82]**



A **B**

Fig. 1.8 A, B Clinical appearance of a lumbar myelmeningocele A **and schematic drawing**B **of the malformation, demonstrating its relationship with the surrounding meningeal and cutaneous layers[83]**

Timing of Surgery

MMC repair should be performed soon after birth provided that the newborn's general condition is good and signs of meningeal infection are absent. According to the literature the operation is usually performed within the first 48 hours of life.[83,86,88] Such delay, whilst not deleterious for neurological function nor for increasing the risk of CSF infection, allows the neurosurgeon to obtain more comprehensive information on the child's clinical condition (including thorough neuro-radiological investigation), and for the parents to become better acquainted with the problems related to the malformation in order to give adequately informed surgical consent.[89,90] Surgery should not be delayed beyond 72 hours of life, as it has been demonstrated that after this time there is a 37% risk of ventriculitis, compared to only 7% when operated upon in a more timely fashion.[86,88] A delay in surgical repair also exposes the myelodysplastic newborn to the risk of deterioration in neurological and bladder function.[91]

At present, surgical repair is generally performed at an early stage. Since MMC is detected prenatally in up to 90% of cases, the spina bifida team has usually already been alerted prior to birth, and the parents usually sufficiently informed of the various clinical and surgical aspects of the spinal malformation, as to make their consent to surgery readily available soon after birth.[83,86,90,92] Due to prenatal diagnosis and counseling, the birth of a child affected by MMC is a planned event in the vast majority of cases (Fig. 1.9). There is still enduring debate

as to the best means to deliver a child with myelomeningocele, namely, whether a cesarean section reduces the risk of neurological dysfunction.[93,94] Without addressing specific obstetric issues, these children are usually delivered at term, or slightly before term, after reaching pulmonary maturity, by means of a planned pre-labor cesarean section.[90, 91, 94] As the team responsible for the initial care of the myelodysplastic newborn (neonatal intensivist, anesthesiologist, and neurosurgeon) has already been mobilized prior to delivery, the time interval to surgical repair is presently much shorter than previously necessary. At our institution, cesarean section is the modality of choice to deliver a fetus with a prenatal diagnosis of open spinal dysraphism, even in cases theoretically amenable to vaginal delivery.[95] Consequently, when a fetus with MMC reaches term, acesarean section is planned to be performed early in the morning in order to have the newborn ready for neurosurgical closure early in the afternoon, as long as the newborn's general condition does not require further investigation. Under such circumstances the spinal defect is repaired within the first 6-12 hours of life, i.e., much earlier than as described in the literature.[90,92,94]

On the other hand there are still cases, fortunately increasingly rare, of children affected by MMC who are delivered without a prenatal diagnosis and who are consequently sent to a tertiary hospital only hours or days after birth. In thesecircumstances, mobilizing the team, acquiring all clinical data as well as giving the parents adequate information and obtaining their consent to the operation, may require more time.

Whenever the operation is delayed beyond 72 hours of life, either due to delayed parental consent or to delayed referral from a peripheral hospital, it seems appropriate to obtain CSF cultures prior to undergoing surgical repair. When these are positive the newborn should be treated with antibiotic therapy and definitive closure delayed until the infection is cleared.[95,96]

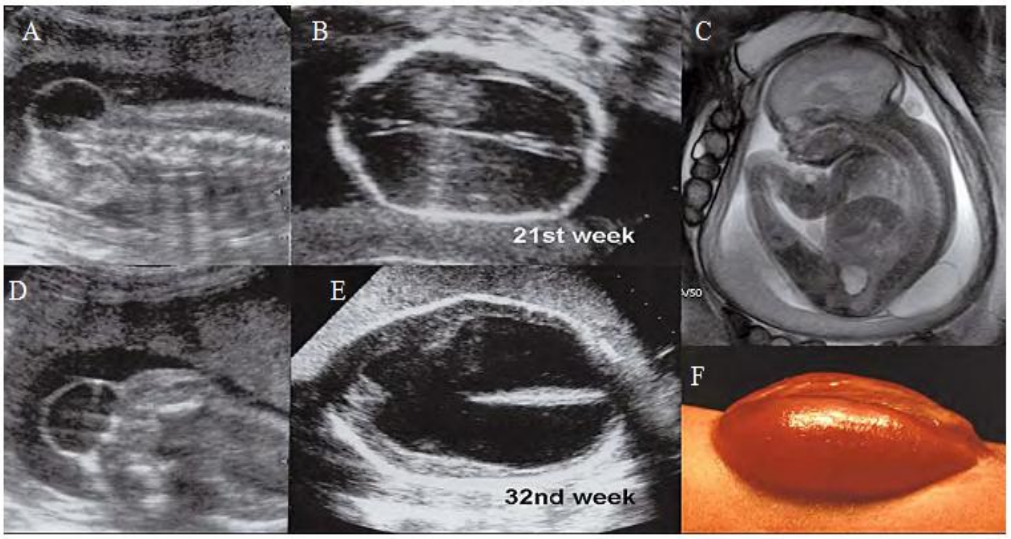


Fig. 1.9 A-F Prenatal diagnosis of myelomeningocele.A, B Ultrasound demonstration of the spinal defect (AP and lateral views) C, D and evolution of the ventriculomegaly from the 21st to the 32nd gestational week. E T2-weighted fetal MRI demonstrating the spinal malformation; note the absence of ventricular dilatation at this stage. F Clinical appearance of the malformation at birth[93,94]

Early Management of Hydrocephalus

Hydrocephalus is so frequently associated with MMC (85-90%) as to be considered part of the malformation. As largely debated in the literature, many factors may contribute to its occurrence, namely aqueduct stenosis, fourth ventricle outlet obstruction, and obliteration of the posterior fossa subarachnoid spaces or their obstruction at the tentorial notch (Fig. 1.10).[96, 97] It is this great variety of pathogenesis that accounts for the different modalities of clinical presentation andtheir different ages of onset. In fact, in less than 15% of the cases hydrocephalus is already overt at birth, manifesting with the classical signs of raised intracranial pressure (ICP) (split sutures, tense anterior fontanel, sunsetting eyes, vomiting,) or even with the life-threatening signs of brainstem dysfunction (poor feedingpoor sucking and swallowing; nasal regurgitation; repeated coughing; weak or high-pitched cry; stridor; apneic spells; pneumonia, etc.), secondary to the impaction of neural structures within the small posterior fossa (dueto the ChiariII malformation)This particular subset of myelodysplastic newborns with significant hydrocephalus warrants early surgical treatment.[83, 98]

Among the presently available surgical modalities for treating hydro-cephalus, ventriculo-peritoneal (VP) shunting remains the treatment of choice. Standard VP shunting not only

ensures immediate relief of intracranial hyper-tension but is also beneficial to spinal wound healing by avoiding CSF pooling and leakage at the site of surgical repair.[83,86,92,98] There has been some debate in the literature as to the best site for positioning the ventricular catheter, i.e., frontal or occipital. Authors almost equally suggest either frontal[99] or occipital[100,101] positioning as associated with a lower percentage of mechanical shunt malfunctions. We utilize the occipital route almost exclusively. The main reason for our choice is the asymmetrical ventricular dilatation, with disproportionally large occipital horns and relatively small frontal horns, which is typical of the hydrocephalus associated with MMC. This asymmetrical enlargement also minimizes the risk of the ventricular catheter coming in contact with and becoming occluded by the choroid plexus. Furthermore, tunneling of the shunt system to the parietal region is easier and the maneuver requires fewer skin incisions than placing the ventricular catheter frontally.[98,100]

There is no general agreement as to the most appropriate timing of the two surgical procedures (MMC repair and VP shunt), should they need to be performed at the same stage. The question is obviously limited to the small percentage of myelodysplastic newborns that require immediate treatment of the associated hydrocephalus; in fact, in the vast majority (more than 85% of cases) treatment of hydrocephalus is usually postponed for weeks to months following MMC repair. When the hydrocephalus requires urgent treatment, many reports in the literature underline the advantages of unifying MMC repair and VP shunting at the same procedure.[102-103] Usually the newborn undergoes insertion of the VP shunt first, and then MMC repair. The advantages derived from combining the two operations are the rapid relief of intracranial hypertension and its beneficial effect on spinal wound healing. One study indicates that there is no significant difference in the infection rate between patients undergoing the two operations at the same stage or separately, provided that they are performed within the first 48 hours of life.[104] We too have adopted that policy on occasions; however, in our experience the association of MMC repair and CSF shunting in the same surgical procedure has been marked by a higher incidence of infectious shunt complications, compared to the cases where the two operations were performed separately.[26] This result has caused us to be more cautious and frankly reluctant to combine the two procedures. In addition, the problem seems overestimated as, in our experience, cases of hydrocephalus requiring such immediate treatment are quite rare. Given that most of the observed infectious complications in our patients were demonstrated to be due to a preexisting CSF sub-clinical infection, in the limited number of patients with significant hydrocephalus requiring prompt

neurosurgical treatment, we have adopted the policy of performing temporary external ventricular drainage contemporaneously to MMC repair. In patients where CSF infection is confirmed, the same route can also be utilized to administer intraventricular antibiotics until resolution of the infection. In conclusion, our present position is to no longer treat hydrocephalus and spinal dysraphism at the same stage, but rather to perform MMC repair first as an independent procedure. As soon as clinical signs of intracranial hypertension occur, or if there is local pooling of CSF at the site of the spinal wound, we proceed to VP shunting. In our experience, postponing VP shunting in this manner neither increases the risk of infection nor alters the final neurological outcome.Recent reports in the literature have proposed endoscopic third ventriculostomy (ETV) as an alternative to VP shunting in children affected by MMC.[105,106] However, these same reports, whilst indicating a relatively high success rate in cases of "secondary" ETV (i.e., in those myelodysplastic children presenting with VP shunt malfunction), underline a poor success rate in cases of "primary" ETV. Furthermore, the young age of the patient, which is typically a contraindication to ETV, acts as a further adverse factor in myelodysplastic newborns.[105,106]

The only report dealing with a significantly high population of myelodys- plastic patients reflects the same considerations, i.e., only 29% success in cases of "primary" ETV and 12.5% success rate in children less than 6 months old.[105] We perform ETV in myelodysplastic children as either a primary or secondary procedure. Our preliminary results[107] have been more positive than those previously reported in the literature, with a significantly higher success rate of "primary" ETV in myelodysplastic newborns.

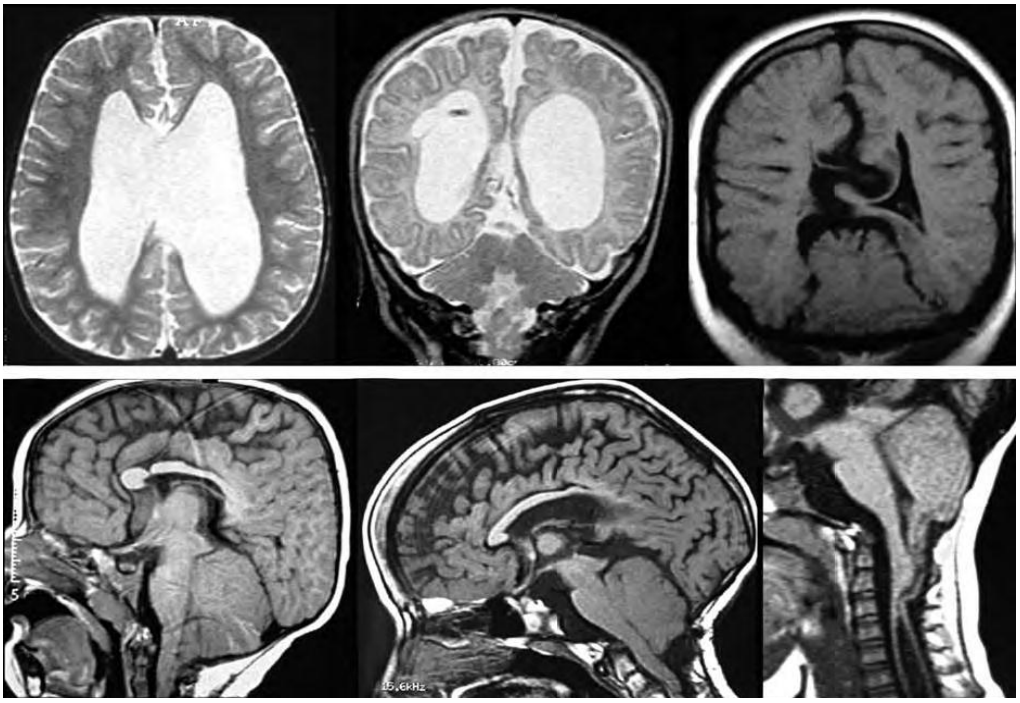


Fig. 1.10 A-F **Radiological features of hydrocephalus associated with myelo-meningocele.** A **T2-weighted axial and** B **T2-weighted coronal views demon-strate a huge ventricular dilatation with disproportionately enlarged occipital horns.** C **Post-operative T1-weighted coronal view shows the reduction in ventricular volume and the abnormal shape of the midline cerebral cortex.** D-F **T1-weighted sagittal images demonstrate the small posterior fossa and the descent of the cerebellar tonsils and inferior vermis into the spinal canal, as well as the upward herniation of the superior vermis associated with other typical aspects of the Chiari II malformation (beaking of the tectum; thinned and malformed corpus callosum; large massa intermedia; stenogyric appearance of the occipital cortex;) Note also the associated hydromyelia.**[96]

Myelomeningocele Repair

Aims of the surgical treatment of MMC are to:

1. Remove the malformed sac.
2. Prevent central nervous system infection by creating a barrier between the spinal canal and the exterior.
3. Restore the normal CSF environment around the malformed spinal cord, thus preserving its residual motor and sensory functions.

These results may be obtained by means of reconstruction of the placode, and multilayer closure of the meningeal, fascial, subcutaneous and skin layers; in other words, surgical

repair should complete the interrupted neurulation process;.[8, 87, 98, 108, 109]

Contemporary surgery of MMC requires magnification (both operative micro-scope and loupes); with optional laser and intraoperative electrical stimulation.[108, 109] Utilization of the operative microscope enables the neurosurgeon to perform the surgery in a safer way than previously possible, especially during neural structure manipulation. Such technical tools have allowed neurosurgeons to obtain better functional results as demonstrated by the frequent observation ofpostoperative neurological improvement.[87]

As myelodysplastic children are prone to develop latex allergy it is appropriate when planning the surgical repair to utilize a latex-free setting, if such a dedicated facility is already available in the hospital, or to prepare a similar surgical environment by sterilizing the operating room with regard to latex proteins and by utilizing only latex-free products[110]

Postoperative Course

After completing skin closure, the wound is cleansed again and covered with sterile gauze. The anus and perineal area are kept separated from the wound dressing by the interposition of an adhesive plastic drape that limits the contact of the wound with urine or fecal material. The newborn is usually observed in the neonatal ICU for the first 1-2 postoperative days, for apnea and/or any other sign of brainstem dysfunction. The child is maintained prone with the lower back slightly elevated above the level of the head to reduce the risk of CSF leak fromthe wound. Should CSF pool beneath the wound or leak through the suture, immediate management of hydrocephalus should be undertaken. Prophylactic intravenous antibiotics are given either for the first 24 hours postoperatively or for a longer time (in our experience 5 days or more if there is significant risk of infection). The wound dressing is changed every 48 hours, or anytime it is soiled. If non-absorbable sutures have been used we remove these on the tenth postopera- tive day, a little later than is usual for other neurosurgical procedures.[111]

Operative mortality is practically absent while morbidity may be significant.[111,112] The most frequent complication is wound breakdown usually second- ary to CSF leak, which is known to be an adverse factor for wound healing.[113] Conversely, wound infection is a much rarer complication of MMC repair, occur-ing in less than 2% of procedures.[112] It is managed by changing wound dressing and intravenous antibiotics. The most severe, though rare, complication of MMC surgery is meningitis with sepsis, which remains the main cause of death in these newborn children. Intravenous antibiotics are the treatment of choice, and

ultimately CSF shunt removal if already implanted.[109.110]

REHABILITATION PROGRAM

Physical therapy

General functional expectations have been developed for patients in each level group to help direct physical therapy goals within an appropriate developmental context from infancy to adulthood. it's establishs baseline of muscles function. As the child develope, the physical therapist monitors joints aligments, muscles imbalances, contractures,postures and signs of neurological dysfunction. Therapist also provides caregivers with instruction in handling and positioning techniques and recommended orthotic postioning devices to prevent soft tissues contractures. The therapy programes designed to parallelthe achivement of gross motor milestones. provides the infants with sitting opportunities to facilitate development ofhead and trunk control[6,7,38]

Near the end of first year of life provides the child with an effective mean of independent mobility in conjunction with theraputic exercisesthat provides trunk control. For patient who are unlikely to ambulate place emphesis on developing proficiency in wheelchair skills. For patients who are likely to ambulate should start with use of swivel walker. Teach the school-aged child community-level wheelchair mobility skills. The physical therapist assist with assessement of community, home and school enviroment to determine any barriers may interfere with the child daily activites.[69]

Occupational therapy

Fine motors skills and independence with activites of daily living often are impaired.initate training early to compensate these deficits and progress along the developmental sequence as closely as possible. upper extremity stabilization and hands use require adequate postural control of the head and trunk.in the first year of life, encourage development of these postural mechanisms or substitute passive support and to promote eye-hand coordination.

Speech therapy

Speech therapy may indicated for patient with speech and/or swalloning dificultes.

Complications

1-myelomeningocele is the most common cause of neurologic bladder dysfunction in children.the nature of urinary tract dysfunction depende on the nature and extent of spinal

cord lesion.Disruption of of the neural axis between pons and the sacral spinal cord by MMC may cause unihibited detrusor contraction or dyssynergia,lack of coordinationof the external bladder sphinector that cause involuntary sphinector activity during sphinector contraction.MMC in the sacral area produce a lower motor lesion resulting in detrusor areflexia. These abnormality may occure singly or in combination and typically result in incontinence and impaired bladder emptying that can lead to vesicouretral reflexand high voiding pressure.if untreated,this can lead to potentially serious complication,including infection upper tract deterioration and may cause renal failure.[60,61]

Treatment strategies are designed both to prevent deterioration of renal function and to establish infection free social continence.these goals can be acomplished by different several methoid including vesicostomy,intermetent catheterization and placement of indwelling catheter.long-term manitenance of low bladder pressure may required use of medications to reduce bladder pressure and/or reduce spastic bladder function.the success rate of intermittent catheterization and/or anticholin-ergic medications in achieving continence is estimated to reach70-80%.

When infection occure antibioticsare used in combination with usual technique.[60,61]

2-Anal sphincter dysfunction and abonrmal anorectal sensation are associated with MMC involving S2-S4 sigments.many individuals with myelomeningocel do not have the sensation and controles needed to defecates.the results is bowel incontinence with related problems of constipation and impaction.fecal incontinence may become serious barrier in atteding school or sustaining intimate relationship.[60]

Assisted bowel programs designed to empty the bowle regularly can establish social continence and prevent constipation. Develop regimen of bowel movement, Usually on dialy or every other day basis. These programes typically attempt to take advantage of gastrocolic reflex by timing the bowel motion after meals, typically breakfast or dinner. Some patients are able ti use valsalva maneuver to defecate, but some may need the assistance of digital stimulation. A high fibers diet some time with use of stool softeners may help to optimize stool size and consistency.

3-Hydrocephalus:in MMC is related to Arnold chairi type II malformationthis condition may cause acute or subacute signs and symptomes of brain stem compression,including laryngeal

and pharyngeal paralysis swollwing difficulty, strider, nystagmus and extremity weakness. surgical decompression of posterior fossa may indicated.[46,48,49]

4-Repeated shunt malfunctions may lead to additional functional and cognitive decline.shunt obstruction may associated by acute or chronic use in ICP. diagnosis may be difficult and signs and symptomes are nonspecific. shunt failure commonly in first 2years of life.[48,67]

5-Tethered cord syndromes: is related to tendency of spinal cord to adher MMC repair and prevent cephalic migration of cord during growth. symptomes include, pain sensory changes, spasticity and progressive scoliosis.surgical releases performed in attempt to return previous level of function and prevent further loss.simillarfinding can occure with intraspinal pathology(lipomas, diastematomyelia and dural bands)syringomyelia caused by hydrocephalus due to entry of CSF to the central canal of spinal cord causing dilatation and pressure.

6-Skin breakdown occure in 85-95% of children with MMC.recurrent decubiti can lead to prolonged morbidity and functional disability. Healing can occure if the precipitating mechanical factors are eliminated. Plastic surgery correction may indicated, in sever cases and may involve orthopedic correction of underlying postural abnormalities. Skin breakdown on lower limbs occure in about 30-50% of cases.the most common area of involvment are perineum and area over kyphotic curve.

7-Bone mineral density is is decrease in patients with MMC, bone reabsorbtion found more commonly in in both limited ambulators and nonambulators than in childern who ambulated regularly. These children at high risk of lower limbs fractures, reduced muscles activity and decrease weight bearing forces result in decreased bone mass.[112]

8-Obesity is prevalent in patient with MMC specially in high lumbar and thoracic lesion due to reduce in capacity for caloric expenditure.the decrease in lower body masculatures will reduce the BMR.in addition,the activity is lower than in unaffected children,both as direct result of lesion-related mobility deficit and as an indirect result of decreased opportunities for disable children to partcipate in physical play[46,112]

9-CSF leak:incidence about 17%it's. arise from:

a.insufficient closure of dura.

b.inappropriate closure of anatomical layers.

c.increase CSF pressure may be due to associated hydrocephalus.
A small amount of transdural leak is likely to occure in most cases of MMC repair,keeping in mind the thinness of dura in newborn even the sutures may serve as suorce of leak.

10-Delerioration in neurological function:deterioration in defficit occure in about 10% after closure, may be due to preparation of patient's skin in iodine,or even during patient transfer to operating room.

11-Ilius occure in about 5% mainly due to prolong bed ridden, poor oral intakes and electrolytes disturbance.

12-Pneumothorax:2% of patient may complicate with emergent pulmonary conditioin like pneumothora, hemothorax and this mainly occure due to massive intraoperative dissection of latissmus dorsi in patients with high lumbar or large. thoracic lesion.[112]

Prognosis

Recent study of patients with prenatly diagnosed MMC suggest that less severe venticulomegaly and lower anatomic level of lesion in prenatal ultrasound predict better developmental outcome. The level of lesion and associated power of lower extremity muscles are the most important factors affecting the achievement in patient with MMC. Approximately 50% of patient ambulate the household distance and about 20% of these use orthotic device. the other50% are use the wheelchair as their primary form of mobility.[9,17]

Several studies show that the ambulation in MMC is related to strength of certain key muscles, including iliopsoas, gluteus medium, hamstring and quadriceps. A motor neurologic level of L5 or quadriceps strength graded as good in the first 3years of life is predictive as good prognosis for ambulation.[9,17]

Maximal ability to ambulate usually is achieved by the time of 9 years of old,the ability to ambulate will decrease in the 2nd decades of life because of increasing body dimensions and high energy requirement.lower extremity muscles deterioration play a role.[38,60]

With proper urologic management more than95% continue with normal renal function, psychological consequenc of bowel and bladder incontinence can have a dramatic impact on patient specially in adolescence. The extent of achievement of acceptable social continence is varies 40-80% for bladder and 30-40% for bowels continence.25% of patients have continent

of both bowle and bladder[9,60]

Females withMMC go thruogh the puberty 1-2 years earlier than unaffected peers. sexual precocity associated with obesity and hydrocephalus, fertility in females not affected, and many females with MMCare able to achieve orgasim. Pregnancy will increase the risk of urinary tract infection, back pain and perineal prolapse postpartum. Male with MMC will show decrease fertility and ability to sustain erection.[7,9,38,60]

Chapter 2

AIMS OF THE STUDY

1- study the epidemiology of myeiomeningocele in our country.

2-study the postoperative complications of myelomeningocele.

3-compare the postoperative complications between infants with paraplegia &those with normal or variable degree of lowerextremity weakness.

PATIENTS AND METHODS

This a prospective study is based on "100"casesof myelomeningocele seen between september 2012 and september 2013 in Alkadymia teaching hospital and neurosurgical hospital in Baghdad,Iraq.this study did not including other types of spinal dysraphism.

For each patient the following data were recorded:-

Age, sex, date, of, birth and family history(age, socioeconomic status, work, prenatal history and antenatal care)

All infants were clinically assessed for neurological and systemic abnormalities.

Patients full in to 2 groups "40" with some deficit in lower extremity &"60" infants with complete paralysis of lower extremity.

The 2 groups had the same surgical principles and postoperative care.The fallow up period ranged between 3 weeks &4 months.

Questionnaire for Infants:
Age,sex,socioeconomic status, B.group, No. in family .Date of birth.
Delivery: NVD. C/S
Associated anomalies: HCP . GIT. UT. CVS. ORTHO. PULMONARY.
Crying: Normal. Abnormal
Leg movement: Rt. Lf. Both
Sphinctors: continent. incontinent
Lesion: T. TL. L. LS.
Status of lesion: Rupture. Unrupture. Infected or not
Skin covering: Complete. Incomplete. Just membrane
Size in cm.

Questionnaire for Parents:-
1.Mother:Age,Disease,B.group.
Associated anomalies:CNS,other sys.
Menstrual cycle: Normal. Abnormal
Age of marriage:
History of abortion: Yes. No.
Vaccination: Complete. Incomplete
Supplement: Fe. Folic acid. Vitamin
2.Father:Age,Disease,B.group.
Associated anomalies: CNS, other sys.Smoking,Alcohol.

Clinical assessment:

Myelomeningocele is seen immediately after birth as a sac in the back, so it is clinical diagnosis. The lesion appears as red, raw neural plate structure devoid ofdura and skin covering. The sac comprising arachnoid laced with thin, fragile vessels can be filled with CSF escaping from the Central canal.

The initial neurological examination of a neonate born with a myelomeningocele should focus on the neurologic sequelae of the NTD.

Specifically, evaluate:

1-Site and level of the lesion:

Occasionally, more than one lesion will be encountered the spinal axis. The shape, placode size, sac integrity, and extent of marginal epithelialzed dura are all noted for surgical reconstruction.

2-Motor and sensory level:

Open neural tube defects should be immediately covered with a saline-moistened sponge to avoid rupture of the sac and dring of the exposed neutral placode.

The neonate is maintained and examined in the prone or lateral recumbent position.

In motor level assessment of infant with myelomeningocele, a particular attention is paid to the observation of movements which can be elicited when stimulation is applied to the infant's face, arms or upper trunk, this is voluntary movement which must be differentiated fromreflex movement. Infant who is warm, hungry and crying will show spontaneous and active movement of intact muscle group in the legs corresponding to the preserved neural segments. Care must be taken to avoid pressure on the neural plate which may evoke brisk leg movement which can be mistaken for normal.

Lesion at T12 or above will have flail legs, L1 to L3 function is required for hip flexion, L2 to L4 function required for knee extension, and L5 to S2 for hip extension and knee flexion. Planter flexion and intrinsic muscles of the feet require preservation of the sacral roots.

Sensory testing is best carried out when infant is quiet, but if he is very lethargic examination is useless and must be repeated later.

First we must determine the lowest level of normal sensation: starting in the sacral dermatomes i.e perianal region, the skin is stimulated over the posterioraspect of the buttocks, thighs and legs, then upwards over successive dermatomes of the anterior surface of the abdomen.

Operative technique

All selected cases for surgery submitted to preoperative available investigations including chest x-ray, blood group, haemoglobin value, total serum bilirubin,ultrasonography&/ or CT scan for the brain.

Intravenous fluid should be commenced preoperatively, cross match blood should be available even for small lesion, any blood loss more than 20 ml is replaced.

Under general anaesthesia with endotracheal intubation in a warm operating room. The patient can be placed prone on transverse soft rolls at the chest and pelvis to allow easy breathing. The skin around the lesion is cleand first by chlorhexidine gluconate 4% then povidone iodine is applied to the normal skin surrounding the lesion, The skin around the lesion is covered with sterile towels.

The lesion is measured, and the outer border demarcating dysplastic tissue and normal epidermis is marked .Determination of the extent of the normal tissue planes at this point and throughout the procedure is critical so that there is enough available tissue for the reconstruction and closure of each successive layer.

The placode preferably is separated from the dysplastic meningeal tissue by the(use of sharp dissection, Minor bleeding ofen is easily controlled by use of gentle pressure with saline cottonoids or, if persistent by low current bipolar cautery. The neural placode dissection is isolated in this circumferential manner.

As the dissection is initiated, the CSF is drained and then as it proceeds, the placode tend to descend ventrally, more clearly demarcating the correct plane. Proper mobilization facilitates subsequent reconstruction.

With the successful circumferential mobilization of the neual placode and its ventral descent, the next step is the removal of the dysplastic meningeal and inadequately vascularized cutaneous layers.

The outer border demarcating the extent of the lesion that was marked at the beginning of the procedure can be excited. Before excision, the neural placode isprotected and kept moist by application of saline soaked cottonoids. Excision begins at the inferior aspect of the defect using a low current, needle-point mopolar cautery or a sharp excision. The dysplastic meningeal and cutaneous tissues are removed to avoid longterm problems with epidermal inclusion cysts.

After that the daysplastic dural plane is identified by its pearly white sheen, as opposed to the yellow-pink hue of the fascial and adipose tissues. The dural layer is incised along the fascial

plane. sufficient tissue must be released so as to form a spacious thecal sac for the spinal cord and nerve roots, avoiding a closure that is too constructive and that may increase the incidence of tethering. The two dissected folds of dura come together and lie apposed in a tension-free manner before suture placement. The dura is then closed in watertight fashion with nonabsorbable suture. In the event that patient's dura is insufficient to form a capacious dural sac around the cord, agraft is inserted.

Direct closure of the dermal and epidermal layers after dural repair, or add another layer to the closure between the neural elements abd the skin. The paraspinal lunber muscle-fascial layer is elevated. The bilateral edges of the mobilized fascia are then closed in a tention-free manner, with care taken not to restrict or compress the underlying dural layer. Prominant bony protuberances may need to be rongeured down.

Adequate undermining , the skin layer closure is completed with a nonabsorbable suture.

Chapter 3

RESULTS

Demographic data

A total of 100 patients, 70 (70%) were females and 30 (30%) males with female:male ratio equal to 2.3:1. Consanguineous marriages were presented in 59% of cases in comparison with 41% of non-consanguineous marriage. All cases were from poor families & no specific social classification in our country. Smoking was found in about 73% of fathers & 5% in mothers. Eighty two cases had abnormal menstrual cycle and 23 cases had abortion before birth of affected infant. (**Table -1**)

Anternal care folic acid supplement & drugs

- ✓ 9 mothers were on folic acid in 1st month of pregnancy.
- ✓ 9 cases had complete vaccination program during pregnancy.
- ✓ 25 mothers were on folic acid from 2nd month of pregnancy.
- ✓ 66 mothers didn’t receive folic acid supplement.
- ✓ 25 mothers receive folic acid irregularly.
- ✓ 61 mothers had +ve drug history during pregnancy like analgesic (paracetol, mefanamic acid , ibubrufen) .
- ✓ 41 mothers take antibiotic like ampicillin .
- ✓ 35 mothers take sedative like diazepam.

- ✓ 20 mothers take antiemetic like metaclopromide

About 67.5% of normal or variable weakness reached the hospital within the first 96 hr. About 76.6% of complete paraplegia reached the hospital within the first 96 hr. no significant difference between both groups regarding the presenting age to hospital (**p value= 0.251**). (**Table -2**).

About three quarters (73%) of cases were from Baghdad, 10% from Diala, 8% from Wasit, 6% from Basra and 3% from Anbar. There is no significant statistical difference between residence and degree of affected lower limb movements (p value= **0.917**). (**Table -3**)

Seventeen 17/40 (42.5 %) infants with normal or variable weakness were mother's age between 30-39 years in comparison with 34/60 (56.6 %) infants with complete paraplegia for same age group of their mothers. The age group 30-39 years for mothers was associated with high incidence of myelomeningocele but not statistically different between both groups (p value= **0.334)**. (**Table -4**)

Lesion characteristics

Regarding site of the lesion, half cases (50; 50%) were lumbar, 32% thoracolumbar, 15% lumbosacral, 2% thoracic and 1% sacral. About 59% of cases had lesion size between 5-10 cm^2, 28% < 5 cm^2, 10% 10-15 cm^2, and 3% > 15 cm^2. Sixty four infants had lesions partially covered by skin, 22% covered by thin membrane, 12% ruptured lesion and 2% covered completely by normal skin. (**Table -5**).

Complications

Primary hydrocephalus was presented in 69% of cases with statistical significant difference between both groups (p value 0.057). While secondary hydrocephalus were significantly presented in 83.3% of paraplegic patients in comparison with 70% of those with normal or variable degree of movements (p value= 0.132).

Preoperative and postoperative infections were presented in both groups with significant differences. As 15% of those with variable degree of movements had preoperative and postoperative infections in comparison with 23.3% and 30% of paraplegic infants (p value 0.307 and 0.085 respectively).

Also CSF leak was occurred in both groups with no statistical difference (p value 0.328) in

which 5 (12.5%) infants with variable degree of movements had CSF leak and 12 (20%) paraplegic infants.

Post-operative neurological deterioration, post-operative ilius and vertebral column deformity were significantly associated with paraplegic infants (p value= 0.008, 0.002 and 0.0001 respectively) while pneumothorax and necrotizing enterocolitis had no significant differences between both groups (p value= 0.151 and 0.284). (**Table -6**)

Table 4-1: Drugs during pregnancy.

N.	Drugs	Starting time
61	Analgesia(paracetamol)	1_{th} mon.
41	Antibiotics(ampicillin)	1_{th} mon._6_{th} mon.
35	Sedative(diazepam)	5_{th} mon._8_{th} mon.
20	Antiemetic	1_{th} mon.-3_{th} mon.

Table 4-2: Folic acid during pregnancy.

Folic acid	Starting time	N.	%
Yes	**1_{th} mon.**	**9**	**9%**
Yes	**2_{th} mon.**	**25**	**25%**
No	**_____**	**66**	**66%**

Table4 -3: Demographic characteristics of studied patients.

Demographic data		**N**	**%**
Gender	Male	**30**	**30%**
	Female	**70**	**70%**
	Total	**100**	**100%**
Consanguinity	Consanguineous marriage	**59**	**59%**
	Non consanguineous marriage	**41**	**41%**
	Total	**100**	**100%**
Socioeconomic status	Poor	**100**	**100%**
Father's Smoking	Yes	**73**	**73%**
	No	**27**	**27%**
	Total	**100**	**100%**
Mother's Smoking	Yes	**95**	**95%**
	No	**5**	**5%**
	Total	**100**	**100%**
Menstrual cycle of mother	Normal	**82**	**82%**
	Irregular	**18**	**18%**
	Total	**100**	**100%**
History of abortion before this birth	Yes	**23**	**23%**
	No	**77**	**77%**
	Total	**100**	**100%**

Table4 -4: Presenting age in both groups.

Age (Days)	variable weakness		Complete paraplegia		P value*
	N	%	%	N	
1st	5	12.5%	20.0%	12	0.251
2nd	3	7.5%	18.3%	11	
3rd	9	22.5%	21.7%	13	
4th	10	25.0%	16.7%	10	
5th	2	5.0%	11.7%	7	
6th	7	17.5%	8.3%	5	
7th	4	10.0%	3.3%	2	
Total	40	100.0%	100.0%	60	

*By using Pearson Chi square.

Table4 5: Residence of patients in both groups.

Province	Normal or variable weakness		Complete paraplegia		P Value*
	No	%	No	%	
Baghdad	**30**	**75.0%**	**43**	**71.7%**	**0.917**
Diala	**3**	**7.5%**	**7**	**11.7%**	
Wasit	**4**	**10.0%**	**4**	**6.7%**	
Babil	**2**	**5.0%**	**4**	**6.7%**	
Anbar	**1**	**2.5%**	**2**	**3.3%**	
Total	**40**	**100%**	**60**	**100%**	

*By using Pearson Chi square.

Table4 -6: Showing mother's age in both groups.

Mother's Age	Normal or variable weakness		Complete paraplegia		P value*
	No	%	No	%	
<20 Yrs	13	32.5%	17	28.3%	0.334
20-29 Yrs	7	17.5%	8	13.3%	
30-39 Yrs	17	42.5%	34	56.7%	
40-49 Yrs	3	7.5%	1	1.7%	
Total	40	100.0%	60	100.0%	

*By using Pearson Chi square.

Table4 -7: Showing characteristic parameters of lesion in both groups.

Characteristic parameters of lesion		No	%
Site of MM	Thoracic	**2**	**2 %**
	Thoracolumbar	**32**	**32 %**
	Lumbar	**50**	**50 %**
	Lumbosacral	**15**	**15 %**
	Sacral	**1**	**1 %**
	Total	**100**	**100%**
Size of Lesion	<5cm	**28**	**28%**
	5-10 cm	**59**	**59%**
	10-15 cm	**10**	**10%**

	>15 cm	**3**	**3%**
	Total	**100**	**100%**
Skin cover	Completely by normal skin	**2**	**2%**
	Partially by skin	**64**	**64%**
	Thin membrane	**22**	**22%**
	Ruptured lesion	**12**	**12%**
	Total	**100**	**100%**

Table4-8: Showing complications of myelomeningocele pre- and post-operatively in both groups.

Complications		**Normal or variable weakness**		**Complete paraplegia**		**Total**		**P value***
		N	%	N	%	N	%	
Secondary Hydrocephalus	Yes	28	70.0%	50	83.3%	78	78.0%	**0.132**
	No	12	30.0%	10	16.6%	22	22.0%	
	Total	40	100.0%	60	100.0%	100	100.0%	
Pre-operative infection	Yes	6	15.0%	14	23.3%	20	20.0%	0.307
	No	34	85.0%	46	76.7%	80	80.0%	
	Total	40	100.0%	60	100.0%	100	100.0%	
Post-operative wound infection	Yes	6	15.0%	18	30.0%	24	24.0%	0.085
	No	34	85.0%	42	70.0%	76	76.0%	
	Total	40	100.0%	60	100.0%	100	100.0%	
CSF Leak	Yes	5	12.5%	12	20.0%	17	17.0%	0.328
	No	35	87.5%	48	80.0%	83	83.0%	
	Total	40	100.0%	60	100.0%	100	100.0%	
Post-operative neurological deterioration	Yes	6	15.0%	24	40.0%	30	30.0%	**0.008**
	No	34	85.0%	36	60.0%	70	70.0%	
	Total	40	100.0%	60	100.0%	100	100.0%	
Post-operative ilius	Yes	2	5.0%	18	30.0%	20	20.0%	**0.002**
	No	38	95.0%	42	70.0%	80	80.0%	
	Total	40	100.0%	60	100.0%	100	100.0%	
Pneumothorax	Yes	0	0.0%	3	5.0%	3	3.0%	0.151
	No	40	100.0%	57	95.0%	97	97.0%	
	Total	40	100.0%	60	100.0%	100	100.0%	
Vertebral Column Deformity	Kyphosis	2	5.0%	20	33.3%	22	22.0%	**0.0001**
	Scoliosis	0	0.0%	19	31.7%	19	19.0%	
	Normal	38	95.0%	21	35.0%	59	59.0%	
	Total	40	100.0%	60	100.0%	100	100.0%	
Necrotizing enterocolitis	Yes	0	0	6	10%	6	6%	0.284
	No	40	40.0%	54	90%	95	95%	
	Total	0	100.0%	60	100.0%	100	100.0%	
Postop.Meningitis	***Yes***	3	7.5%	22	36.66%	25	25%	0.005
	No	37	92.5%	38	63.33%	75	75%	

Chapter 4

DISCUSSION

This a prospective study of 100casesof myelomeningocele seen in Alkadymia teaching hospital and neurosurgical hospital in Baghdad, from September 2012 and September 2013. It does not represent the condition in our country as a whole since the severest cases which considered beyond help are not referred, or die before reaching the hospital, the second reason is the availability of neurosurgeons in many governorates in our country who can deal with such cases. Thus true incidence of the condition in Iraq is difficult to be obtained from this study alone, but it may give some information about the natural history of the condition in our country.

Sex distribution

A female predominance is seen with female: male ratio about 2.33:1, which is slightly similar to previous Iraqi study as well as other literature. [114-116]

Age of presentation

All patients (100%) were seen in the first week after birth with a peak in the third and fourth day (42; 42%). Only 17 cases (17%) presented within 24 hours and 6 cases (6%) were presented at 7th day after birth. This result was comparable to Al-Hori's result. The reason for that delay in the presentation mainly due to the difficulties and insecure transportation from far areas to Baghdad as well as the deterioration of the medical education and general culture in our people makes parents neglect the instructions of referring doctors.

Geographical distribution

About three quarters (73%) of cases from Baghdad. This is due to large population density and high birth rate and availability of neurosurgical centers in different areas in Iraq (like Mosul, Erbil and Basrah) which can manage these cases. This result was comparable to previous literature.[115]

Parents history

It has been found that mother age group 30-39 years born affected babies more than other age group (51%) which is higher than previous Iraqi study for same age group (43.47%).[115]This increment in incidence of myelomeningocele with an increasing maternal age was clearly studied in previous studies. Thirty percent of mothers 19 years old or younger had an affected child and this result agreed with Vieira et al. [117]Theseresults supports the hypothesis that

there is an increased risk of having an offspring with NTDs for older and younger mothers.[117,118]

Marriage among relatives carries more risk to develop this condition in the community (59%) which is comparable to previous literature. (115)All cases were belong to families regarded as socioeconomically poor. Poor families tend to have more children than other. Mothers of this group also tend to have more miscarriage and probably receive less medical care. [119]

High percentage of mothers had history of gynecological disorder and cycle abnormalities (82%) and 23% of cases had abortion before birth of affected infant. This may be related to the bad psychological state because of daily terrorism and disaster situation in our country as well as psychological trauma was found in all Iraqi females in previous the Iraqi literatures.[120, 121]

The majority of fathers (73%) were smokers (5% of mothers were smokers). The active and passive smoking may have an effect on the development of this defect as reported in previous studies.[115, 122]

Only small number of mothers (9; 9%) that had folic acid supplement during the first month of pregnancy, 25% were on supplement from 2nd month of pregnancy and 66% didn't receive folic acid supplement at all. Only 9% had completed vaccination schedule. This reflect the lack of active antenatal care units that observe the pregnant women from the first few days of pregnancy till child birth.

High percentage of mothers (61%) had history of drug ingestion during the first trimester of pregnancy. These drugs were analgesic (paracetol, mefanamic acid, ibubrufen), antibiotic like ampicillin, sedative like diazepam, and antiemetic like metaclopromide. Many mothers mentioned that they used these drugs without consultation of physician. This hap hazard use of these drugs may have adverse effects on the development of normal baby.

Pathology

In 50% of studied cases the lesions were located in the lumbar region. This is similar to results reported by other investigators.[115, 11] The vast majority of cases (88%) were covered partially by skin or thin membrane. This makes lesions liable to ruptured with minimal trauma, subsequent local infections and meningitis which may end with death. The size of the lesions varies, the majority (72%) of cases the size is more than 5 cm^2 as the complications

rate is related to lesion size.[115, 122, 123]

Associated anomalies

Primary hydrocephalus was seen in 69% of cases which is similar to previous reported results.[115, 118, 122]

The majority of cases (60%) were with complete paraplegia before surgical repair. The others had various degrees of weakness of lower limbs. In this study and previous Iraqi study (65.21%), [115]the number of infants with complete paraplegia of lower limbs seems to be higher than reported by other literatures [118,122]and this may be related to multiple etiological factors or other unknown causes related to disaster and war in the last decades in our country.

Management

During the last fifty years, the policy of the management of myelomeningocele undergo several changes especially those infants with complete paraplegia.

The medical, social, and ethical issues provoked heated debate. Some centers put several criteria to deal with this group of patients, others decide to operate all patients, but before operation, physician must reviewed current knowledge regarding the outcome and late complications of myelomeningocele and must make this information available to the family to assist the parent in deciding these issues for their child.[124, 125]

The inclusion criteria for surgery in this study were to operate every infant who can withstand general anesthesia, and have no major defects that incompatible with their life.

Wound infections were one of the most common complications. When we compare the pre and post operative wound infection in both moving and non-moving group, the former were had the same incidence of wound infection pre and postoperatively while the second one had an increment in wound infection. This may be explained by fact that infant with paraplegia may had also more associated anomalies in cardiovascular, respiratory, urinary and anal sphincters and in general mainly due to poor oral intake in nonmoving MM and pre op. contamination due to poor wound care(pre, intra and postoperative care are the same in tow groups of study). Other thingthat might increase risk of infection in our patients ,the majority of them are nursed in supine position leading to decrease blood flow to repair site and necrosis giving the opportunity to bacterial growth .Further workup may be needed to explore the exact mechanism behind that including the immune system.

Post operative meningitis one of the majors life threatening complication for infants with MMC we compare the post op. meningitis in both groups of study and the nonmoving group had an increment in risk, and is mainly associated with preop. Contamination (urine, fecal materials and septic dressing)

The other important complication is post-operative CSF leaks which were more commonly presented in infants with complete paraplegia (12%). From total of 17 cases with post-operative CSF leaks, 12 of them were from lumbar and lumbosacral areas. Impaired wound healing in paraplegic infants could be a factor in the development of CSF leak in addition to large skin defect mainly present in nonmoving MM and associated difficulty of operative closure.

One of the commonest finding is hydrocephalus,42 infants out of 69 (60.88%). Majority of them had complete paraplegia. The majority of secondary hydrocephalus appeared within ten days after myelomeningocele repair. This result agreed with other studies. [15, 118].Many factors may contribute to its occurrence, namely aqueduct stenosis, fourth ventricle outlet obstruction, and obliteration of the posterior fossa subarachnoid spaces(pre or postoperative meningitis) or their obstruction at the tentorial notch.[126, 127]Hydrocephalus affects neurocognitive outcome and result in morbidity and mortality caused by shunt malfunction and infection.[127, 128]Significant Hydrocephalus may complicate the management of airway, reduced response to hypoxia and hence susceptible to post-operative apnoeic episodes.[128]

Post-operative pneumothorax was occurred in 3 cases all of them were complete paraplegic infants mainly due to aggressive subcutaneous dissection in attempt for skin closure. Necrotizing enterocolitis developed in 6 paraplegic infants where major G.I abnormality occure in nonmoving MMC(dignosed post operatively ;abdominal distention, discoloration and bloody diarrhea).Vertebral column deformities occur in two forms: kyphosis: Occurs in 22 cases at time of surgery, 20 cases were from complete paraplegia,and scoliosis 19 cases at time of surgery all of them were from complete paraplegic group.Vertebral column deformities were more commonly presented with paraplegic infants which is agreed with other studies**. [126, 127]**

Forty percent of cases with complete paraplegia developed further neurological deterioration inform impaired anal & urethral sphincter control in comparison with 15% of those with variable degree of lower limb weaknessdeveloped further neurological deterioration inform

of decrease motor activity, this deteriorations maily due to (cord tethering, dural constriction, arachnoid inculation and epi [dermoid] formation). Many authers suggests that patients with upper thoracic myelomeningocele have a low risk of voiding disorders and deterioration unless other conditions, such as a congenital tethered cord than these present or have lower thoracic or lumbar myelomeningocele, the severity of lower limbs involvement is correlated with development of secondary HCP[127,128] postoperative Ilius commonly occure in non moving MMC where they mainly complain from electrolytes disturbance.[127, 128]

Chapter 5

CONCLUSIONS

1. Myelomeningocele is a common pediatric neurosurgical problem in our country.
2. Clear female predominance (female:male about 2.3:1).
3. Majority of cases did not referred to our hospital in the right time and this adversely affect the outcome of management.
4. High incidence of this malformation was seen in infants of mother's age group between 30-39 years.
5. Marriage among relatives carries more risk to develop this condition.
6. All affected infants belonged to poor families.
7. Majority of mothers did not take folic acid in the right way as well as taking non prescribed medicines.
8. Secondary hydrocephalus,post-operative wound infection,post-operative meningitis, post-operative neurological deterioration, post-operative ilius, and vertebral column deformities were more associated with paraplegic infants than those with normal or variable degrees of movements.
9. There is strong relation between the degree of neurological deficit of lower limbsand the presence of primary hydrocephalus.70% of complete paraplegia had primary hydrocephalus with 67.5% of other group.
10. Smoking one of the major causes leading to conginetal anomalies.
11. Risk of NTD increase in disasters and war.

RECOMMENDATIONS

- When newborn presented with major neurological deficit and associated anomalies, multidisciplinary intervention is required to prevent the progressive deterioration of other body systems. So we must decide to operate or not operate.

- More clinical attempts to decrease and eliminate the incidence of NTD like stem cells or nano technology.
- Using of new minimal invasive surgical technique like endoscope.
- For those patients with CSF leaks, placement of a shunt during the same operation for closure of myelomeningocele. This is not only decreases future anesthetic risk, but also it decreases the chance of CSF leaking through the myelomeningocele closure.
- There is need for a mass education on the value of planned pregnancy, early attendance of ANC and the relevance of peri-conceptual folic acid.
- Further studies in this condition are required in Iraq to show the true incidence of such condition and its relation with current circumstances.
- Using of microscope routinely in MMC for better repair.

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