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ORIGINAL ARTICLE

Low level myelomeningoceles: do they need prenatal surgery?

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Abstract

Background Postnatal closure of a myelomeningocele remains the standard of care in many countries. The prenatal closure has given hope for decreasing the damage to the neural placode and has challenged classic management. However, this technique presents potential sources of complications. Patients with MMC with an anatomical level of L4 and below have a better functional prognosis than higher level malformations. Are they still candidates for prenatal surgery?

Objective To evaluate outcome of MMC with an anatomical level of L4 and below and discuss, with support of the literature, the indications to perform prenatal closure in this particular group of patients.

Materials and methods Twenty-nine children were included in this observational study. The level of the vertebral malformation was sacral in 12 cases (41.4%) or lumbar (level ≤ L4) in 17 cases (58.6%). All the patients was operated postnatally for closure of the MMC with microsurgical technique as soon as possible after clinical evaluation (range 0–97 days).

Results Only 11 out of 29 patients (37.9%) needed of a CSF diversion. A Chiari II malformation was present before MMC closure in 17 patients (58.6%) and only in 5 (17%) after. Twenty-six patients (89.7%) were able to walk. Seven (23%) and 16 (55%) of our patients have a normal bladder and bowel control, respectively. All school-aged children attend school.

Conclusions The functional outcome for low-level MMC is good when managed with modern microneurosurgical techniques with a low risk for the patient and the mother. Therefore, we do not suggest prenatal surgery for subgroup of infant with MM.

Keywords Spinal dysraphism · Multidisciplinary management · Pediatric · Postnatal surgery · Myelomeningocele · Prenatal surgery

Abbreviations

CM	centimeter
CM-II	Chiari type II malformation
CPC	Choroid plexus coagulation
CS	Cesarean-section
CSF	Cerebro spinal fluid
ETV	Endoscopic third ventriculostomy
GMF-CS	Gross motor function classification system
Gr	grams
MMC	Myelomeningocele
MOMS	Management of myelomeningocele study
MRI	Magnetic resonance imaging
US	scan ultra-sound scan
VP	Shunt ventriculo-peritoneal Shunt
WG	Week of gestation

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Introduction

Prevalence of spina bifida (SB) birth has remained stable since of 2000 [1]. Myelomeningocele (MMC) is the most severe malformation among spinal dysraphisms compatible with life. Multi-disciplinary management has resulted in better outcomes though the level of the malformation remains an important prognostic factor [2]. Patients with a malformation located at the level of L4 and below have a better prognosis [2].

Prenatal closure of the neural tube defect aimed to decrease the damage to the neural placode and prevent the Chiari type II malformation (CM-II) [3]. Several techniques for prenatal surgical managements have been developed each with its own drawbacks which should be evaluated and pondered. Prenatal surgery is actual a dual surgery for both the mother and the child, with possible complications for both of them.

The aims of the study are to evaluate the outcomes of a personal series of MMC patients with the spinal malformation located at the L4 level or below operated postnatally and to compare the results obtained to those reported in literature in myelodysplasic subjects treated prenatally.

Material and methods

Out of 97 patients operated on for a MMC, we have considered all the patients with a lesion at the level of L4 and below. Twenty-nine children so selected included 13 girls and 16 boys. They had been diagnosed at birth (13 cases) or prenatally (16 cases), and all of them had undergone a pre-surgical MRI. The time of the surgical closure ranged from 0 to 97 days of life. All the patients considered here had been followed and examined at regular time intervals by our multidisciplinary team. Details of the collected data and scores used for the clinical assessment have already been published [2]. Consensus for the inclusion in the study were obtained by all the patients or their families. The study was accepted by the local ethical committee. The mean time of follow-up was 9.1 years (minimum 1 year; maximum 18 years; SD, 4.9 years).

Concerning the delivery methods, all but 1 patient with a prenatal diagnosis was delivered by cesarean section (CS). Nineteen patients (65.5%) were delivered vaginally with only one of them having undergone a prenatal diagnosis. Mean gestational age at birth for the CS group was 38 weeks of gestation (WG) and 2 days (minimum 37WG + 6, maximum 39WG) and for the vaginal delivery group was 39WG and 2 days (minimum 37WG + 7, maximum 41WG). Mean cranial perimeter at birth was 35 cm (minimum 30 cm, maximum 42 cm). Mean birth weight was 3050 g (gr) (minimum 2080 g, maximum 4050 g). No maternal complications were noted. The decision to performed a CS was taken by the obstetrician regarding the history of former vaginal delivery or not and the difficulties expected if a vaginal delivery would have been done.

The level of the vertebral malformation was sacral in 12 cases (41.4%) or lumbar (level ≤ L4) in 17 cases (58.6%). Among sacral lesions, the distribution was S1 in 6 cases, S2 in 4, and S3 in 2. Among lumbar lesion, the repartition was L4 in 4 cases and L5 in 13.

Concerning hydrocephalus management, the decision to treat was described previously [4].

Results

Neurological examination at birth showed foot mobility in 24 cases (83%), knee mobility in 27 cases (93%), and hip mobility in 28 cases (97%). Postnatal preoperative cerebral MRI studies showed the absence of CM-II in 12 patients (41.4%) (Fig. 1a, b, c, d) and a ventricular dilatation in 13 patients (44.8%).

Orthopedic examination at birth showed the presence of club foot in 7 cases (24.1%) and hip luxation in 2 cases (6.9%).

The microsurgical closure of the malformation was realized within 48 h after birth in 83% of the case. No intraoperative complications were reported. There were 5 cases of scar infections (17%) which needed another surgery.

Eleven patients (37.9%) needed CSF diversion. Two procedures were used: a ventriculo-peritoneal shunt (VP shunt) alone ($n = 2$) or a concomitant VP shunt and an endoscopic third ventriculostomy (ETV) ($n = 9$). Mean time between the closure of the malformation and the need of a CSF diversion treatment was 14 days (minimum 7 days, maximum 27 days). Only 1 patient needed multiple (3) shunt revisions.

On the last MRI exam available, 24 (83%) patient did not have a CM-II. Among the 5 patients with a remaining CM-II, only 1 had to undergo a cranio-vertebral junction decompression, 5 years after the closure.

Four patients had retethering which needed a second surgery. Mean time between the initial closure and the tethered cord surgical release was 6.5 years (minimum 3.9 years, maximum 13.6 years). After surgery, all patients were improved.

Clinical data at follow-up

Using the ASIA score, 14 patients (48.3%) had a level of neurological function that was at least one level better than expected according to the anatomical level of the malformation. Only 2 patients (6.9%) had a level of neurological function that was worse than expected. ASIA level of motor deficit for each leg are described in Table 1. Twenty-five patients (86.2%) had a GMF-CS of 1 or 2.

Concerning the walking capacities, if we exclude the patient younger than 2 years old and considered too young to walk ($n = 2$), 26 patients (89.7%) were able to walk and 1 (3.4%) was not able to walk at all. Mean age at the walking acquisition was 21 months (range, 12–51 months; SD, 9 months). Six patients (20.7%) used a wheelchair. Among wheelchair users, 1 subject used it totally and independently; 5 used it partially, only for long distances (walking patients). All wheelchair users were able to use it independently.

Nineteen (65.5%) patients used a functional orthosis and 4 used a postural one (13.8%).

Eighteen patients (62.1%) had at least one orthopedic deformity. Nine subjects had undergone an orthopedic treatment:

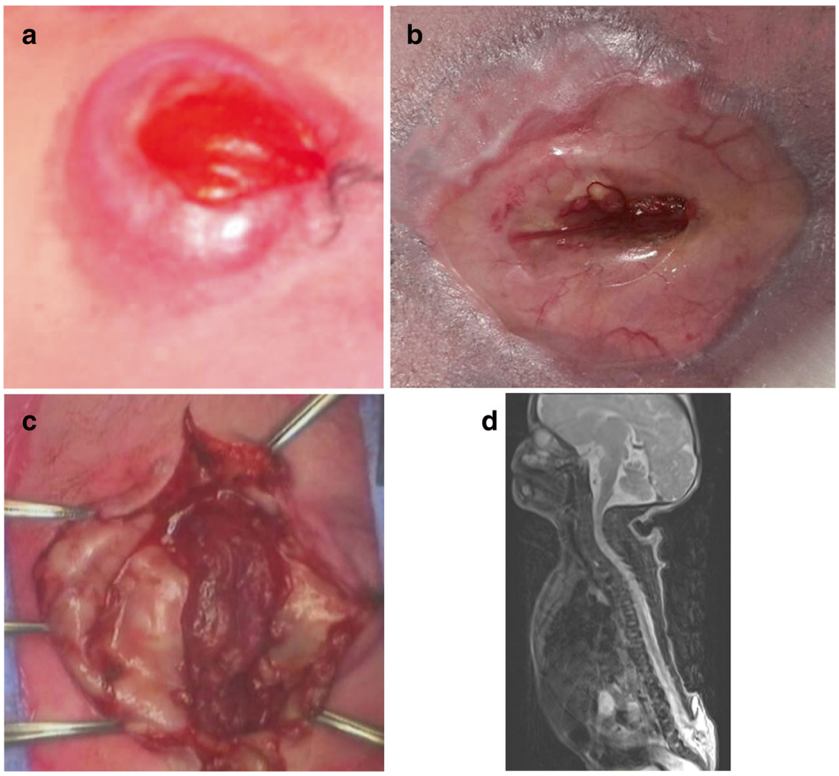

Fig. 1 Low-level myelomeningocele at birth (**a**) and at surgery (**b** and **c**). Sagittal T2-weighted MRI scan image showing the absence of a Chiari type II malformation (**d**)

an early talipes equinovarus foot correction with cast (3 cases), foot surgery (6 cases). No patient required a surgical correction for kyphoscoliosis.

If we exclude 4 patients who were too young to go to school (less than 3 years old), all children attended normal school, except 2 children that needed of a special school program.

Seventeen (58.6%) patients followed at least one rehabilitation program.

The regimens for bowel and bladder management are presented in Figs. 2 and 3. We considered patients who took oral treatment for constipation as having normal bowel transit. All urinary tract and renal examination by US scan as well as blood creatinine levels resulted normal in all cases. Only two radioisotope renal studies were abnormal with sequalae of pyelonephritis.

Table 1 Repartition of the population depending on the Asia level of motor deficit for each leg

Level of deficit	Leg side	
	Right	Left
Sacral	37.9%	31%
L5	20.7%	20.7%
L4	6.9%	10.3%
L3	6.9%	3.4%
No deficit	37.9%	34.5%

Discussion

The management of MMC constitute a challenge for pediatric neurosurgeon still nowadays. Multi-disciplinary management represents the standard of care. Currently, prenatal treatment is offered as a procedure that prevents the CM-II and decreases the incidence of the associated hydrocephalus and the need of CSF shunt.

When the prenatal diagnosis is made, three options are offered to the family, the choice of which depends on ethical considerations, religious, socio-cultural, and legal issues that vary from one country to another. The first option is to terminate the pregnancy. In France, such an option is allowed at all stages of the pregnancy and is the most common choice [1]. The second option is to continue the pregnancy and delivery the fetus in centers where an appropriate closure of the malformation may be performed postnatally. Postnatal treatment represents the standard of care in many institutions worldwide and also in France, and obviously is the only option in newborns in which the prenatal diagnosis had not been obtained. In case of prenatal recognition of the malformation, prenatal repair is the third option. Differently from the USA, Brazil, or some other European countries that have acquired considerable experience in the intra-uterine treatment, the experiences in France are still limited with only two centers proposing this technique. Two different techniques have been described: the open and the endoscopic one.

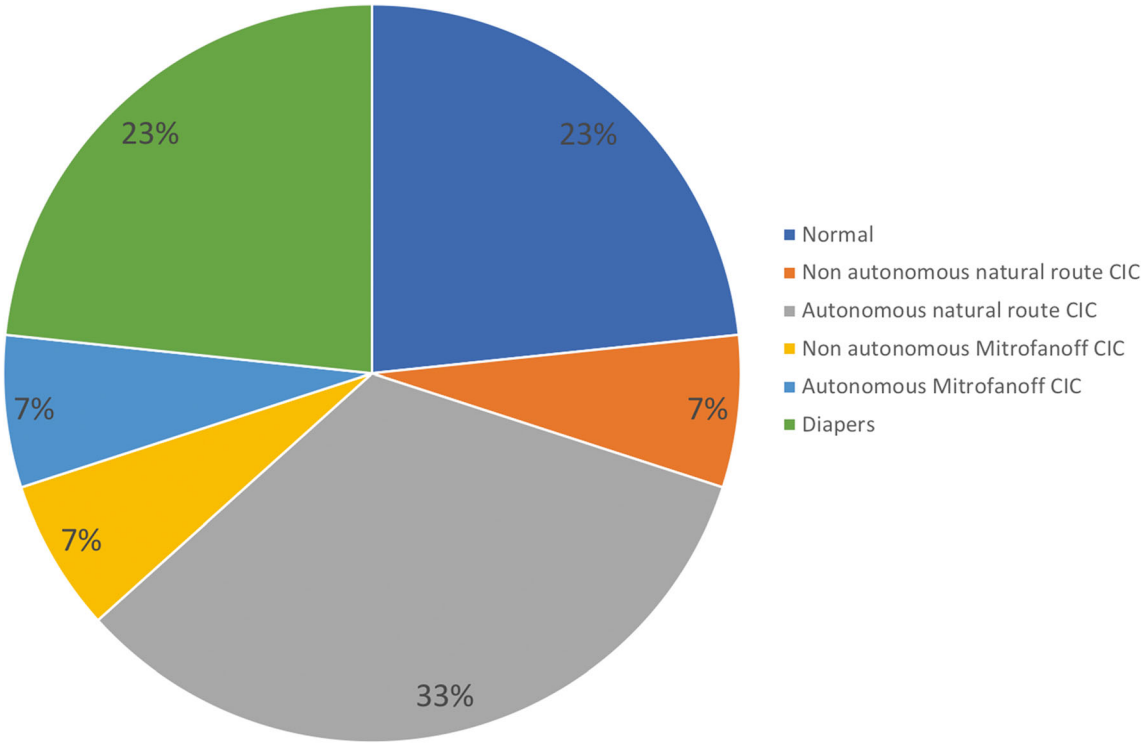

Fig. 2 Pie chart showing the distribution of the population depending on the regimen for bladder management

The MOMS study compared the results of the antenatal versus postnatal closure of MMC and concluded that the prenatal treatment prevented the occurrence of CM-II, decreased the incidence of hydrocephalus and improved the neurological outcome [3]. This study had a significant impact on the international community of pediatric neurosurgeons in spite of some limitations. In particular, the MOMS study reported a percentage of newborns requiring a permanent CSF shunt of 40% versus 82% of newborns with MMC treated postnatally. However, compared to our rate of VP shunt implantation (54%) [2], the MOMS rate (82%) of children operated on after birth considered for comparison purposes seems very high.

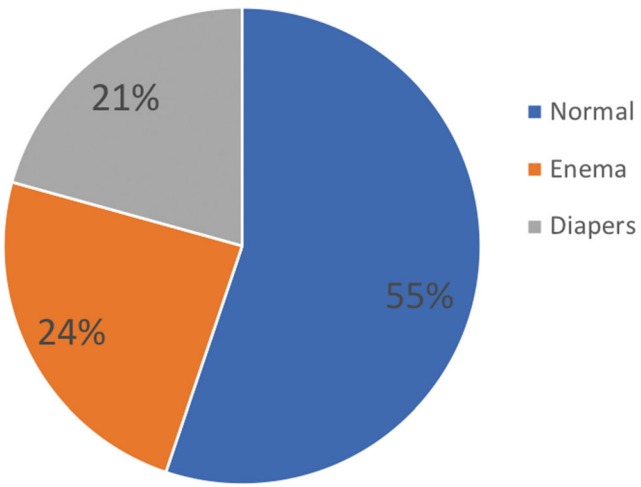

Fig. 3 Pie chart showing the distribution of the population depending on the regimen for bowel management

The MOMS study did not specifically evaluate the rate of VP shunt in cases of low-level MMC so that it is not possible to make a comparison for this specific subgroup of MMC. In this study, the rate of VP shunt is quite low (37.9%). The rate of extrathecal CSF shunt in subjects operated postnatally may be further diminished using ETV which proved to be effective also in a significant percentage of cases of hydrocephalus associated to MMC [4]. For the endoscopic antenatal procedure, there is no randomized trial to evaluate its effectiveness on the reduction of VP shunt insertion but values around 45% of patients requiring shunt have been reported in a recent review of the literature which concluded that the necessity for a CSF shunt implant did not differ in the groups of prenatal and postnatal management of MMC [5].

Emphasis was given also on the economic costs reported to be higher for the postoperative management [6]. Materno-fetal complications may occur in both types of MMC management but show some difference in type and severity [3, 7]. Prenatal surgery was associated with an increased risk for membrane separation (30% vs 0%, $p < 0.0001$), oligohydramnios (19% vs 3%, $p < 0.001$), spontaneous membrane rupture (40% vs 7%, $p < 0.0001$), spontaneous onset of labor (39% vs 13%, $p < 0.0001$), and earlier gestational age at birth (≥ 37 WG, 17% vs 77% and < 30 WG, 10% vs 0%, $p < 0.0001$) [7].

The improvement of surgical techniques would likely decrease the rate of such complications [8]. Recently, Belfort

et al. published a mixed technique of fetoscopic and open approach with the lowest rate of preterm delivery than in any previously reported cohort of fetal MMC repair [9]. For the first time, the authors reported on the possibility of a vaginal delivery in case of prenatal treatment [9]. Vaginal delivery is still under debate even though no significant difference in motor outcomes was found when compared to caesarian section [10]. It offers a clear advantage for the mother in terms of futures pregnancies.

Prematurity represents one major complication for both techniques. Actually, it has been reported in 10 to 34% of the myelodysplasic subjects [3, 7, 11–13]. In our series, prematurity was relatively less frequent as the mean gestation age at birth was almost 39WG and no birth before 33WG were recorded. The mean birth weight was 3050 g.

Efficacy of the closure of the defect

A surgical endpoint to study when evaluating the results of MMC surgery is the efficacy of the closure of the malformation. For the antenatal management, it is important to differentiate the two methods. The open procedure seems to assure better results than the endoscopic one. Indeed, the rate of a second postnatal closure following a failing or an incomplete antenatal closure following the antenatal is zero in the MOMS study [14] and 2 out of 18 case in the series by Zamłyński et al. [13]. For the endoscopic procedure, Pedreira et al. reported, in a series of 10 patients, 2 failures of the antenatal procedure and 2 postnatal closures (one because of a antenatal failure) [11]. Graf et al., in a series of 72 patients, reported 20 patient needed postnatal reoperation while no prenatal failures was experienced by the authors [12]. For the open technique, the MOMS trial had not reported any case of failure with the need of a postnatal surgery [14].

Chiari II malformation

Secondary results of the MOMS trial that sparked a large interest is the reversibility of the CM-II with the absence of tonsil ptosis in 36% in the antenatal group versus only 4% in the postnatal group ($p = 0.001$) [3]. Two authors reviewed all the published data on this subject [5, 15]. Reversibility was effective in 15 to 71% for the open technique [3, 13, 16, 17]. For the endoscopic technique, only two studies analyzed this factor with a reversal in 57% [9] and 85% [11]. In a previous paper, we reported on a personal series of MMC infants in whom the CM-II was present at birth in 77% and whose CM-II faded away in 40% of the cases after the postnatal closure [18]. In the series here considered of patients with low level malformation, 17% of our patients have a CM-II after the closure of the MMC that is comparable to the best result of the antenatal series.

Tethered cord syndrome

Robust data are still lacking on the results of both antenatal techniques as far as the risk of retethering is concerned. Danzer et al. reported a 10-year follow-up, using the open technique on 42 patients with a rate of retethering of 33% [19]. As for the endoscopic technique, only one case has been described requiring a dethetering procedure after 1 year the initial operation [11, 12]. We want to highlight that the endoscopic technique does not aim to reconstruct the different anatomical layers and does not create a peri-medullary space, so that a high risk of late re-tethering should be expected, at least theoretically. As re-tethering can occur more than 6 years after the initial surgery, at the moment there is not a sufficient amount of information to discuss this specific complication.

Neurological and orthopedic results

Walking performance of the MOMS trial had also shown a significant improvement with an independent walk in 42% of the cases versus only 21% in the postnatal group ($p = 0.01$). This is explained by the improvement of the neurological deficit by 2 neurological level [3]. This is of paramount importance as it is known that the earlier and the better the patient can walk, the better his/her outcome will be [20]. As it is also reported that the walking status can worsen with time [21–23], it is mandatory to wait longer to analyze the evolution of the walking status after a prenatal closure. Danzer et al. with a mean follow-up of 10 years gave ideas of the long-term walking outcome: 79% of patients are community ambulatory, 7% are house ambulatory, and 14% are wheelchair dependent [19]. These results are the best in the literature to date. For the endoscopic procedure, it is difficult to draw any conclusions as the number of patients is limited and the follow-up is short. However, Verbeek et al. reported an improvement of the walking status [24].

Few details are reported on the orthopedic issues in the antenatal series. In the MOMS, the talipes equinovarus rate is identical in both groups (50%) [3].

Bowel and bladder management

The bowel and bladder management results were not in the MOMS outcome criteria. However, the principal cause of morbidity and mortality in MMC patient is renal complications leading to renal failure, which can affect up to 20% of the patients [25]. Results of bladder outcomes have been published but are they are still sparse. The large majority of studies did not demonstrate superiority of open prenatal MMC repair on urinary tract function compared to standard postnatal closure [26–33]. Brock et al., reporting on the urological results of the MOMS series, did not find any significant differences between post- and prenatal surgery on the rate of patient

on clean intermittent catheterization (CIC). However, they did find that images of the bladder had better features such as less vesical trabeculation and a more normal shape [26]. There is only one study which suggests a positive effect of prenatal closure versus postnatal closure with 50% of the patient in the prenatal group with neurogenic bladder dysfunction requiring CIC and anticholinergic therapy in 50% in the prenatal and in 100% in the postnatal group. Moreover, significant bladder wall thickening was more frequent in the postnatal group as well as febrile urinary tract infections [34]. Regarding the endoscopic technique, the only study published to date, did not demonstrate any advantages over open prenatal closure or standard postnatal management [35].

Neuropsychological outcome

In low-level MMC, the global intellectual functions are not compromised and permit a good school integration and quality of learning. Unfortunately, one important limitation of this analysis is that we do not have objective measures of intelligence such as intellectual quotient.

Generality

We are convinced that the good results obtained in MMC patients with the low-level defect located should lead to a risk/benefit discussion on the advantages of the prenatal management. With postnatal management, complications for the mother and the rate of preterm delivery are lower than with the prenatal technique. The use of microsurgery, improving the dissection of the neural plate and sparing of roots has helped to improve the clinical results, to reduce of the rate of infectious complications, retethering, hydrocephalus, and CM-II.

Conclusions

Surgical repair of neural tube defect in the postnatal closure remains the gold standard of treatment in most of pediatric neurosurgical service.

Prenatal closure is proposed and more and more reported since the MOMS in 2011. The goal of the prenatal management is to decrease the rate of hydrocephalus and CM-II and to improve the neurological status of patients. Its main limitations are complications for the mother and induction of preterm delivery.

Our results of postnatal surgery for the low-level MMCs are quite satisfying with good walking capacities, schooling, and functional outcomes of the operated-on children.

We are aware that this series of a limited selected specific population of low-level malformation cannot be compared to the prenatal series that include high level malformations too. However, it shows that the risk of postnatal surgery is low for the patient and quite nil for the mother. On this ground, we suggest that the prenatal surgery could be proposed only for high-level located MMC. Our results stress also that a clear and specific information should be given to families during prenatal counseling concerning the best attitude to adopt in case of low located MMC.

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