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Factors Affecting the Development of Hydrocephalus in Patients with Spinal Neural Tube Defects

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ABSTRACT

AIM: To identify factors that could prevent the formation of spina bifida and determine the causes of hydrocephalus.

MATERIAL and METHODS: We retrospectively evaluated the data of 51 patients with neural tube defects (NTD) who were surgically treated at Sanliurfa Training and Research Hospital between December 2021 and October 2022.

RESULTS: The mean maternal folate level was 7.02 ± 3.66 µg/L. Of the 51 mothers, 14 (27.5%) had low folate levels and 37 (72.5%) had normal folate levels. The mean maternal vitamin B12 level was 287.29 ± 91.64 ng/L. Of the 51 mothers, 9 (17.6%) had low vitamin B12 levels and 42 (82.4%) had normal vitamin B12 levels. Ventriculoperitoneal shunt surgery was performed in 19 (37.3%) of 51 patients. The area of neural tube defect was significantly higher in infants who underwent VP shunt surgery due to hydrocephalus than in infants without hydrocephalus. The risk of developing hydrocephalus increased as the severity of NTD type increased. Furthermore, the risk of developing hydrocephalus increased as the anatomical levels of NTD increased.

CONCLUSION: Although the optimum blood folate level for preventing MMC remains uncertain, the upper limit of the normal reference should be targeted. Hydrocephalus is an important cause of morbidity and mortality in patients with SB and its incidence is higher in patients with an anatomical higher NTD, a more severe type of NTD, and a large defect diameter. Furthermore, hydrocephalus is more common in patients with SM and female patients.

KEYWORDS: Folate, Defect area, Meningomyelocele, Hydrocephalus

ABBREVIATIONS: MMC: Meningomyelocele, **MS:** Myeloschisis, **MC:** Meningocele, **SB:** Spina bifida, **VP:** Ventriculoperitoneal, **CM:** Chiari malformation, **DIAM:** Diastematomyelia, **DST:** Dermal sinus tract, **LCL:** Low conus localization, **SM:** Syringomyelia, **CCA:** Corpus callosum agenesis, **CSF:** Cerebrospinal fluid, **USG:** Ultrasound, **ECHO:** Echocardiogram, **MR:** Magnetic resonance, **ASD:** Atrial septal defect, **PDA:** Patent ductus arteriosus, **VSD:** Ventricular septal defect

INTRODUCTION

Meningomyelocele (MMC) is type of spina bifida (11) in which the spinal neural tube does not close during embryonic development (28). Its frequency range between 0.2 and -10 per 1000 across different geographical regions (5). The etiology of MMC includes common genetic mutations, inadequate nutrition, low blood folate level, family history of SB, history of radiation, history of diabetes in the parents, maternal history of seizure and low socioeconomic status. Furthermore, MMC is more common in low socioeconomic status countries (11,24). MMC can present as weak-

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ness in the extremities, urinary and bowel dysfunction, orthopedic problems, structural abnormalities, postural problems, and cosmetic problems below the level of the defect (11).

Cranial and spinal imaging for neuropathological screening in patients with MMC revealed the presence of Chiari malformation (CM), diastematomyelia (DIAM), low conus localization (LCL), syringomyelia (SM) and corpus callosum agenesis (CCA) (26,29). Infants with MMC may also develop hydrocephalus. Hydrocephalus is an abnormal progressive accumulation of cerebrospinal fluid (CSF) in the ventricles and an important cause of morbidity and mortality in individuals with MMC (19). Currently, the recommended treatment for patients with MMC is closure of the defect at the earliest (28).

Our clinic is a referral hospital in our region and in close proximity to a war zone. Thus, we frequently encounter MMC in our practice. In this study, we aim to describe the etiological, clinical, radiological and surgical characteristics of patients with MMC and share our experience regarding the causes of hydrocephalus and methods to prevent MMC.

MATERIAL and METHODS

Study Design

We retrospectively analyzed the data of 51 patients with SB who underwent surgical treatment at Sanlıurfa Training and Research Hospital between December 2021 and October 2022. Ventriculoperitoneal (VP) shunt surgery was performed in patients who developed hydrocephalus in the postoperative period. Patients who required revision surgery for complications such as CSF fistula and wound closure defect after the SB operation were revised. Patients were followed up during their admission to the neonatal intensive care unit or ward. Data of mothers who were referred to the neurosurgery outpatient clinic after the prenatal diagnosis in the gynecology outpatient clinic were also obtained.

The following patient data were analyzed: age, sex, birth weight, birth week, type of delivery, head circumference, APGAR score, presence of additional systemic anomalies, interval between birth and operation for MMC, defect diameter, need for VP shunt surgery, postoperative complications, and revision surgery for postoperative complications. The systemic ultrasound (USG), echocardiogram (ECHO) and magnetic resonance (MR) images of the patients were evaluated. The mothers' age, blood folate and vitamin B12 levels, number of children, family history, and history of antiepileptic use were also evaluated.

The study was approved by the Clinical Research Ethics Committee of the Faculty of Medicine, Harran University (No: HRU /22.23.14, date: 11.28.2022). And conducted in accordance with the principles of the Declaration of Helsinki.

Statistical Analysis

Statistical Package for the Social Sciences (version 26) was used for all statistical analyseis. Descriptive statistical methods (mean and, standard deviation and, median and, frequency, as well as percentage and, minimum - maximum) were used to evaluate the study data. The suitability of the quantitative data to normal distribution was evaluated using the Shapiro -Wilk test and graphical analyses. The Student's t-test was used for the comparisons of normally distributed quantitative variables between two groups, and The Mann-Whitney U test was used for the comparisons of nonnormally distributed quantitative variables between two groups. Qualitative data were compared using the Pearson chi-square test, Qualitative data were compared using Fisher's exact test and the Fisher-Freeman-Halton test. Statistical significance was set at $p<0.05$.

RESULTS

The mean age of the mothers was 27.18 ± 5.37 years and the median age was 27 years (range: 16-40). A family history of SB was present in 9 patients (17.6%) and absent in 42 patients (82.4%). Only one mother had a history of antiepileptic drug use. Of the 51 mothers, only 40 (78.4%) were administered antenatal folate supplement. The mean maternal folate level was 7.02 ± 3.66 µg/L (median, 7 µg/L [range: 2-20]. Although 14 (27.5%) mothers had low folate levels, 37 (72.5%) had normal folate levels. The mean vitamin B12 level was 287.29 ± 91.64 ng/L (median, ng/L 277 [range: 144-590]. Although nine mothers (17.6%) had low vitamin B12 levels, 42 (82.4%) had normal vitamin B12 levels. Among the infants, 4 (7.8%), 16 (31.4%), 7 (13.7%), 10 (19.6%) were first, second, third, fourth-born children, respectively. The remaining infants (n=14) (27.5%) were the fifth or later child of their mothers (Table I).

Of the 51 infants, 22 (43.1%) were female and 29 (56.9%) were male. The mean gestational age was 37.84 ± 2 weeks (median, 39 years [range: 30-40] weeks. The mean birth weight was 3055.49 ± 503.24 g, (median, 3020 g [range: 1670-4270]. The mean head circumference at birth was 35.27 ± 19.4 cm (median, 35 cm [range: 30-47]. Of the 51 infants, 8 (15.7%) were born by normal vaginal delivery and 43 (84.3%) were born by cesarean section. The mean APGAR scores at 1 and 5 min were 8.14 ± 1.06 and 9.45 ± 0.83, respectively, The median APGAR scores at 1 and 5 min were 8 (range: 4-10) and 10 (range: 6-10), respectively. The systemic USG yielded a normal study in 39 (76.5%) patients. However, renal abnormalities were detected in 12 (23.5%). The thyroid function test yielded a normal result in 41 (80.4%) patients, Hypothyroidism was detected in 10 (19.6%) patients. An orthopedic anomaly was present in 25 (49.0%) patients. Echocardiography revealed normal findings in 48 (94%) patients, ASD (atrial septal defect) in one patient and PDA (patent ductus arteriosus) in one patient, VSD (ventricular septal defect) in one. No motor deficit was observed in 23 (45.1%) patients. However minimal deficit, minimal movement and, paraplegia was observed in 2 (3.9%), 6 (11.8%), 18 (35.3%) patients, respectively (Table II).

The mean area of the defect was 33.55 ± 22.21 cm^2 (median, 29 cm^2 [range: 4-80]. Of the 51 patients, 18 had a meningocele (MC), 10 had a myeloschisis (MS) and 23 had a myelomeningocele (MMC) (Table III). The SB defect was located in the lumbar region, sacral and the thoracic regions in 26 (51.0%), 17 (33.3%), and 5 (9.8%) patients, respectively

Table I: Descriptive Characteristics of Mothers

Maternal Age	Mean ± SD Median (Min-Max)	27.18 ± 5.37 27 (16-40)
Family history, n (%)	No Yes	42 (82.4) 9 (17.6)
Antiepileptic Use, n (%)	No Yes	50 (98.0) 1 (2.0)
Taking Folate Supplements, n (%)	No Yes	40 (78.4) 11 (21.6)
Folate level	Mean ± SD Median (Min-Max) Low Normal	7.02 ± 3.66 µg/L 7 (2-20) µg/L 14 (27.5) 37 (72.5)
Vitamin B12 level	Mean ± SD Median (Min-Max) Low Normal	287.29 ± 91.64 ng/L 277 (144-590) ng/L 9 (17.6) 42 (82.4)
Number of children, n (%)	1. Child 2. Child 3. Child 4. Child ≥5.Child	4 (7.8) 16 (31.4) 7 (13.7) 10 (19.6) 14 (27.5)

Table II: Birth Characteristics of the Patients

Gender, n (%)	Female Male	22 (43.1) 29 (56.9)
Birth week	Mean ± SD Median (Min-Max)	37.84 ± 2.47 week 39 (30-40) week
Birth weight	Mean ± SD Median (Min-Max)	3055.49 ± 503.24 g 3020 (1670-4270) g
Birth Head Circumference	Mean ± SD Median (Min-Max)	35.27 ± 1.94 cm 35 (30-47) cm
Type of Birth, n (%)	Normal C/S	8 (15.7) 43 (84.3)
APGAR 1st Minute	Mean ± SD Median (Min-Max)	8.14 ± 1.06 8 (4-10)
APGAR 5th Minute	Mean ± SD Median (Min-Max)	9.45 ± 0.83 10 (6-10)
Systemic USG, n (%)	Normal Kidney anomaly	39 (76.5) 12 (23.5)
TFT result, n (%)	Normal Hypothyroidism	41(80.4) 10 (19.6)
Orthopedic anomaly, n (%)	No Yes	26 (51) 25 (49.0)
Ecocardiography, n (%)	Normal ASD PDA VSD	48 (94) 1 (2.0) 1 (2.0) 1 (2.0)
Motor function, n (%)	No deficit Minimal deficit Minimal movement One leg Immobile Paraplegia	23 (45.1) 2 (3.9) 6 (11.8) 2 (3.9) 18 (35.3)

Table III: Operation-Related Characteristics Of Babies

Defect Area	Mean ± Sd Median (Min-Max)	33,55 ± 22,21 cm^2 29 (4-80) cm^2
Spina Bifida Types, n(%)	Meningocele Meningomyelocele Myeloschisis	18/51 (35,29) 23/51 (45,09) 10/51 (19,6)
Spina Bifida Type and Treated Hydrocephalus Rates, n(%)	Meningocele Meningomyelocele Myeloschisis	3/18 (16,6) 9/23 (39,13) 7/10 (70)
Spina Bifida Localization and Additional Pathology Localization, n(%)	Thoracal Lumbar Sacrum Cervical (MMC) - Lumbar (DST) Lumbar (MMC) - Thoracal (DST) Lumbar (MMC) – Thoracal (MMC) - Cervical (DST)	5/51 (9,8) 26/51 (50,98) 17/51 (33,33) 1/51 (1,96) 1/51 (1,96) 1/51 (1,96)
Level of spina bifida and Treated Hydrocephalus Rates, n(%)	Thoracal Lumbar Sacrum Cervical (MMC) - Lumbar (DST) Lumbar (MMC) - Thoracal (DST) Lumbar (MMC) - Thoracal (MMC) – Cervical (DST)	4/5 (80) 9/26 (34,61) 3/17 (11) 1/1 (100) 1/1 (100) 1/1 (100)
MR Finding, n(%)	Normal CM VM LCL CCA DIAM SM	2 (3,9) 36 (70,6) 36 (70,6) 21 (41,2) 21 (41,2) 2 (3,9) 5 (9,8)
Operation time	Mean ± Sd Median (Min-Max)	26,96 ± 17,80 hours 24 (5-72) hours
Postop complication, n(%)	None CSF leaking CSF leaking-wound necrosis Wound necrosis	44 (86,2) 3 (5,8) 1 (2,0) 3 (5,9)
VP shunt operation, n(%)	No Yes	32 (62,7) 19 (37,3)
Re-operation, n(%)	No VP shunt revision Wound Debridement - VP shunt revision Wound Debridement	45 (88,2) 2 (4,0) 1 (2,0) 3 (5,9)
Length of Hospital Stay	Mean ± Sd Median (Min-Max)	21,82 ± 17,31 days 14 (5-70) days

***CM:** Chiari Malformation, **VM:** Ventriculomegaly, **LCL:** Low Conus Localisation, **CCA:** Corpus Callosum Agenesia, **DIAM:** Diastometamyelia, **SM:** Syringomyelia, **DST:** Dermal Sinus Tract, **MMC:** Meningomyelocele, **MS:** Myeloschisis, **MC:** Meningocele, **CSF:** Cerebrospinal Fluid, **VP:** Ventriculoperitoneal*

(Figure 1). Furthermore, one patient (2%) exhibited a dermal sinus tract (DST) in the thoracic region and an MMC in the lumbar (Figure 2), and another patient (2%) exhibited an MMC in the cervical region and a (DST) in lumbar region. In one patient (2%), there was a DST in the cervical region and an MMC in the thoracic and lumbar regions (Table III).

The rates of treated hydrocephalus according to SB types, were as follows; meningocele,16.6% (n=3), MMC 39.13% (n=9), and myeloschisis 70% (n=7) (Table III). The rates of treated hydrocephalus according to the level of SB were as follows: thoracic region, 80% (n=4), lumbar region, 34.61% (n=9) and sacral region, 11% (n=3) (Table III).

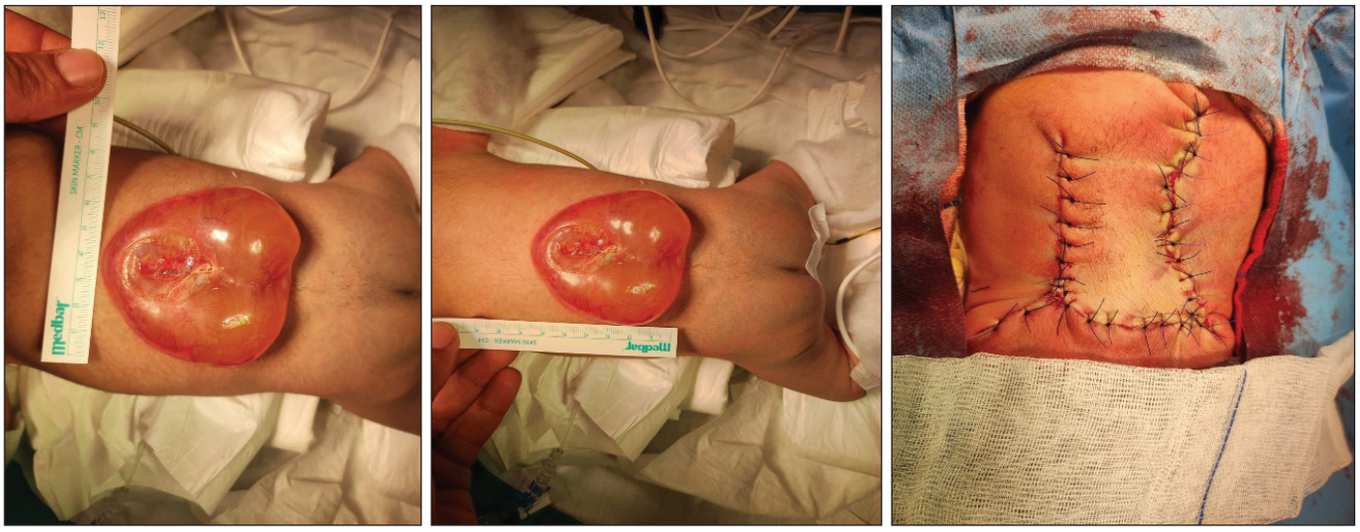

Figure 1: Preoperative and postoperative pictures of a case with lumbar meningomyelocele.

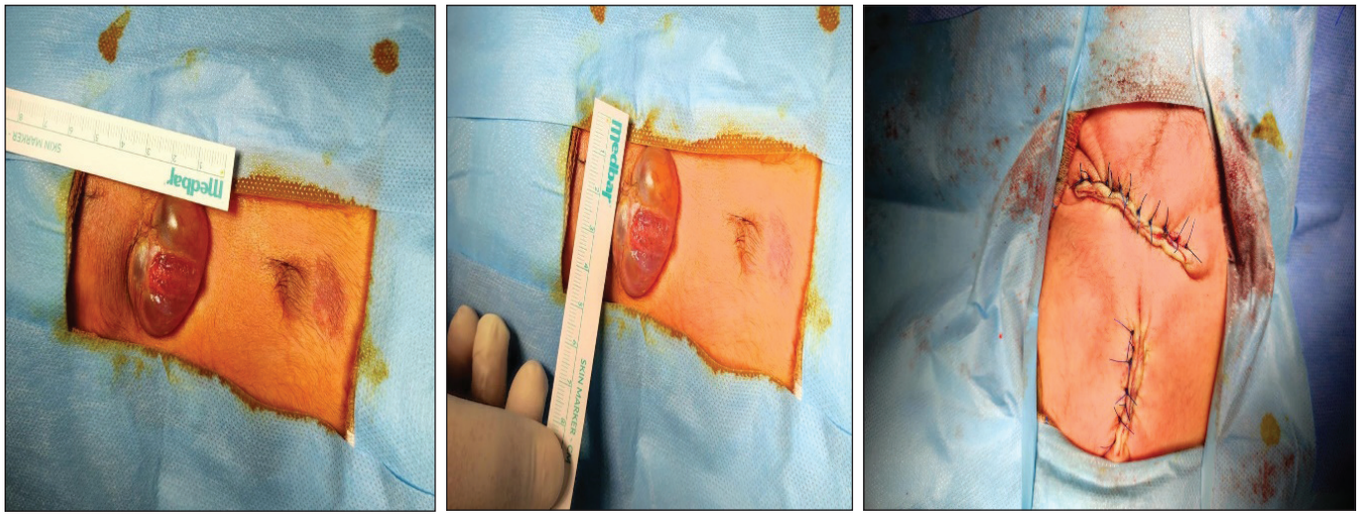

Figure 2: Preoperative and postoperative pictures of the case with lumbar meningomyelocele and thoracal DST.

The mean operative time was 26.96 ± 17.80 h (median, 24 h [range: 5-72]. No complication developed in the postoperative period in 44 (86.2%) patients. However, a CSF fistula, CSF leakage with wound necrosis, and wound necrosis alone developed in three (5.8%), one (2.0%), three (5.9%) patients, respectively. Hydrocephalus developed in 19 (37.3%) patients and it was treated by VP shunt insertion. Hydrocephalus did not develop in 32 (62.7%) patients (Figure 3). The incidence of hydrocephalus according to the SB type was as follows: MMC (39.13%), meningocele (16.6%), and myeloschisis (70%) (Table III). VP shunt revision surgery was performed in two (4.0%) patients. Wound debridement and VP shunt revision were performed in one (2.0%) patient. Wound debridement alone was performed in three (5.9%) patients. The mean hospitalization duration of the patients was 21.82 ± 17.31 days, median, 14 days [range: 5-70] (Table III).

Female patients required VP shunt operation significantly more frequently than male patients (p=0.001). However, there was no statistically significant correlation between VP shunt operation and the other patient characteristics such as maternal age, family history, folate supplementation, folate level, vitamin B12 level, number of children, head circumference at birth, defect location and surgical timing. Furthermore, there was no correlation between hydrocephalus and the presence of neurologic deficit. However, there was a statistically significant correlation the area of the defect and VP shunt surgery (p=0.001). The defect area was larger in patients who underwent the VP shunt operation than in those who did not undergo surgery. Additionally, the duration of hospitalization was statistically significantly longer in these patients (Table IV). There was also a statistically significant correlation between SB type and hydrocephalus. The more severe SB type, the higher the risk of developing hydrocephalus. Moreover, higher

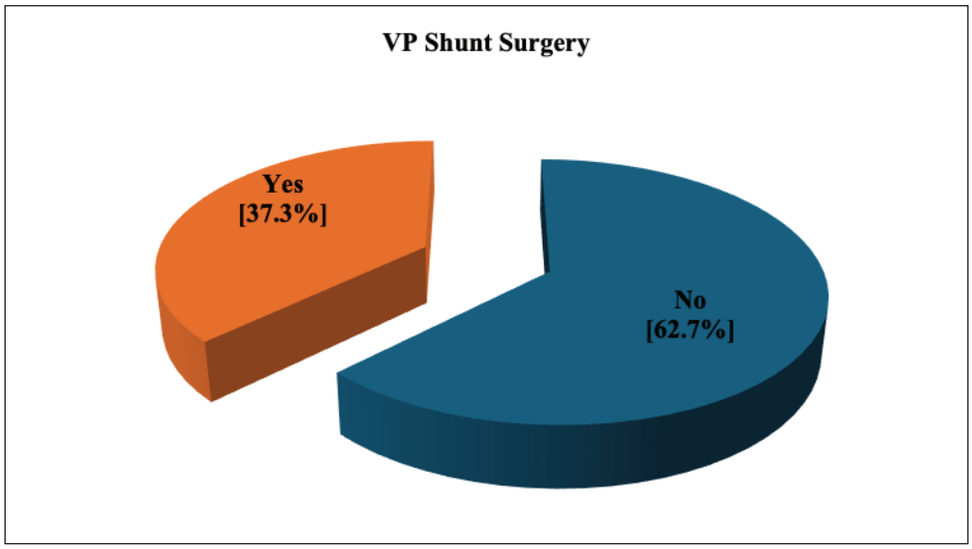

Figure 3: Percentage of MMC patients who underwent VP shunt surgery.

Tablo IV: Evaluation of the Presence of V/P Shunt Surgery According to the Characteristics of Mothers and Babies

		No VP Shunt (n=32)	Yes VP Shunt (n=19)	p-value
Baby gender, n(%)	Female Male	8 (36.4) 24 (82.8)	14 (63.6) 5 (17.2)	[b]0.001**
Maternal age	Mean ± SD Median (Min-Max)	26,97 ± 5.36 26.5 (16-40)	27.53 ± 5.52 27 (19-37)	[a]0.724
Family history, n(%)	No Yes	28 (66.7) 4 (44.4)	14 (33.3) 5 (55.6)	[c]0.266
Taking folate supplements, n(%)	No Yes	25 (62.5) 7 (63.6)	15 (37.5) 4 (36.4)	[c]1.000
Folat, n(%)	Low Normal	9 (64.3) 23 (62.2)	5 (35.7) 14 (37.8)	[b]0.889
Vitamin B12, n(%)	Low Normal	5 (55.6) 27 (64.3)	4 (44.4) 15 (35.7)	[c]0.711
Number of children, n(%)	1. child 2. child 3. child 4. child ≥5. child	4 (100.0) 10 (62.5) 3 (42.9) 7 (70.0) 8 (57.1)	0 (0.0) 6 (37.5) 4 (57.1) 3 (30.0) 6 (42.9)	[d]0.465
Birth Head Circumference	Mean ± SD Median (Min-Max)	34.50 ± 1.27 34 (32-38)	36.58 ± 4.29 35 (30-47)	[e]0.103
Type of Birth, n(%)	Normal C/S	6 (75.0) 26 (60.5)	2 (25.0) 17 (39.5)	[c]0.694
Defect Area	Mean ± SD Median (Min-Max)	24.81 ± 16.81 16 (4-80)	48.26 ± 22.80 49 (9-80)	[e]0.001**
Surgery Time	Mean ± SD Median (Min-Max)	26.53 ± 17.99 24 (6-72)	27.68 ± 17.94 24 (5-72)	[e]0.746
Length of Hospital Stay	Mean ± SD Median (Min-Max)	13.56 ± 9.13 12 (5-40)	35.74 ± 19.05 40 (6-70)	[e]0.001**

*[a]Student-t Test, [b]Pearson Chi-Square Test, [c]Fisher's Exact Test, [d]Fisher Freeman Halton Test [e]Mann Whitney U Test. **p<0.01.*

Table V: Logistic Regression Results of Factors Affecting VP Shunt Surgery

	p-value	ODDS	95% C.I.ODDS Lower	95% C.I.ODDS Upper
CM	0.342	2.803	0.335	23.436
VM	0.919	1.084	0.229	5.123
LCL	0.758	1.280	0.267	6.130
CCA	0.694	0.726	0.147	3.578
SM	0.036*	12.885	1.175	141.243
Defect area	0.001**	1.063	1.026	1.103

**p<0,05, **p<0,01.*

levels of SB lesions exhibited an increased risk of developing hydrocephalus.

We found that the existence of CM, LCL and CCA in addition to MMC on MR imaging was statistically significantly more common in patients who underwent VP shunt surgery than in those who did not undergo surgery. Furthermore, there was a statistically significant association between the presence of SM and VP shunt operation (p=0.036) (Table V).

DISCUSSION

Morbidity and mortality in patients with MMC vary according to age, sex, ethnicity, level and severity of the lesion, presence of multiple birth defects and the treatment method. Low birth weight, higher levels of spinal cord involvement and the presence of congenital anomalies are considered to be poor prognostic factors. Although a maternal age of less than or more than 40 years is reportedly a risk factor for MMC, data regarding mother's age in association with MMC are limited in literature. In our study, the average maternal age was 27 years (range, 16-40) (15,30). No study has reported a relationship between the number of children and MMC. However, in our study, 7.8% of patients with MMC were first-born children, and 27.5% of the patients were born the fifth-born child or later. No parallelism was found a higher number of children and the incidence of MMC. Cesarean delivery prevents the tearing of the MMC pouch. Previous studies have reported a varying cesarean birth rate of 69% to -80% (3). In our study, this rate was higher (84.3%).

Surgical timing may prevent further deterioration of motor functions, contribute to the well-being of the genitourinary system, and reduce the risk of infectious complications. However, an analysis of a national database showed no significant difference in the infection rates between the same day and next day surgery for MMC. However, performing MMC surgery 48 h after delivery increased the infection rates. Furthermore, infections are associated with a 54% increase in the duration of hospitalization. Therefore, if the closure of MMC is delayed beyond the first 24 h after birth, there is a significant increase in the infection and hospitalization rates (22). The mean interval between birth and MMC surgery in our study was 26.9 h and all patients were operated within 72 h of delivery.

MMC is an important public health challenge that can affect systems such as neurological, genitourinary, orthopaedic and circulatory systems and the organs such as the skin. Thus, a multidisciplinary approach is required for the management of this disease. Yorulmaz et al. reported orthopedic complications, urinary system complications, congenital heart diseases and hypothyroidism in 31.1%, 23.1%, 27.5%, 7.5% of the patients, respectively (30). Similarly in our study, orthopedic complications, urinary system complications, congenital heart diseases and hypothyroidism were observed in 49%, 23.5%, 6% and, 19.6% of the patients, respectively.

In this study, the neurological examination yielded normal results in only 45.1% of the patients. Similarly, Rehman et al. reported that 42% of their study participants did not exhibit any neurological deficit (23). Patients with neurological deficits were included in physical therapy program after discharge. In the same study, the authors observed that the defect was frequently (86%) located in the lumbosacral (23). Similarly, we found that 90.8% of the patients had lumbar or sacral involvement.

No complications developed after the MMC surgery in 86% of the patients. However, a CSF fistula, wound necrosis, and a combination of CSF fistula and wound necrosis developed in 5.8%, 5.8%, and 2% of patients, respectively. In the study by Khan, CSF fistula and wound problems developed in 23.7% and 13.5% of their patients, respectively (12). Therefore, the rate of postoperative complications in our study was lower than that reported in the literature.

Folate deficiency is a vital risk factor for the development of MMC, especially in low socioeconomic regions. Its prevalence reduced by 5 - 6 per 10,000 and 19% after implementation of a folic acid enriched dietary supplementation program in China and in the USA, respectively (6,9). Furthermore, supplementation with 0.4 µg of folate per day reduces the occurrence of neural tube defects by 70% (6). Only 21% of patients in our study were administered antenatal folate supplementation. Furthermore, the median maternal folate level in our study was 7 (range: 2-20) which is slightly higher than the minimum value of the normal range (normal range: 3-34 µg/L in our laboratory. Nevertheless, to prevent the development of neural tube defects, we need to target the

upper limit of the normal range, because none of our patients exhibited a folate value level of > 20 µg/L. The maternal vitamin B12 levels in our study were within the normal range. Only one mother had a history of antiepileptic drug use.

Hydrocephalus is one of the most common coexisting condition in patients with MMC. Its incidence varies between 65% and 85% in the literature (1,10,14,16,25,27). And it may become symptomatic after pouch repair. Shunt insertion is commonly performed to treat hydrocephalus. In our study, 37.3% of the patients underwent VP shunting. Data regarding the incidence of hydrocephalus according to SB type and anatomic level of SB are lacking. Kim et al. demonstrated that the more rostral lesions are associated with higher rates of treated hydrocephalus (13) which is similar to our study's findings. Dysfunction and infections may develop after shunt surgery. In our study, the shunt was revised in 9.3% of the patients which is consistent with the findings in the literature. The mean head circumference in our study was 35.27 cm, which is lower than that reported in another study conducted in our country (21,30). Hydrocephalus plays a crucial role in increasing the morbidity and mortality in patients with MMC. It prolongs hospitalization and causes a significant financial burden. In our study, we examined patients who developed hydrocephalus. In our study, maternal age, family history, head circumference, operative time, defect area, maternal folate and vitamin B12 levels, folate supplementation status, mode of delivery and number of children were not statistically significantly correlated with the incidence of hydrocephalus. However, the incidence of hydrocephalus was statistically significantly higher in patients with a larger defect diameter, patients with SM and female patients. The incidence of hydrocephalus according to sex in previous reports has varied across countries and regions (20). In our study, the incidence of hydrocephalus was higher in female patients than in male patients.

A crucial challenge of MMC surgery is the closure of the skin defect, A larger defect is more challenging to repair. Various repair methods have been described in the literature, including skin grafts, skin flaps, and muscle or musculocutaneous flaps (18). Clinical practices regarding defect closure may vary, in some clinics, the entire may be repaired by neurosurgeons, whereas in some other clinics a plastic surgeon may repair it, in other clinics small defects may be repaired by neurosurgeons and large defects may be repaired by plastic surgeons. In our study, we requested the assistance of a plastic surgery in only five patients (9.8%). As the size of the defect increases, the amount of affected neural tissue also increases. Thus, the size of the defect is a vital prognostic factor. However, studies on this aspect are limited, and in these limited studies the defect was correlated with the patient's neurological status (4,7,8,18). In our study, there was a significant difference between the defect size and development of hydrocephalus. The mean defect area was 48.26 cm^2 in patients with hydrocephalus and 24.81 cm^2 in patients without hydrocephalus. This difference in defect area between the two groups was statistically significant (p=0.001). No study till date has demonstrated a relationship between the defect area and hydrocephalus incidence. We hypothesize that the higher incidence of hydrocephalus in patients with a larger defect area may be explained by the simple rules of physics. After the defect repair, CSF volume equivalent to the volume of the defect will enter into the normal CSF circulation. This increased CSF load will result in hydrocephalus. As the area for CSF circulation decreases, the head circumference will increase and hydrocephalus will become clinically apparent.

In our study, only two (2.9%) patients did not exhibit any additional neurological pathology on MR imaging. In the rest of our patients, a CM, VM, LCL, CCA, DIAM or SM was detected. A CM and VM was detected in 70.6 % of our patients. VP shunt surgery was performed in 19 of the patients with VM. Previous studies have reported a CM incidence of 67% to 95% in patients with MMC, and 10-30% of these patients are symptomatic (2,17,26). The incidence of CM has decreased after the recent introduction of intrauterine fetal MMC operations. However, according to MOMS, the procedure involves serious risks (up to 30%) for the fetus and mother (20). CCA is another anomaly observed in patients with MMC, with an incidence of 30% to 50% (17). In our study, the incidence of CCA, LCL and DIAM were 41 %, 41.2%, 3.9%, respectively. The incidence of SM in patients with MMC is reportedly 30% - 75% (29). However, in our study, it was 9.8%. This is similar to the findings (8.5) of another study (30). Hence, we hypothesize that the incidence of SM varies according to the geographical region. We observed that our neurological imaging were consistent with those in the literature. Furthermore, more VP shunt surgeries were performed in patients with SM than in patients with other coexisting conditions. As there is no information on this aspect in the literature, we believe that this result may be incidental.

CONCLUSION

Myelomeningocele (MMC) is a neural tube defect that may develop despite normal maternal folate levels, making it difficult to define the optimum protective threshold. In our study, no maternal blood folate level exceeded 20 µg/L, suggesting that the upper limit of the normal range may be a reasonable target. Hydrocephalus frequently accompanies MMC and often requires shunt placement, which carries risks such as infection and malfunction. We found that hydrocephalus is more common in patients with higher-level or severe spinal defects, larger lesions, spinal meningoceles, and in female patients. The limited sample size is a study limitation, and further validation is needed.

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Declarations

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AUTHORSHIP CONTRIBUTION

Study conception and design: BE, YB

Data collection: BE, YB, MK

Analysis and interpretation of results: BE, BU, MK, HA

Draft manuscript preparation: BE, YB, HA

Critical revision of the article: BE, YB

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All authors (BE, YB, HA, BU, MK) reviewed the results and approved the final version of the manuscript.

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