Thirty-day medical and surgical readmission following prenatal versus postnatal myelomeningocele repair

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OBJECTIVE Hospital readmission is an important quality metric that has not been evaluated in prenatal versus postnatal myelomeningocele (MMC) repair. This study compares hospital readmission outcomes between these two groups as well as their etiologies.

METHODS The medical records of patients who had undergone MMC repair in the period from 2011 to 2017 at a single academic medical center were retrospectively reviewed. Collected clinical data included surgery and defect details, neonatal intensive care unit (NICU) stay, and any readmissions or surgical procedures up to 1 year after surgery. Patient and defect characteristics, readmission outcomes at 30 and 60 days and 1 year after discharge from the NICU, and cerebrospinal fluid (CSF) diversion surgery rates were analyzed with the two-tailed t-test and/or k-sample test on the equality of medians.

RESULTS A total of 24 prenatal and 34 postnatal MMC repairs were completed during the study period. Prenatally repaired patients were born more prematurely ($p < 0.001$) and with lower birth weights ($p < 0.001$), although the NICU stay was similar between the two groups ($p = 0.59$). Fewer prenatally repaired patients were readmitted at 30 days ($p = 0.005$), 90 days ($p = 0.004$), and 1 year ($p = 0.007$) than the postnatal repair group. Hydrocephalus was the most common readmission etiology, and 29% of prenatal repair patients required CSF diversion at 1 year versus 81% of the postnatal repair group ($p < 0.01$). Prenatal patients who required CSF diversion had a higher body weight ($p = 0.02$) and an older age ($p = 0.01$) at the time of CSF diversion surgery than the postnatal group.

CONCLUSIONS Patients with prenatal MMC repair had fewer hospital readmissions at 30 days, 60 days, and 1 year than the postnatal repair group, despite similar NICU lengths of stay. The prenatal repair group had lower requirements for CSF diversion at 1 year and was older with greater body weights at the time of CSF diversion surgery, compared to those of the postnatal repair group. Future study of hospital quality metrics such as readmissions should be performed to better understand outcomes of these two procedures.

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KEYWORDS myelomeningocele; prenatal; postnatal; readmission; hydrocephalus

MYELOMENINGOCELE (MMC) is a complex congenital neural tube defect involving dorsal herniation of the spinal cord, with resultant leakage of cerebrospinal fluid (CSF) and external exposure of neural elements.^{1,6} Myelomeningocele patients have variable degrees of orthopedic, bowel, and bladder dysfunction; hydrocephalus; and brainstem compression. Their care is complex and multidisciplinary.¹⁸ Early in life, patients require frequent visits, admissions, and interventions. While their visits often become less frequent, MMC patients need life-

long medical care. The life expectancy of these patients has improved over the last few decades, which reflects a need for comprehensive care beyond the initial defect repair surgery.^{8,27}

The two options for surgical repair of MMC are well known. Prenatal (intrauterine) repair has been compared to postnatal repair in terms of the need for surgical treatment of hydrocephalus and subsequent revision, severity of symptomatic Chiari malformation, ambulation, urological function, and retethering.^{1,3,5,12,25} Prenatal repair

ABBREVIATIONS CSF = cerebrospinal fluid; ETV = endoscopic third ventriculostomy; MMC = myelomeningocele; NICU = neonatal intensive care unit; NSQIP = National Surgical Quality Improvement Program.

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has reduced requisite surgical treatment of hydrocephalus, with improvement in motor and neurodevelopmental outcomes.¹¹ However, prenatal repair introduces additional risk to the fetus and the expectant mother, including preterm birth.¹⁴ Preterm birth, differences in urological function, secondary effects of reducing hydrocephalus treatment, as well as other factors, have implications immediately postdischarge and throughout a patient's life, which have not been characterized.

Readmission has become an important quality metric for all surgical populations, including the pediatric neurosurgery population.^{7,16,23,28} A recent study of the pediatric neurosurgical population found that postnatal MMC repair had a readmission rate of 14% within 30 days, which accounted for 15% of all unplanned readmissions.²³ A National Surgical Quality Improvement Program (NSQIP) study of postnatal MMC patients found frequent readmissions for hydrocephalus-related causes as well as for wound dehiscence.⁶ However, hospital readmission outcomes within the prenatal MMC population remain unclear. This study compares readmission and etiology of readmission in patients who underwent prenatal versus postnatal repair of MMC to better understand immediate postsurgical hospital care in these populations.

Methods

This study was approved by the University of North Carolina institutional review board. We conducted a retrospective review of the medical records of MMC patients who had undergone prenatal or postnatal MMC repair between 2011 and 2017 at a single academic medical center. We queried the medical records for details about operative MMC repair, neonatal intensive care unit (NICU) stay, and any readmissions or surgical procedures the patient had at 30 days, 60 days, and 1 year following discharge from the NICU. We also queried the records regarding the need for CSF diversion and subsequent treatment.

Patients were excluded if they had not been born at our institution or had received postoperative care elsewhere resulting in fragmented or missing follow-up in our medical record system. All data were analyzed using Stata software (StataCorp LLC). Means were compared using a two-tailed t-test. Medians were compared using a k-sample test on the equality of medians.

Results

A total of 58 MMC repairs were performed at our institution in the study period, and 24 were prenatal and 34 were postnatal (Table 1). The average gestational age at repair was 24.4 weeks for the prenatally repaired patients. All postnatal repairs were completed within 48 hours of birth. Patients undergoing prenatal repair were on average born significantly more prematurely (32.1 vs 36.9 weeks, $p < 0.001$) and had a significantly lower birth weight (1.8 vs 2.8 kg, $p < 0.001$) than the postnatal group. There was no significant difference in the percentage of patients with a lesion at L3 or below between the groups (66.7% prenatal vs 67.6% postnatal, $p = 0.97$). The NICU length of stay was not significantly different between the two cohorts (median stay 25.5 days prenatal vs 17 days postnatal, $p = 0.59$).

TABLE 1. Patient and defect characteristics in postnatal and prenatal groups

Variable	Prenatal	Postnatal	p Value
No. of pts	24	34	
Females	12 (50%)	19 (55.9%)	0.66
Birth weight in kg (SD)	1.8 (0.61)	2.8 (0.88)	<0.001
GA at birth in wks (SD)	32.1 (3.1)	36.9 (3.4)	<0.001
Median LOS in NICU in days (range)	25.5 (5.5–41.5)	17 (10–48)	0.59
Mean LOS in NICU in days (SD)	34.1 (33.0)	30.9 (35)	0.73
GA at repair in wks (SD)	24.4 (0.3)	NA	
Age at repair in days (range)	NA	1 (0–2)	
Level of defect*			
Thoracic	0 (0%)	4 (11.8%)	
L1	1 (4.2%)	4 (11.8%)	
L2	5 (20.8%)	1 (2.9%)	
L3	6 (25.0%)	9 (26.5%)	
L4	6 (25.0%)	7 (20.6%)	
L5	4 (16.7%)	5 (14.7%)	
Sacral	0 (0%)	2 (5.9%)	
Not documented	2 (8.3%)	2 (5.9%)	
Lesion at L3 or lower	16 (66.7%)	23 (67.6%)	0.97

GA = gestational age; LOS = length of stay; NA = not applicable; pts = patients.

* Two patients in each group did not have data on the level of defect.

At 30 days, 1 patient in the prenatal group (5%) had been readmitted, compared with 13 (39%) in the postnatal group ($p = 0.005$; Table 2). This difference between the two groups persisted at 90 days (19% vs 57%, $p = 0.004$) and at 1 year (47% vs 85%, $p = 0.007$). The most common reason for readmission among all patients at 30 days was hydrocephalus, followed by wound dehiscence; other causes included urinary tract infection, fever, and respiratory illnesses. One patient in the postnatal group was readmitted 11 days after discharge with apneic episodes related to Chiari malformation type II and brainstem compression.

At 1 year, 5 (29%) of 17 prenatal MMC repair patients with at least 1 year of follow-up required CSF diversion, compared to 22 (81%) of 27 postnatal repair patients ($p < 0.01$; Table 3). The majority of patients requiring CSF diversion underwent placement of a ventriculoperitoneal shunt (24/27 [89%]), while a minority underwent endoscopic third ventriculostomy (ETV; 3/27 [11%]). Among those patients requiring CSF diversion, the prenatal MMC patients were heavier (7.0 vs 4.5 kg, $p = 0.02$) and older (7.2 vs 2.2 months, $p = 0.01$). Shunt survival rates were similar between the two groups. Of those patients undergoing shunt placement with 6 months of follow-up, 2 (40%) of 5 patients in the prenatal group and 10 (45%) of 22 patients in the postnatal group required revision. For those patients with at least 1 year of follow-up after shunt placement, 3 (60%) of 5 in the prenatal group required revision compared with 12 (57.1%) of 21 in the postnatal group. Of the 3

TABLE 2. Reasons for hospital readmission at 30 days, 90 days, and 1 year

Variable	Prenatal	Postnatal	p Value
30-day readmission	1 (5%)	13 (39%)	0.005
No. of pts w/ data	21	33	
Hydrocephalus related	0	6 (46%)	
Wound dehiscence	0	3 (23%)	
UTI	0	1 (8%)	
Fever	1 (100%)	0	
Respiratory illness	0	1 (8%)	
Other	0	2 (15%)	
90-day readmission	4 (19%)	17 (57%)	0.004
No. of pts w/ data	21	30	
Hydrocephalus related	2 (50%)	8 (47%)	
Wound dehiscence	0	3 (18%)	
UTI	0	1 (6%)	
Fever	2 (50%)	1 (6%)	
Respiratory illness	0	2 (12%)	
Other	0	2 (12%)	
1-yr readmission	8 (47%)	23 (85%)	0.007
No. of pts w/ data	17	27	
Hydrocephalus related	2 (25%)	11 (48%)	
Wound dehiscence	0	4 (17%)	
UTI	1 (12.5%)	3 (13%)	
Fever	2 (25%)	1 (4%)	
Respiratory illness	2 (25%)	2 (9%)	
Other	1 (12.5%)	2 (9%)	

UTI = urinary tract infection.

patients who underwent ETV (1 in prenatal group and 2 in postnatal group), none has needed revision or placement of a shunt with at least 7 months of follow-up.

Discussion

This study compares the 30-day, 90-day, and 1-year readmission rates between prenatal and postnatal MMC repair groups. We found that patients who had undergone prenatal MMC repair had significantly lower readmission rates at all endpoints following discharge from the NICU. The most common reason for readmission was hydrocephalus in both groups, followed by wound complications in the postnatal group. The prenatal repair group also needed CSF diversion at a lower rate than the postnatal repair patients, consistent with prior research.^{1,25}

Readmissions are used as a quality metric in evaluations of both surgeons and hospitals,¹⁶ and understanding such metrics is an important step in improving quality. Several studies of the pediatric neurosurgical population have evaluated causes of readmissions. A single-center study of readmissions found a rate of 11% within 30 days and 18% within 90 days.⁷ To date, no study has reported readmission rates for prenatal MMC repair patients. However, some studies have reported rates of readmission within the postnatal MMC repair population. A review of the NSQIP

TABLE 3. Differences in the CSF diversion requirement, with age and weight at the time of surgery

Variable	Prenatal	Postnatal	p Value
Requiring CSF diversion at 1 yr	5/17 (29%)	22/27 (81%)	<0.01
Weight at CSF diversion in kg (SD)	7.0 (3.6)	4.5 (2.6)	0.02
Age at CSF diversion in mos (SD)	7.2 (5.9)	2.2 (4.0)	0.01
Shunt survival at 6 mos after placement	3/5 (60%)	12/22 (55%)	
Shunt survival at 1 yr after placement	2/5 (40%)	9/21 (43%)	

database demonstrated an overall unplanned readmission rate of 11% at 30 days.⁶ While our readmission rate for postnatal MMC is higher than the rate in that study (39% vs 11%), we included admissions for hydrocephalus including elective shunt placement, likely contributing to a higher readmission rate. However, we considered these readmissions important to include, as they gave a more complete picture of the patient's overall health and time in the hospital.

Prematurity has been associated with an increased risk of readmission, both in the general pediatric population²⁸ and in the pediatric neurosurgical population.⁷ These premature patients often have medical comorbidities resulting in prolonged NICU stays and increased readmission rates. Additionally, parents and providers may be more vigilant in these populations, with a lower threshold for readmission. As previously established, our data indicated that prenatal MMC patients are more likely to be born prematurely. In a study of postnatally repaired MMC, prematurity was not associated with increased readmission rates.⁶ In our study, the decreased rate of readmissions in prenatally repaired patients is likely attributable to the lower rates of requisite CSF diversion. Complications of shunts and failed ETVs are common reasons for readmission in the pediatric neurosurgical population in general^{7,19,23,24} and the MMC population specifically.^{4,6,10,15,26}

Hydrocephalus contributed the most to the difference in readmission rates between prenatal and postnatal repair. Within the 1st year, only 2 patients who had undergone prenatal repair were readmitted for hydrocephalus-related issues, compared to 11 of the postnatally repaired patients. While the different rates of CSF diversion explain much of this difference, there were also differences in the timing of hydrocephalus treatment. We found that patients undergoing prenatal MMC repair weighed more and were older at the time of CSF diversion. MMC patients have a relatively elevated rate of revisions per patient in the 1st year of life, with a subsequent decline in shunt malfunction over a lifespan.^{4,10} Several studies have shown benefit from CSF diversions at older ages.^{2,9,17,20,21} Shunts placed into infants younger than 6 months of age increase the risk for shunt malfunction²² and infection.²⁰ Additionally, a low body weight is a risk factor for negative shunt outcomes.^{13,17} Thus, MMC patients undergoing prenatal

repair may benefit not only from a lower risk of requisite shunting, but also from a heavier weight and an older age if CSF diversion is required.

This study is limited by its single-center nature, resulting in a relatively low number of patients. With a small cohort, identifying predictive factors for readmission within each group was not feasible. Larger studies incorporating all centers performing prenatal MMC repair would be informative for counseling expectant parents about the risks and benefits of prenatal versus postnatal MMC repair. We were also only able to capture readmissions to our institution. It is possible that some patients were readmitted to other hospitals without our knowledge. However, given the medical complexity of these patients, we believe most would have been transferred to our institution if there had been a need for admission and ongoing care. Another limitation is the lack of the standardization of treatments for hydrocephalus. An individual surgeon clinically decides to treat hydrocephalus, as well as whether to place a shunt or perform ETV.

Conclusions

While patients undergoing prenatal MMC repair were born more prematurely than those undergoing postnatal MMC repair, they still had significantly lower readmission rates at 30 days, 90 days, and 1 year, despite similar NICU lengths of stay. Additionally, prenatally repaired patients required fewer CSF diversion procedures at 1 year, and when they did require CSF diversion, they were significantly heavier and older, which could contribute to greater long-term shunt survival. This study provides the first comparison of hospital readmission rates between prenatal and postnatal MMC repair patients and indicates that further study of hospital quality metrics such as readmission is important to understand the differential outcomes of these procedures.

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Disclosures

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Author Contributions

Conception and design: Quinsey, Cools, Goodnight, Elton. Acquisition of data: Cools, Mulvaney. Analysis and interpretation of data: Mulvaney. Drafting the article: Cools, Northam. Critically revising the article: Quinsey, Cools, Northam, Goodnight, Elton. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Quinsey. Statistical analysis: Mulvaney.

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