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MOMS: Obstetrical Outcomes and Risk Factors for Obstetrical Complications Following Prenatal Surgery

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Abstract

Background—The Management of Myelomeningocele Study (MOMS) was a multi-center randomized trial to compare prenatal and standard postnatal closure of myelomeningocele. The trial was stopped early at recommendation of the Data and Safety Monitoring Committee and outcome data for 158 of the 183 randomized women published.

Objective—In this report, pregnancy outcomes for the complete trial cohort are presented. We also sought to analyze risk factors for adverse pregnancy outcome among those women who underwent prenatal myelomeningocele repair.

Study Design—Pregnancy outcomes were compared between the two surgery groups. For women who underwent prenatal surgery antecedent demographic, surgical and pregnancy complication risk factors were evaluated for the following outcomes: premature spontaneous membrane rupture on or before 34 weeks 0 days (PPROM), spontaneous membrane rupture at any gestational age (SROM), preterm delivery at 34 weeks 0 days or earlier (PTD) and non-intact hysterotomy (minimal uterine wall tissue between fetal membranes and uterine serosa, or partial or complete dehiscence at delivery) and chorioamniotic membrane separation. Risk factors were evaluated using chi-square and Wilcoxon tests and multivariable logistic regression.

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Results—A total of 183 women were randomized: 91 to prenatal surgery and 92 to postnatal surgery groups. Analysis of the complete cohort confirmed initial findings: that prenatal surgery was associated with an increased risk for membrane separation, oligohydramnios, spontaneous membrane rupture, spontaneous onset of labor and earlier gestational age at birth. In multivariable logistic regression of the prenatal surgery group adjusting for clinical center, earlier gestational age at surgery and chorioamniotic membrane separation were associated with increased risk of SROM (odds ratio [OR] 1.49, 95% confidence interval [CI] 1.01-2.22; OR 2.96, 95% CI 1.05-8.35, respectively). Oligohydramnios was associated with an increased risk of subsequent PTD (OR 9.21, 95% CI 2.19 - 38.78). Nulliparity was a risk factor for non-intact hysterotomy (OR 3.68, 95% CI 1.35 – 10.05).

Conclusions—Despite the confirmed benefits of prenatal surgery, considerable maternal and fetal risk exists compared with postnatal repair. Early gestational age at surgery and development of chorioamniotic membrane separation are risk factors for ruptured membranes. Oligohydramnios is a risk factor for preterm delivery and nulliparity is a risk factor for non-intact hysterotomy at delivery.

Keywords

prenatal surgery; fetal therapy; fetal spina bifida; fetal myelomeningocele

Introduction

The NIH-sponsored Management of Myelomeningocele Study (MOMS) was initiated in 2003 to compare the safety and efficacy of prenatal repair of myelomeningocele with that of standard postnatal repair. The trial was stopped in 2010 before reaching the target sample size, at the recommendation of its Data and Safety Monitoring Committee (DSMC) according to prespecified stopping rules for the efficacy of prenatal surgery. Results of the trial were reported (8) based on 158 women who had undergone randomization before July 1, 2009, as this was the cohort analyzed for the DSMC. Findings in that report demonstrated a significant improvement in the primary outcomes at 12 and 30 months of age, and in multiple secondary outcomes, including reversal of hindbrain herniation and ambulation by 30 months, in the prenatal repair group. However, prenatal surgical intervention was associated with significantly higher rates of oligohydramnios and chorioamniotic separation, as well as spontaneous membrane rupture and preterm delivery ($p<0.001$). Moreover, of those in the prenatal surgery group, only 64% had an intact, well-healed hysterotomy site from the prenatal repair surgery observed at cesarean delivery.

The initial MOMS report summarized the pregnancy outcomes of 86% of the 183 randomized. The primary objective of the current report is to update the final pregnancy outcome results from the MOMS trial, as well as to analyze risk factors for preterm premature rupture of membranes, spontaneous membrane rupture at any gestation, early preterm delivery, and uterine dehiscence among those women who underwent prenatal repair. It is the authors' view that these additional components are anticipated to enhance the knowledge of benefits, risk assessment, and informed consent process for future families considering fetal myelomeningocele repair, where maternal and fetal characteristics match those set forth in the inclusion and exclusion criteria of the trial.

Material and Methods

Study population and design

Patient recruitment, study procedures, details of the primary and secondary outcome parameters, as well as the perioperative management algorithm for prenatal myelomeningocele surgery have been described in detail in the previous MOMS trial publication (8). Briefly, eligible pregnant women with a fetus diagnosed with myelomeningocele and between 19 and 25 weeks of gestation were randomized at one of the three MOMS clinical centers to either prenatal or postnatal surgical repair. Women randomized to the postnatal surgery group went home and returned at 37 weeks of gestation to their maternal-fetal surgery center for cesarean delivery and postnatal repair by the center's neurosurgical team. Given the anticipated increased risk of preterm labor, patients randomized to prenatal myelomeningocele surgery remained close to the MOMS center to permit standardized management after the surgery, including tocolysis therapy, weekly ultrasound evaluations, and delivery at 37 weeks of gestation if still undelivered. In addition to the usual content of a prenatal care visit and assessment of post-surgery maternal well being, a targeted ultrasound was performed to evaluate amniotic fluid volume and the status of the hysterotomy and membranes, to assess for potential oligohydramnios, dehiscence or chorioamniotic membrane separation, during the weekly out-patient visits.

When chorioamniotic membrane separation was seen by ultrasound, patients were placed initially on outpatient bed rest. If the membrane separation progressed and extended to the placental cord insertion site, patients were admitted and placed on bed rest, with fetal heart rate testing obtained every shift or if decreased fetal movement was reported by the patient. Diagnosis of oligohydramnios was managed by hospital admission with assessment of fetal heart rate or non-stress tests every shift when the amniotic fluid index was less than 5 cm. Tocolytic therapy using indomethacin prior to 32 weeks gestation and/or magnesium sulfate was initiated for palpable contractions with documented cervical change. Preterm labor unresponsive to tocolytics or due to chorioamnionitis, suspected uterine rupture, placental abruption or a non-reassuring fetal status was treated by cesarean delivery. If the patient experienced rupture of membranes at less than 34 weeks of gestation, she was managed expectantly until 34 weeks of gestation at which time she was delivered by cesarean section. If preterm labor was diagnosed and the likelihood of delivery was high prior to 32 weeks (e.g. PPROM, vaginal spotting, or non-reassuring antepartum fetal surveillance), a single course of betamethasone therapy was given to minimize complications of prematurity.

At 37 weeks gestation, delivery took place by elective cesarean section because of the presence of the hysterotomy scar. Although the same abdominal laparotomy incision was used for the cesarean delivery as for the prenatal surgery, the fetus was preferably delivered via a lower uterine segment incision.

Statistical analysis

The updated analysis comparing the prenatal versus postnatal repair groups was performed according to the intention-to-treat principle. Relative risks (RR) and 95% CIs were calculated.

For the analysis within the prenatal repair group of risk factors for adverse pregnancy outcome, only women who actually underwent prenatal surgical repair were included. We evaluated risk factors for five outcomes: chorioamniotic membrane separation defined as separation from the uterine wall that did not spontaneously resolve on or before 34 weeks 0 days (CMS), preterm premature rupture of membranes (PPROM), defined as any spontaneous rupture on or before 34 weeks 0 days; spontaneous membrane rupture at any gestational age (SROM); preterm delivery at 34 weeks 0 days or before; and non-intact hysterotomy defined as very thin uterine wall with minimal tissue present between the fetal membranes and uterine serosa, or partial or complete dehiscence of the hysterotomy site at delivery.

A core of ten risk factors was evaluated for every outcome. Obstetrical and demographic risk factors were maternal age, body mass index at the time of randomization, nulliparity, previous cesarean delivery, pre-operative cervical length, and gestational age at surgery. Risk factors associated with the prenatal surgery included posterior versus anterior fundal hysterotomy, duration of uterine surgery (hysterotomy incision to closure) and total duration of surgery (maternal skin incision to closure), time on magnesium sul-fate tocolysis post surgery. Additionally, oligohydramnios (amniotic fluid index < 5cm) and chorioamniotic membrane separation were included for all outcomes except CMS. For all outcomes, oligohydramnios and chorioamniotic membrane separation had to occur prior to the outcome to be considered as a risk factor. In addition to the twelve risk factors listed above, we included spontaneous labor and spontaneous membrane rupture as risk factors for non-intact hysterotomy. In univariable analysis, continuous variables were compared with the Wilcoxon test; categorical variables were compared with the chi-square or Fisher's exact test as appropriate.

Any risk factor that was found to be associated (with $p < 0.10$) with one of the five outcomes in univariable analysis was included in a multivariable logistic regression for that outcome. However because the total duration of prenatal surgery and the duration of uterine surgery were highly correlated, only total duration of surgery was included in the multivariable logistic regression. To take into consideration potential differences in surgery practice across the MOMS centers, each logistic regression model was adjusted by clinical center. Adjusted OR and 95% CI were calculated.

For all analyses a nominal p-value of less than 0.05 was considered to indicate statistical significance. No adjustment was made for multiple comparisons.

Results

One hundred eighty-three women were randomized, including 91 in the prenatal surgery group and 92 in the postnatal surgery group, representing an additional 25 women compared with the previous report. For the full MOMS cohort, baseline characteristics are presented in Table 1 and pregnancy complications and outcomes by surgery group are shown in Table 2. As previously published, there are no differences between the surgery groups except for spina bifida lesion level L3 or lower and female gender, both of which were more common in the postnatal surgery group. As in the original report, this updated analysis shows that

patients that underwent prenatal surgical myelomeningocele repair were at significantly increased risk for chorioamniotic membrane separation, oligohydramnios, spontaneous rupture of membranes, spontaneous onset of labor and earlier gestational age at birth. Significant prematurity risk was observed in the prenatal surgery group, with 11% of prenatal surgery births occurring before 30 weeks, 38% between 30 weeks 0 days and 34 weeks 6 days, 32% from 35 weeks to 36 weeks 6 days and only 17% delivering at 37 weeks or later. The hysterotomy site was evaluated in 88 patients; only 65% of women in the prenatal surgery group were described as having an intact, well-healed hysterotomy at time of cesarean delivery. Non-intact hysterotomy was reported in 31 (35%) with complete (N=2) or partial dehiscence (N=8) reported in 10 women (11%). There was also a significant increase in placental abruption, pulmonary edema, and need for maternal transfusion in the prenatal repair group.

Of the 91 women assigned to the prenatal surgery group, one woman refused prenatal surgery after randomization and for one woman, surgery was initiated but was abandoned before the hysterotomy was accomplished because of fetal distress. Analyses of risk factors for CMS, PPROM, SROM, preterm delivery ≤ 34 weeks 0 days, and non-intact hysterotomy in the remaining 89 women are shown in Tables 3,4,5,6,7. Seventy-two (81%) of these women experienced at least one of the five outcomes. Results of the multivariable logistic regression are shown in Table 8.

Chorioamniotic membrane separation ≤ 34 weeks 0 days (CMS) occurred at a mean of 3.6 days after surgery (SD 2.7). Only longer duration of postoperative magnesium sul-fate tocolytic therapy was associated with an increased risk of CMS (Table 3); but this was no longer significant in the logistic regression analysis adjusting for clinical center (Table 8).

In the univariable analysis of risk factors for PPROM, total surgery duration, and uterine surgery duration were associated with PPROM (Table 4). In the multivariable logistic regression analysis surgery time was not significant.

In univariable analyses, earlier gestational age at the time of prenatal surgery, chorioamniotic membrane separation and length of both total and uterine surgery were associated with SROM (Table 5). In the multivariable model, nulliparity, gestational age at prenatal surgery and chorioamniotic membrane separation were significant. Nulliparity was associated with 65% decrease in odds for spontaneous rupture than multiparity. Later gestational age at prenatal surgery was associated with a decrease in odds for spontaneous rupture of 4.7% for every day later of gestational age that surgery was performed. Membrane separation was associated with an approximate 3-fold increase in odds compared with those who did not have membrane separation. Length of surgery was not significant.

For preterm birth at or before 34 weeks 0 days, in univariable analysis, total length of surgery, uterine surgery time, and oligohydramnios were all associated with an increased risk (Table 6). In the multivariable analysis, only oligohydramnios remained significant, with an increase in odds of over 9 fold compared with those who were not diagnosed with oligohydramnios.

In the univariable analysis of risk factors for non-intact hysterotomy, nulliparity and greater duration of postoperative magnesium sulfate tocolytic therapy were associated with increased risk (Table 7). In multivariable logistic regression analysis adjusting for clinical center, nulliparous women had an increase in odds of non-intact hysterotomy of almost 4 fold, compared with multiparous women.

Discussion

The current analyses summarize the overall pregnancy outcomes and complications for the entire MOMS population. Our results indicate that half of the children that underwent prenatal surgery are born before 35 weeks, with 11% delivered before 30 weeks of gestation. Chorioamniotic membrane separation, which increases the risk of spontaneous rupture of membranes, was observed in one third of pregnancies that underwent prenatal surgery. Further, despite a multilayered closure of the uterus at the time of fetal intervention, oligohydramnios and various degrees of uterine dehiscence were seen in 20% and 11%, respectively. This relationship is not surprising given that any degree of hysterotomy separation would allow the amniotic fluid to leak into the maternal abdomen. Importantly, there were no maternal deaths or uterine ruptures in the trial participants.

Earlier gestational age at the time of prenatal surgery and chorioamniotic membrane separation are associated with subsequent spontaneous membrane rupture. Recent publications of large patient cohorts post-MOMS have found PPROM rates of 32.3% (31/96)[2] and 30.7% (27/88)[3] which are similar to our present finding of 28.0% (25/89) suggesting little progress in decreasing PPROM given present protocols. However, the rate of CMS may be decreasing as we found an incidence of 33.0% compared to their incidence of 22.9% (22/96)[2] and 23.6% (21/89)[3] respectively. Soni, et al[3] also demonstrated a linear relationship of gestational age at prenatal surgery to the incidence of CMS and PPROM with a risk of 60% when surgery is performed at 20-21 weeks compared to 0% at 25 weeks 6 days, the latest gestational age that prenatal myelomeningocele is offered, and based on the analysis of their curve suggested delaying fetal repair until ≥23 weeks to decrease these complications and increase chances of benefit by decreasing preterm deliveries. Development of oligohydramnios places patients at increased risk for preterm delivery by 34 weeks. Why the nulliparous uterus is at higher risk for non-intact hysterotomy is not clear; however, nulliparous patients should be counseled that they may be at higher risk for hysterotomy complications following prenatal surgery.

There are limitations to this analysis. The results of the MOMS trial cannot be generalized to individuals who will undergo prenatal myelomeningocele surgery at centers that have less experience with the technique or patients who fall outside the eligibility criteria set forth by the MOMS study at this time. Outcome may be less favorable than those in the trial and maternal and fetal morbidity and mortality may be greater. Safety and effectiveness in populations which lie outside the MOMS criteria will need to be established gradually and conservatively, ideally by experienced interdisciplinary teams working in collaboration on outcome studies of changes to the original MOMS protocol.

Existing and emerging programs need to assure sufficient referral volumes and/or robust simulation programs to maintain the necessary expertise of their multidisciplinary teams. Therefore, for patient safety and optimal outcome, prenatal myelomeningocele surgery should be limited to high-volume prenatal surgery centers with an interdisciplinary team of experts who follow standardized protocols to perform prenatal myelomeningocele surgery. Nonetheless, it also seems likely that as experience grows, further technical developments will allow for refinements in surgical method and medical management, which will improve results and an increased safety profile. In addition, innovations in minimally invasive fetoscopic techniques for myelomeningocele prenatal coverage may decrease the incidence of CMS, PPROM and preterm delivery and improve future outcomes and reduce maternal morbidity.

Although our data provide a number of important observations regarding the impact of prenatal myelomeningocele surgery on short-term maternal and fetal complications, additional studies are warranted to evaluate subsequent maternal reproductive and pregnancy outcomes such as fertility, spontaneous abortion and recurrent uterine dehiscence as described by Wilson, et al[4]. The ongoing MOMS2 study will analyze these issues as part of the follow-up of women and their children in the MOMS trial at 6 – 10 years of age.

In summary, prenatal myelomeningocele surgery is a complex surgical procedure that requires an experienced multidisciplinary team with a dual focus on both the maternal and fetal patients. Despite the confirmed benefits of prenatal myelomeningocele surgery, considerable maternal and fetal risk exists. PPROM, oligohydramnios, uterine dehiscence and preterm labor continue to be major counseling issues for prenatal surgery candidates. The information presented in the original MOMS report, and updated and expanded here, may be of value in the essential task of providing appropriate counseling to prospective patients and families. Appropriate patient selection continues to be important to maintaining favorable outcomes, as does the provision of care in experienced high-volume centers with broad and well-integrated multidisciplinary teams. Developing innovations in minimally invasive fetoscopic techniques for myelomeningocele prenatal repair may decrease the incidence of complications and continue to improve long term outcomes in the future.

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Table 1

Demographic Data and Baseline Characteristics*

	Prenatal Surgery (N=91)	Postnatal Surgery (N=92)
Fetal sex female	42 (46.2)	57 (62.0)
Gestational age at randomization – wks	23.7 ± 1.4	23.9 ± 1.3
Maternal age at screening – yrs	29.2 ± 5.2	28.7 ± 4.8
Race/Ethnicity		
White Non-Hispanic	85 (93.4)	86 (93.5)
Black Non-Hispanic	1 (1.1)	1 (1.1)
Hispanic	3 (3.3)	4 (4.3)
Other	2 (2.2)	1 (1.1)
Married or living with partner	84 (92.3)	86 (93.5)
Years of schooling	14.9 ± 1.7	14.9 ± 1.7
Body Mass Index at screening – kg/m^2	26.3 ± 3.7	26.3 ± 3.9
Currently smoking	6 (6.6)	5 (5.4)
Either parent with familial history of NTD	9 (9.9)	16 (17.4)
Nulliparous	37 (40.7)	37 (40.2)
Previous uterine surgeries (including cesarean)	12 (13.2)	11 (12.0)
Cervical length (mm, transvaginal)	39.5 ± 7.6	39.4 ± 5.9
Anterior placenta	43 (47.3)	39 (42.4)
Lesion level L3 or lower	62 (68.1)	76 (82.6)
Any clubfoot on ultrasound	24 (26.4)	19 (20.7)

* Intent to treat analysis of full randomized cohort; data presented as n (%) or mean ± SD.

Table 2

Pregnancy Complications and Outcomes*

	Prenatal Surgery (N=91)	Postnatal Surgery (N= 92)	Relative Risk (95% CI)	p-value
Chorioamniotic membrane separation	30 (33.0)	0 (0.0)	NA	<0.0001
Pulmonary edema	5 (5.5)	0 (0.0)	NA	0.03
Any monthly biophysical profile < 8	14 (15.4)	8 (8.7)	1.77 (0.78-4.01)	0.17
Oligohydramnios	19 (20.0)	3 (3.3)	6.40 (1.96-20.89)	<0.001
Placental abruption	6 (6.6)	0 (0.0)	NA	0.01
Gestational diabetes	7 (7.7)	5 (5.4)	1.42 (0.47-4.30)	0.54
Chorioamnionitis	2 (2.2)	0 (0.0)	NA	0.25
Preeclampsia / gestational hypertension	3 (3.3)	1 (1.1)	3.03 (0.32-28.62)	0.37
Spontaneous membrane rupture	40 (44.0)	7 (7.6)	5.78 (2.73-12.22)	<0.0001
Spontaneous labor	39 (42.9)	13 (14.1)	3.03 (1.74-5.29)	<0.0001
Maternal transfusion at delivery	8 (8.8)	1 (1.1)	8.09 (1.03-63.37)	0.02
Description of hysterotomy			NA	N/A*
Intact, well healed	57/88 (64.8)			
Very thin	21/88 (23.9)			
Some dehiscence	8/88 (9.1)			
Complete dehiscence	2/88 (2.3)			
Gestational age at birth - wks	34.0 ± 3.0	37.3 ± 1.1		<0.0001
Gestational age at birth			NA	<0.0001*
< 30 wks	10 (11.0)	0 (0.0)		
30 wks 0 days - 34 wks 6 days	35 (38.5)	4 (4.3)		
35 wks 0 days - 36 wks 6 days	29 (31.9)	11 (12.0)		
≥ 37 wks	17 (18.7)	77 (83.7)		

*Intent to treat analysis of full randomized cohort; data presented as n (%) or mean ± SD.

Table 3

CMS at or before 34 weeks 0 days by Risk Factor

Factors	Membrane Separation N = 20	Membrane Separation N = 69	p-value
Maternal age (yrs)	29.4 ± 6.6	29.3 ± 4.9	0.98
Body mass index (kg/m^2)	26.1 ± 3.7	26.3 ± 3.8	0.98
Parity			0.28
Nulliparous	6/36 (16.7)	30/36 (83.3)	
Multiparous	14/53 (26.4)	39/53 (73.6)	
Previous cesarean delivery			0.46
Yes	4/12 (33.3)	8/12 (66.7)	
No	16/77 (20.8)	61/77 (79.2)	
Pre-operative cervical length (mm)	41.1 ± 7.8	39.1 ± 7.6	0.44
Gestational age at surgery (wks)	23.5 ± 1.7	24.1 ± 1.2	0.23
Gestational age at surgery			0.10
< 24 weeks	12/39 (30.8)	27/39 (69.2)	
≥ 24 weeks	8/50 (16.0)	42/50 (84.0)	
Hysterotomy location			0.40
Posterior/fundal	12/46 (26.1)	34/46 (73.9)	
Anterior	8/43 (18.6)	35/43 (81.4)	
Total duration of surgery (min)	110.9 ± 25.0	103.1 ± 24.3	0.12
Duration uterine surgery (min)	64.8 ± 22.3	58.2 ± 22.3	0.17
Time on MgSO4 tocolysis (hrs)	21.0 ± 3.6	22.5 ± 3.2	0.02

Per protocol analysis of the 89 women who underwent prenatal surgery; data presented as n (%) or mean ± SD

Table 4

PPROM at or before 34 weeks 0 days by Risk Factor

Factors	PPROM N = 25	No PPROM N = 64	p-value
Maternal age (yrs)	28.9 ± 5.7	29.5 ± 5.1	0.56
Body mass index (kg/m^2)	26.5 ± 4.0	26.2 ± 3.6	0.77
Parity			0.31
Nulliparous	8/36 (22.2)	28/36 (77.8)	
Multiparous	17/53 (32.1)	36/53 (67.9)	
Previous cesarean delivery			1.00*
Yes	3/12 (25.0)	9/12 (75.0)	
No	22/77 (28.6)	55/77 (71.4)	
Pre-operative cervical length (mm)	40.0 ± 7.9	39.4 ± 7.6	0.70
Gestational age at surgery (wks)	23.7 ± 1.3	24.1 ± 1.4	0.19
Gestational age at surgery			0.15
< 24 weeks	14/39 (35.9)	25/39 (64.1)	
≥ 24 weeks	11/50 (22.0)	39/50 (78.0)	
Hysterotomy location			0.66
Posterior/fundal	12/46 (26.1)	34/46 (73.9)	
Anterior	13/43 (30.2)	30/43 (69.8)	
Total duration of surgery (min)	117.2 ± 25.7	100.3 ± 22.6	0.005
Duration of uterine surgery (min)	71.3 ± 25.2	55.5 ± 19.8	0.008
Time on MgSO4 tocolysis (hrs)	21.4 ± 3.0	22.6 ± 3.3	0.14
Oligohydramnios before PPROM			0.23
Yes	7/17 (41.2)	10/17 (58.8)	
No	18/72 (25.0)	54/72 (75.0)	
Membrane separation before PPROM			0.06
Yes	9/20 (45.0)	11/20 (55.0)	
No	16/69 (23.2)	53/69 (76.8)	

Per protocol analysis of the 89 women who underwent prenatal surgery; data presented as n (%) or mean ± SD

Table 5

Spontaneous Rupture of the Membranes (SROM) at any Gestational Age by Risk Factor

Factors	SROM N = 40	No SROM N = 49	p-value
Maternal age (yrs)	30.3 ± 5.6	28.5 ± 4.8	0.13
Body mass index (kg/m^2)	26.5 ± 3.7	26.0 ± 3.7	0.58
Parity			0.07
Nulliparous	12/36 (33.3)	24/36 (66.7)	
Multiparous	28/53 (52.3)	25/53 (47.7)	
Previous cesarean delivery			0.81
Yes	5/12 (41.7)	7/12 (58.3)	
No	35/77 (45.4)	42/77 (54.6)	
Pre-operative cervical length (mm)	39.4 ± 8.1	39.7 ± 7.3	0.75
Gestational age at surgery (wks)	23.5 ± 1.5	24.3 ± 1.2	0.02
Gestational age at surgery			0.02
< 24 weeks	23/39 (59.0)	16/39 (41.0)	
≥ 24 weeks	17/50 (34.0)	33/50 (66.0)	
Hysterotomy location			0.12
Posterior/fundal	17/46 (37.0)	29/46 (63.0)	
Anterior	23/43 (53.5)	20/43 (46.5)	
Total duration of surgery (min)	112.0 ± 26.9	99.2 ± 21.1	0.02
Duration uterine surgery (min)	66.4 ± 25.3	54.4 ± 18.3	0.04
Time on MgSO4 tocolysis (hrs)	22.1 ± 3.4	22.3 ± 3.2	0.72
Oligohydramnios			0.12
Yes	4/15 (26.7)	11/15 (73.3)	
No	36/74 (48.7)	38/74 (51.4)	
Membrane separation			0.01
Yes	19/30 (63.3)	11/30 (36.7)	
No	21/59 (35.6)	38/59 (64.4)	

Per protocol analysis of the 89 women who underwent prenatal surgery; data presented as n (%) or mean ± SD

Table 6

Preterm Delivery at or before 34 Weeks 0 Days by Risk Factor

Factors	Delivery ≤ 34w 0d N=38	Delivery > 34w 0d N=51	p-value
Maternal age (yrs)	28.3 ± 5.3	30.0 ± 5.1	0.10
Body mass index (kg/m^2)	26.8 ± 4.0	25.8 ± 3.5	0.18
Parity			0.78
Nulliparous	16/36 (44.4)	20/36 (55.6)	
Multiparous	22/53 (41.5)	31/53 (58.5)	
Previous cesarean delivery			0.48
Yes	4/12 (33.3)	8/12 (66.7)	
No	34/77 (44.2)	43/77 (55.8)	
Pre-operative cervical length (mm)	39.9 ± 7.5	39.3 ± 7.7	0.67
Gestational age at surgery (wks)	23.9 ± 1.3	24.0 ± 1.5	0.69
Gestational age at surgery			0.31
< 24 weeks	19/39 (48.7)	20/39 (51.3)	
≥ 24 weeks	19/50 (38.0)	31/50 (62.0)	
Hysterotomy location			0.31
Posterior/fundal	22/46 (47.8)	24/46 (52.2)	
Anterior	16/43 (37.2)	27/43 (62.8)	
Total duration of surgery (min)	112.2 ± 26.4	99.6 ± 21.9	0.02
Duration uterine surgery (min)	66.1 ± 24	55.2 ± 20.1	0.03
Time on MgSO4 tocolysis (hrs)	21.6 ± 3.2	22.7 ± 3.25	0.21
Oligohydramnios before PPROM			<0.001
Yes	14/17 (82.4)	3/17 (17.7)	
No	24/72 (33.3)	48/72 (66.7)	
Membrane separation before PPROM			0.08
Yes	12/20 (60.0)	8/20 (40.0)	
No	26/69 (37.6)	43/69 (62.3)	

Data presented as n (%) or mean ± SD

Table 7

Non-Intact Hysterotomy by Risk Factor

Factors	Non-intact hysterotomy N = 31	Intact hysterotomy N = 57	p-value
Maternal age (yrs)	29.7 ± 6.1	29.1 ± 4.8	0.61
Body mass index (kg/m^2)	26.7 ± 2.9	26.0 ± 4.1	0.27
Parity			0.004
Nulliparous	19/36 (52.8)	17/36 (47.2)	
Multiparous	12/52 (23.1)	40/52 (76.9)	
Previous cesarean delivery			0.20
Yes	2/12 (16.7)	10/12 (83.3)	
No	29/76 (38.2)	47/76 (61.8)	
Pre-operative cervical length (mm)	40.7 ± 7.7	38.9 ± 7.7	0.40
Gestational age at surgery (wks)	24.0 ± 1.4	24.0 ± 1.4	0.97
Gestational age at surgery			0.47
< 24 weeks	15/38 (39.5)	23/39 (60.5)	
≥ 24 weeks	16/50 (32.0)	34/50 (68.0)	
Hysterotomy location			0.41
Posterior/fundal	14/45 (31.1)	31/45 (68.9)	
Anterior	17/43 (39.5)	26/43 (60.5)	
Total duration of surgery (min)	108.2 ± 25.3	103.7 ± 23.9	0.31
Duration uterine surgery (min)	62.7 ± 24.4	58.5 ± 21.3	0.42
Time on MgSO4 tocolysis (hrs)	23.1 ± 2.6	21.8 ± 3.5	0.02
Spontaneous labor			0.99
Yes	13/37 (35.1)	24/37 (64.9)	
No	18/51 (35.3)	33/51 (64.7)	
SROM			0.09
Yes	10/39 (25.6)	29/39 (74.4)	
No	21/49 (42.9)	28/49 (57.1)	
Oligohydramnios			0.48
Yes	8/19 (42.1)	11/19 (57.9)	
No	23/69 (33.3)	46/69 (66.7)	
Membrane separation			0.92
Yes	10/29 (34.5)	19/29 (65.5)	
No	21/59 (35.6)	38/59 (64.4)	

Data presented as n (%) or mean ± SD

Table 8

Logistic Regression Analysis Adjusted for MOMS Center

Model	Adjusted OR	95% CI	p-value
Chorioamniotic Membrane Separation			
Time on MgSO4 tocolysis (hrs)	0.92	0.71 – 1.20	0.55
PPROM			
Total duration of surgery (min)	1.03	0.995 – 1.07	0.09
Membrane separation	1.78	0.57 – 5.58	0.32
SROM			
Nulliparous	0.35	0.13 – 0.99	0.05
Gestational age at surgery (wks)	0.67	0.45 – 0.99	0.04
Total duration of surgery (min)	1.03	0.99 – 1.06	0.16
Membrane separation	2.96	1.05 – 8.35	0.04
PTD ≤ 34.0 weeks			
Maternal age (yrs)	0.97	0.88 – 1.07	0.54
Total duration of surgery (min)	1.03	0.99 – 1.07	0.11
Oligohydramnios	9.21	2.19 – 38.78	0.003
Membrane separation	1.82	0.55 – 6.06	0.33
Non-intact hysterotomy			
Nulliparous	3.68	1.35 – 10.05	0.01
SROM	0.60	0.22 – 1.69	0.34
Time on MgSO4 tocolysis (hrs)	0.95	0.75 – 1.22	0.70