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Low Transverse versus Midline Abdominal Skin Incisions for in utero Spina Bifida Repair

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Keywords
Fetal surgery · Spina bifida · Myelomeningocele · Skin incisions · Wound complications · Scar assessment

Abstract
Objective: The 2 types of maternal skin incisions for in utero spina bifida repair are low transverse (LT) incision perceived to be cosmetic benefit and midline longitudinal (ML) incision, typically associated with a reduction in surgical time and lower blood loss. Our objective was to compare short- and long-term outcomes associated with these 2 types of skin incisions following in utero spina bifida repair. ***Methods:*** Prospective observational cohort of 72 patients undergoing fetal spina bifida repair at a single institution between September 2011 and August 2018. The decision for the type of incision was at the discretion of the surgeons. The primary outcome was total operative time. Secondary outcomes included an analog scale of wound pain score on postoperative day 3, duration of postoperative stay, and postoperative wound complications within the first 4 weeks. The Patient Scar Assessment Questionnaire, a validated questionnaire, was obtained for all patients (≥6 months from delivery) using 4 categories (appearance, consciousness, satisfaction with appearance and with symptoms), with higher scores reflecting a poorer perception of the scar. ***Results:*** There were 43 women (59.7%) in the LT group and 29 (40.3%) in the ML group. In all patients, the same incision was used during cesarean delivery. The total operative time was higher in the LT group by 33 min ($p < 0.001$), primarily due to abdominal wall incision time (open and closure). No significant differences were found between the groups in pain score, length of postoperative stay, or the rate of wound complications. Fifty-three patients (73.6%) responded to the questionnaire, 36/43 from the LT group and 17/29 from the ML group. There was no difference in the scores of appearance, consciousness, and satisfaction with appearance and symptoms between the groups. ***Conclusion:*** ML incisions shorten operative times without altering long-term incision-related satisfaction when compared to LT incisions.

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Introduction

The randomized trial of prenatal versus postnatal myelomeningocele repair, the Management of Myelomeningocele Study (MOMS trial) [1], has established in utero fetal spina bifida repair as the new standard of care option for select patients [2]. In utero spina bifida repair was associated with a reduced need for hydrocephalus-related shunting by 1 year, along with improvement in neurological function at 30 months when compared to the postnatally repaired cohort [3]. The optimal surgical approach for women undergoing in utero spina bifida repair remains controversial. One aspect of that controversy includes the type of abdominal incision used.

There are 2 types of maternal skin incisions commonly used for fetal surgery, a midline longitudinal (ML) incision, and a low transverse (LT) incision. In the previous studies evaluating skin incisions for cesarean deliveries, abdominal midline skin incisions were associated with a reduced surgical time from incision to hysterotomy and less blood loss, but with a higher risk for wound complications compared to LT incisions that may also have cosmetic benefit [4–7].

In the MOMS trial and the largest reported cohort of women post the MOMS trial, midline skin incisions were used for women with a BMI greater than 30, or with a previous midline incision, while Bennett et al. [8] used a midline skin incision for all women using a modified uterine surgical approach [1, 9]. We surmised that the rapidly growing fetus along with other physiological changes in pregnancy may influence wound healing and on related complications. There are no available studies assessing the use of these 2 types of skin incisions as a result of fetal surgery. Our objective was to compare short- and long-term outcomes associated with these 2 types of skin incisions performed during in utero spina bifida repair.

Methods

Study Design and Patient Population

This was a prospective study of all women undergoing prenatal in utero spina bifida repair from September 2011 to August 2018 at The Fetal Center, McGovern Medical School in Houston, TX, USA.

Women with a referring diagnosis of fetal myelomeningocele underwent a detailed ultrasound evaluation. In utero spina bifida repair was offered to patients who satisfied the MOMS' inclusion criteria [10]. In addition, we offered in utero spina bifida repair to patients with a prepregnancy BMI between 35 and 40, under an institutional review board-approved protocol. All women were approached by the study's team members for participation in an observational study, which included yearly outcome surveys housed in the institution's Research Electronic Data Capture (REDCap) system. The details of the surgical procedure performed to repair spina bifida defects in utero were similar to what has been described in the MOMS' study [10]. Briefly, all women underwent presurgical epidural catheter placement for postoperative pain management, and general anesthesia was administered prior to the procedural start. Intravenous cephazolin (1,000 mg) was administered preoperatively. A sterile ultrasound transducer was used to map the fetus's position in addition to the placenta. Prior to incision, the patient received tocolysis consisting of a magnesium drip dispensing a 6 g bolus over 30 min, followed by a continuous infusion of 2 g/h throughout the operation. The type of incision was at the discretion of the surgeons, which included either a ML or LT skin incision. For the ML incision, the skin was incised 1 inch above the symphysis pubis to the umbilicus level. Then, to expose the rectus muscle, the subcutaneous fatty layer was dissected using electrocautery, followed by entry into the peritoneal cavity with a midline vertical incision through the fascia. If performing a LT incision, the surgeon would incise the abdomen approximately 2 inches above the symphysis pubis and extend the incision laterally to about 1–2 inches from the anterior superior iliac spine. Subcutaneous fatty layer dissection off the deeper fascial layer up to the umbilicus was performed superiorly, whereas to the symphysis pubis it was dissected inferiorly to facilitate exposure. Then, the rectus fascial layer was entered into through the midline. The uterus was exposed, and the position of the fetus was reconfirmed by ultrasound. Fetal version was performed to bring the fetal lesion to the fundal part of the uterus for easier access if needed. An Alexis® O™ C-Section Retractor (Rancho Santa Margarita, CA, USA) was placed in order to expose the uterus. A hysterotomy was then performed under sonographic guidance by electrocautery between 2 trans-uterine sutures in the location of the hysterotomy, followed by the use of a uterine stapler (Covidien Auto Suture, Norwalk, CT, USA). Thereafter, the fetus was given an intramuscular injection of fentanyl (20 mcg/kg) and vecuronium (0.2 mg/kg). The myelomeningocele was repaired under microscope visualization. The neural placode was dissected from the surrounding tissue, and then, the dura and fascia layers were identified and closed using a running suture. Skin closure was performed using a running Monocryl suture. If it was not possible to obtain skin closure, relaxing incisions were made, or a patch was utilized (Alloderm [Life Cell, Branchburg, NJ, USA] or AmnioGuard [TissueTech Inc, Miami, FL, USA]) to facilitate closure. Following repair of the myelomeningocele defect, the fetus was repositioned back within the uterine cavity. During the entire procedure, ultrasonography was used to monitor the fetus. Prior to closure of the uterus, 1 g of vancomycin in warm Lactated Ringers Solution was injected into the uterine cavity. The uterine incision was closed using 0-polydioxanone with continuous locking and multiple mattress sutures to buttress the primary closure. This was then followed by suturing the omentum over the uterine incision using 2-O polyglactin, followed by closure of the fascia using 0-looped polydioxanone. For lower transverse skin incisions, to reduce the risk of seroma formation due to a large potential space in the subcutaneous layer, in some of the cases, Jackson-Pratt (Cardinal Health, Dublin, OH, USA) was placed bilaterally for drainage purposes. For both types of skin incisions, the subcutaneous fatty layer was closed using 2-O polyglactin suture in a continuous running fashion. Finally, the

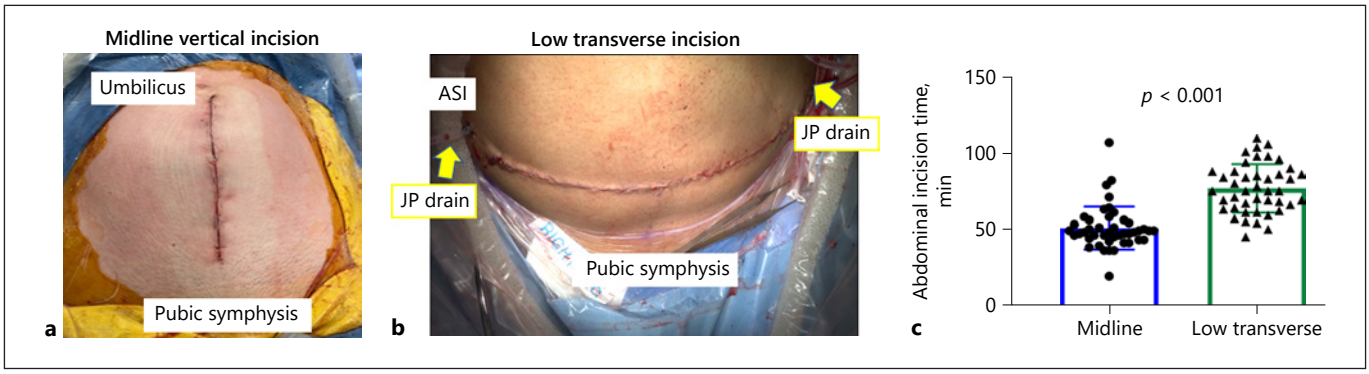

Fig. 1. The appearance of the abdominal incisions and the surgical times required to perform them during in utero spina bifida repair. **a** Representative image of a midline vertical abdominal skin incision. **b** Representative image of a LT abdominal skin incision. **c** Abdominal incision times required to perform midline versus LT skin incisions (n = 29 for midline skin incision; n = 43 for LT skin incision; test performed ex. Unpaired student's T test ± SD or SEM). LT, low transverse.

skin layer was closed using a 4-O poliglecaprone suture in a continuous running fashion, followed by applying adhesive 2-octyl cyanoacrylate (Dermabond, Johnson and Johnson, Passaic, NJ, USA) to the skin edges.

Postoperatively, the patient was moved to recovery. Cephazolin (1 g every 6 h for a total of 4 doses) was administered in addition to intravenous magnesium for a 24 h period. Indomethacin was given at 50 mg preoperatively, and subsequent to surgery it was provided at 25 mg every 6 h for 48 h. Oral nifedipine (10–20 mg every 4–6 h) was also prescribed following the procedure. Epidural was kept in place for postoperative pain management until postoperative day 3. Tylenol and Oxycodone were used for pain as necessary. All patients remained in the hospital until they were able to ambulate in addition to having good postoperative pain management on oral medications. Jackson-Pratt drains were removed before the patient was discharged. Outpatient follow-up was scheduled within a week from discharge. Abdominal incisions were assessed for dehiscence, seroma collection, or infection during this visit and all subsequent weekly visits prior to delivery.

All women that underwent prenatal repair were scheduled for delivery by cesarean section at 37 weeks. The same abdominal skin incision made during prenatal surgery was used for cesarean delivery. If the patient experienced preterm labor, chorioamnionitis, suspected uterine rupture, placental abruption, or a nonreassuring fetal status prior to 37 weeks, she was delivered via cesarean section according to the recommended guidelines.

Depending on the patient's preference, the validated Patient Scar Assessment Questionnaire (PSAQ) [11] was completed either by email or telephonically. The PSAQ has 5 subscales, of which 4 are validated and used in scoring assessments. The validated subscales include appearance, consciousness, satisfaction with appearance, and satisfaction with symptoms. The appearance subscale is an objective assessment of the scar's presence and severity of coloration, width, flatness, texture, shininess, and overall appearance. The consciousness subscale inquires about how noticeable the scar is to oneself, to others, and the overall individualized self-consciousness of the scar. Satisfaction with appearance includes measures of scar color, redness, length, width, texture, and whether or not it matches the patient's surrounding skin tone. When considering the subscale of satisfaction with symptoms, satisfaction with itchiness, pain, discomfort, numbness, odd sensations, and overall troublesomeness of symptoms was interrogated. Each subscale consisted of a set of 4-point categorical responses, with 1 point assigned to the most favorable category and 4 to the least favorable. Each subscale also contained a single global assessment item with higher scores reflecting a poorer perception of the scar.

Prospective data were collected by reviewing maternal records at delivery and postdelivery discharge records. The following preoperative variables were collected: maternal demographics (age, race, marital status, family history of neural tube defect, previous uterine surgery, BMI, and smoking) and ultrasound findings at the first evaluation (gestational age [GA], placental location, lesion level, type of lesion, presence of a sac, and cervical length). Operative variables including GA at procedure, estimated fetal weight, the location of the skin and uterine incision, need for version, use of skin or dura patch, time of surgery, time of hysterotomy, time of fetal repair, intraoperative complications, estimated blood loss, need for maternal transfusion, and the need for Jackson-Pratt (JP) drainage. Postoperative data included the assessment of variables such as pulmonary edema, pain score at day 3, wound seroma or infection, and length of hospital stay. Delivery outcomes included the following variables, GA at delivery, premature preterm rupture of membranes (PPROM), hysterotomy status at delivery, postpartum hemorrhage, wound complications, and neonatal outcomes.

The primary outcome of interest was the total operative time for the prenatal repair. Secondary outcomes were immediate complications following prenatal repair, such as wound pain score on the analog scale postoperatively on day 3, postoperative length of stay, wound complications within 4 weeks of surgery as well as long-term scar assessment as assessed by the PSAQ.

Statistical Analysis

Comparisons of skin incision groups were either performed using a χ^2 test for categorical variables with a Fisher's exact test as appropriate, an unpaired Student's t test for normally distributed continuous data, or a Mann-Whitney U test for nonparametric distributed data. Continuous variables are reported as mean with

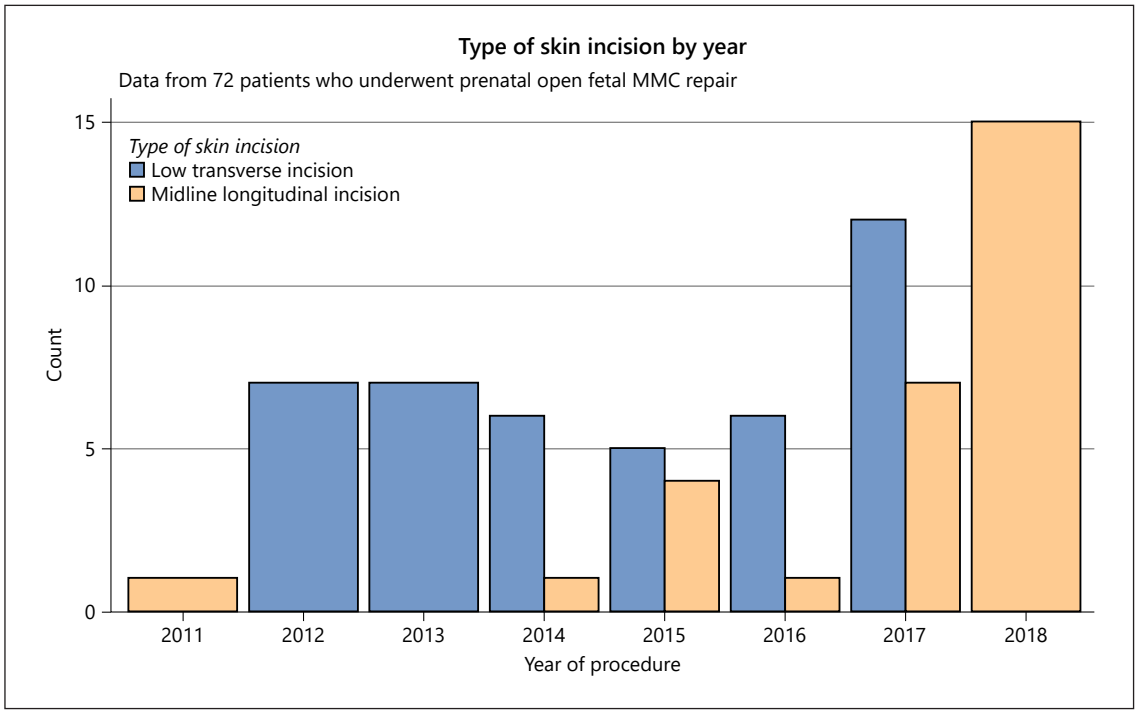

Fig. 2. Type of skin incision by year. Data from 72 women that underwent open in utero spina bifida repair.

SD or as median with interquartile range as appropriate. Categorical data are reported as proportions and percentages. We used R core Team software (2019; R: a language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria) and considered a p value <0.05 statistically significant.

Results

Seventy-two women underwent prenatal repair of their fetus's spina bifida defects during the study period, of which 29 (40.3%) patients had a midline vertical incision (Fig. 1a), and 43 (59.7%) had a LT skin incision (Fig. 1b). Based on the timeline of different type of incision chosen during the study period, the LT incision was preferred at the beginning of our experience, which was gradually transitioned to the midline vertical (Fig. 2). Baseline characteristics of the 2 groups in this study are presented in Table 1. We found that all demographic, clinical, and ultrasound findings were similar between the groups.

Outcome differences between the 2 groups are presented in Table 2. The primary outcome; the time to completion of surgery was lower in the midline incision group by approximately 33 min ($p < 0.001$). This difference was mainly driven by a shorter abdominal wall operation time with a midline incision by an average of 21 min ($p < 0.001$) (Fig. 1c) together with a reduction in hysterotomy time by 9 min ($p = 0.008$) when compared to the LT incision group. However, no difference in fetal surgery time was found between the 2 groups. Women who underwent a midline incision did not have a JP placed, whereas 16% of the patients in the LT incision group had a JP inserted during the procedure ($p < 0.001$). The length of stay in the midline incision group was shorter compared to those that had a transverse incision ($p = 0.008$). This finding was confounded by 4 cases in the LT incision group that developed a wound seroma. Wound complication rates were similar between the groups, with composite wound complication rates of 0% in midline group and of 12% in the LT incision group ($p = 0.077$). There were no differences found in immediate prenatal repair outcomes between the groups, such as pain score on day 3.

There was no difference in the rate of pregnancy complications between the groups (Table 3). Delivery and neonatal outcomes are described in Table 4. The GA at delivery in the midline incision group was 1.6 weeks longer than in the LT incision group ($p = 0.035$), and correspondingly the birth weights were higher in the midline

Table 1. Baseline characteristics of the study groups

Characteristics	Midline incision, $N = 29$	LT incision, $N = 43$	p value
Maternal age, years	29.0±4.7	29.0±5.0	0.876
Race/ethnicity			
Non-hispanic white	21 (72.4)	26 (60.5)	0.360
Non-hispanic black	3 (6.9)	1 (2.3)	
Hispanic	6 (20.7)	14 (32.6)	
Non-hispanic other	0 (0)	2 (4.6)	
Married/living with a partner	26 (89.6)	41 (95.3)	0.553
BMI at intake	29.0±5.4	27.3±3.6	0.120
Smoker	0 (0)	2 (4.7)	0.512
Family history of NTD	1 (3.5)	7 (16.3)	0.132
Nulliparous	7 (24.1)	15 (34.9)	0.478
Previous uterine surgery	8 (28.6)	10 (23.8)	0.867
GA at evaluation	23.1 (22.1–24.1)	23.1 (22.1–23.9)	0.968
Cervical length, mm	42.8 (37.7–48.2)	41.0 (35.0–46.0)	0.268
Anterior placenta	13 (44.8)	22 (51.2)	0.774
Lesion upper level on US			
Thoracic	2 (6.9)	2 (4.6)	0.221
L1–L2	4 (13.8)	8 (18.6)	
L3–L4	15 (51.7)	18 (41.90)	
L5–S1	8 (27.6)	15 (34.9)	
Type of lesion			
MMC	16 (55.2)	26 (60.5)	0.839
Myeloschisis	13 (44.8)	17 (39.5)	
Gender of fetus (male)	17 (58.6)	23 (53.5)	0.851

Data are provided as N (%) or mean±SD or median (IQR). NTD, neural tube defect; GA, gestational age.

incision group. We found that neonatal hyperbilirubinemia occurred less frequently in the midline incision group when compared to the LT skin incision group (2 vs. 14%, respectively; $p = 0.015$). Contrasting neonatal complication rates were not found between the 2 types of incision groups.

In our cohort, 53/72 (73.6%) completed the PSAQ, of which 17/29 (58.6%) were from the midline incision group, and 36/43 (83.7%) were from the LT incision group. These 2 groups reported similar ratings for scar appearance, perceived consciousness of the scar, satisfaction with appearance of the scar, and with scar-related symptoms (Table 5).

Discussion

In this study, we found that maternal midline abdominal skin incisions are associated with a shorter operative time compared to lower transverse incision for in utero spina bifida repair. This reduction in surgical time was partially attributed to reduced abdominal wall operation times (opening and closing) in addition to hysterotomy times in the former-mentioned group. Furthermore, GA at delivery following a midline abdominal incision surpassed the LT incision group by a week. We also noted a nonsignificant trend toward more wound separation and seroma rates in the LT skin incision group compared to the midline incision group. A similar trend was seen in the previous studies evaluating the 2 types of incision for cesarean deliveries [5].

To the best of our knowledge, this is the first study addressing outcomes between different types of abdominal skin incisions that are commonly used in fetal surgery. In the MOMS trial, midline skin incisions were used for women with a BMI greater than 30 or with a previous vertical scar [1]. Reports from the literature on incision types related to fetal surgery subsequent to the MOMS trial identified a larger cohort of patients that underwent fetal surgery similar to the MOMS' protocol excepting for modification of the hysterotomy surgical technique [9]. However, the overall rates of midline incisions were not

Table 2. Fetal surgery outcomes between the study groups

Characteristic	Midline incision, $N = 29$	LT incision, $N = 43$	p value
GA at surgery, weeks	25.3 (25.0–25.4)	25.1 (24.7–25.6)	0.387
US EFW, g	716±72.6	693±89.0	0.251
External cephalic version	12 (41.4)	23 (53.5)	0.443
Need for a patch	13 (44.8)	14 (32.6)	0.420
Length of surgery, min	135±25.7	168±24.0	<0.001
Abdominal wall incision time (opening and closure), min	18.2±17.8	39.5±17.1	<0.001
Hysterotomy time, min	80.1±12.7	89±14.9	0.008
Fetal surgery time, min	34.0 (29.8–38.2)	37.0 (31.0–45.5)	0.076
Intraoperative complications			
None	28 (96.6)	40 (93.0)	0.644
Uterine bleeding	0 (0)	0 (0)	
Fetal bradycardia	1 (3.45)	3 (6.98)	0.644
Abruption	0 (0)	0 (0)	
Anesthesia complications	0 (0)	0 (0)	
JP drainage	**0 (0)**	**7 (16.3)**	**<0.001**
EBL, mL	200 (50–200)	150 (100–200)	0.976
Maternal transfusion	1 (3.45)	1 (2.33)	1.00
Immediate maternal postoperative information			
Pulmonary edema	2 (6.9)	2 (4.65)	1.00
Length of hospitalization, days	4 (4–4)	4 (4–5)	**0.008**
Pain score on POD3	4 (3.2–5)	5 (3–6)	0.644
Wound infection	0 (0)	1 (2.33)	1.00
Wound seroma	0 (0)	4 (9.30)	0.143
Wound separation	0 (0)	2 (4.65)	0.512
Composite wound outcome*	0 (0)	5 (11.6)	0.077

Data are provided as N (%) or mean ± SD or median (IQR). Values in bold are significant at $p < 0.05$. GA, gestational age; EFW, estimated fetal weight; JP, Jackson-Pratt; EBL, estimated blood loss; POD, postoperative day. * Composite wound complications within 4 postoperative weeks included surgical site infection, cellulitis, seroma/hematoma, and separation of the wound.

Table 3. Maternal outcome following fetal surgery

Outcome	Midline incision, $N = 29$	LT incision, $N = 43$	p value
Placental abruption	1 (3.45)	3 (6.98)	0.644
Gestational diabetes	1 (3.45)	1 (2.33)	1.0
Preeclampsia or gestational hypertension	0 (0)	0 (0)	
PPROM	5 (17.2)	10 (23.3)	0.749
Chorioamnionitis	2 (6.9)	4 (14.0)	0.461
Spontaneous labor	3 (10.3)	6 (14.0)	0.731
Hysterotomy at delivery			
Intact	27 (93.1)	31 (75.6)	0.146
Thin	2 (6.90)	8 (19.5)	
Focal area of dehiscence	0 (0)	2 (4.88)	
PPH	0 (0)	1 (2.33)	1.0
Blood transfusion at delivery	0 (0)	0 (0)	
Wound hematoma/separation	0 (0)	0 (0)	
Wound infection	0 (0)	1 (2.33)	1.00

Data are provided as N (%). PPROM, premature preterm rupture of membrane; PPH, postpartum hemorrhage.

Table 4. Delivery and neonatal outcomes of the study groups

Outcome	Midline incision, $N = 29$	LT incision, $N = 43$	p value
GA at birth, weeks	**36.9 (35.9–37.1)**	**35.3 (33.6–37.0)**	**0.035**
Perinatal death	2 (6.90)	1 (2.38)	0.563
Birth weight, g	**2,880 (2,530–3,030)**	**2,424 (2,189–2,889)**	**0.032**
Apgar <5 at 5, min	1 (3.57)	3 (7.32)	0.641
Apnea	6 (20.7)	14 (33.3)	0.370
Ventilator support	7 (24.1)	17 (40.5)	0.240
Pneumothorax	0 (0)	0 (0)	
RDS	6 (20.7)	14 (33.3)	0.370
Patent ductus arteriosus	1 (3.45)	1 (2.38)	1.0
Sepsis	0	4 (9.52)	0.140
Necrotizing enterocolitis	1 (3.45)	0 (0.0)	0.408
Hyperbilirubinemia	**2 (6.9)**	**14 (35.0)**	**0.015**
Periventricular leukomalacia	0 (0)	0 (0)	
Shunt placement	3 (10.3)	8 (19.0)	0.506
ETV	1 (3.45)	1 (2.44)	1.0
Foot deformity	10 (34.5)	14 (33.3)	1.0
CSF leakage	3 (10.3)	2 (4.76)	0.393
Chiari malformation	11 (39.3)	16 (38.1)	1.0
Neonatal death	2 (6.90)	1 (2.30)	0.563
Length of NICU stay, days	13.0 (6.00–32.0)	15.5 (7.00–34.5)	0.436

Data given as N (%) or median (IQR). GA, gestational age; RDS, respiratory distress syndrome; ETV, endoscopic third ventriculostomy; CSF, cerebrospinal fluid; NICU, neonatal intensive unit.

reported in both studies. The Fetal Center at Vanderbilt has previously reported on improved maternal outcomes when compared to the MOMS' trial, showing reduced rates of PPROM, chorioamniotic membrane separation, and prolongation of pregnancy when using a modified surgical approach [8]. The surgical approach used in the aforementioned study detailed performing a midline incision for all patients, as well as a modified approach for uterine entry and fetal and membrane manipulation. The contribution of the type of skin incision to the outcome cannot be extrapolated from those studies. In our cohort, the main difference in the surgical approach between the groups was by the type of abdominal skin incision.

During a cesarean delivery, previous studies have shown that midline skin incision has been associated with a shorter duration of time from skin incision to hysterotomy and has traditionally been used to expedite delivery in emergent cases or in the setting where greater fetal exposure is needed [7, 12]. Our findings are in agreement with those studies, reflecting faster exposure of the uterus with a midline incision than when a LT incision is performed during fetal surgery.

Although we did not find any differences in PPROM rates or spontaneous preterm births, a shorter fetal surgery time with a midline incision may explain the prolongation of pregnancy compared with procedures using a LT incision. The causality between the length of in utero procedures versus and preterm birth risk should be evaluated in a larger cohort after controlling for various confounders including experience, membrane anchoring, and maternal factors.

There is disagreement in the literature about whether a vertical midline abdominal incision during a cesarean delivery is a risk factor for wound complications. Haidir

Table 5. The PSAQ

Assessment	Midline incision, $N = 17$	LT incision, $N = 36$	p value
Total score	69.0±15.5	63.6±16.9	0.259
Appearance	23.6±5.6	20.8±4.5	0.074
Consciousness	16.9±4.5	14.6±4.8	0.085
Satisfaction with appearance	18.6±9.4.6	16.5±5.3	0.150
Satisfaction with symptoms	9.8±3.9	11.8±4.5	0.115

Data are provided as mean ± SD.

al. [13] reported that midline incisions are a risk factor for surgical site infection in a secondary analysis of 3,696 women with a surgical site infection following a primary or repeat cesarean delivery. However, other studies in obese and nonobese patients undergoing a cesarean delivery found no differences in the risks for wound seroma, dehiscence, or infection following midline incisions versus LT incisions [7, 12, 14]. Our findings are consistent with the latter studies as no differences were found in wound complication rates between the 2 types of skin incisions. It is important to emphasize that comparison between skin incision complications during cesarean delivery versus skin incisions from open fetal surgery would be very difficult due to major surgical differences between the 2 procedures. First, during a cesarean delivery with LT incision (pfannenstiel incision), the subcutaneous tissue is not dissected off the underlying fascia as it is in fetal surgery which may cause a higher risk for subcutaneous seroma accumulation during fetal surgery. Second, during cesarean delivery, the fascia is incised laterally and then dissected off the underlying rectus muscle predisposing to greater risk for bleeding and hematoma formation. And finally, the LT incision used in fetal surgery is usually longer in length than a standard cesarean section and may, therefore, be associated with higher wound complication rates. In our cohort, although the difference in wound complications between the 2 incisions was not statistically different, there was a trend toward a higher rate of wound compilations in the LT incision group (12%) compared to the midline incision (0%). The differences in wound complications should be confirmed in larger studies of women undergoing open fetal surgery.

To avoid bias of fetal surgery expertise, our novel study was conducted at a single tertiary center by the same surgeons. In addition, since this study included patients from a diverse population, without any being lost to follow-up, the results are generalizable to women with a prenatal diagnosis of spina bifida. The biggest limitation of this study is the relatively small sample size. Since this was a single tertiary study, our findings should be evaluated in bigger studies. For example, previous studies have shown that LT skin incisions may be associated with a lower risk of incisional hernias compared to midline incisions. The development of postoperative hernias was not assessed in this study and should be assessed in a long-term follow-up study [6].

Preclinical studies in animal fetuses have shown that exposure to common anesthetic medications such as propofol, midazolam, or inhalational agent's causes apoptosis as well as learning disabilities [15–18]. Accordingly, in 2016, the FDA has raised concerns about the effects of repeated or lengthy procedures (>3 h) using general anesthesia and sedative drugs on the fetal brain for pregnant patients in their third trimesters [19]. Minimizing the fetal exposure to those agents is an important part of the surgical approach in fetal procedures [20, 21]. In this cohort, we found that a midline incision reduced the operative time by 37 min. Long-term neonatal neurological outcomes of reducing surgical times through use of a midline incision should be assessed in future studies.

Given that the length of fetal surgical procedures under general anesthesia may be a risk factor for prematurity and for possible long-term neurological complications, the evaluation of factors decreasing procedural times is essential in the field. Midline abdominal skin incisions seem to be associated with shorter surgical durations, ultimately prolonging the pregnancies of women whom underwent in utero spina bifida repair of their fetuses.

Statement of Ethics

Our research complies with the guidelines for human studies, and the research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. This research was approved from the institutional review board and documented with the approved protocol (HSC-MS-15-0168). Written informed consent was obtained from all willing and eligible participants.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

M.F. and R.P. were involved in planning, drafted the manuscript, and supervised the work. E.B. performed the analysis and designed the figures. K.T., M.A., K.M., S.F., and B.S. aided in interpreting the results and worked on the manuscript. All authors discussed the results, provided critical feedback, and helped shape the research, analysis, and manuscript.

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