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## Factors Associated With Gastroschisis Outcomes

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### Abstract

**Objective**—To identify perinatal variables associated with adverse outcomes in infants prenatally diagnosed with gastroschisis.

**Methods**—A retrospective review was conducted of all inborn pregnancies complicated by gastroschisis within the five institutions of the University of California Fetal Consortium from 2007 to 2012. The primary outcome was a composite adverse neonatal outcome comprising death, re-operation, gastrostomy, and necrotizing enterocolitis. Variables collected included antenatal ultrasound findings, maternal smoking or drug use, gestational age at delivery, preterm labor, elective delivery, mode of delivery, and birth weight. Univariate and multivariate analysis was utilized to assess factors associated with adverse outcomes. We also evaluated the association of preterm delivery with neonatal outcomes such as total parenteral nutrition (TPN) cholestasis and length of stay.

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For a list of contributing members of the University of California Fetal Consortium, see the Appendix online at <http://links.lww.com/xxx>.

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**Results**—There were 191 infants born with gastroschisis in University of California Fetal Consortium institutions at a mean gestational age of  $36\ 3/7 \pm 1.8$  weeks. Within the cohort, 27 (14%) had one or more major adverse outcomes including three deaths (1.6%). Early gestational age at delivery was the only variable identified as a significant predictor of adverse outcomes on both univariate and multivariate analysis (OR 1.4; 95% CI 1.1-1.8 for each earlier week of gestation). TPN cholestasis was significantly more common in infants delivered < 37 weeks of gestational age (38/115 (33%) compared with 11/76 (15%);  $p < 0.001$ ).

**Conclusions**—In this contemporary cohort, earlier gestational age at delivery is associated with adverse neonatal outcomes in infants with gastroschisis. Other variables such as antenatal ultrasound findings and mode of delivery did not predict adverse neonatal outcomes.

## Introduction

Gastroschisis is an abdominal wall abnormality that results in herniation of bowel and other abdominal contents. In the United States the rate of gastroschisis has increased from 2.32 per 10,000 live births in 1995 to 4.42 per 10,000 live births in 2005 (1). Risk factors for gastroschisis include tobacco and illicit drug use, low socioeconomic status, low body mass index (BMI), and young maternal age (1-3).

While the overall neonatal mortality rate for gastroschisis remains low at 5-10%, pregnancies with gastroschisis have a relatively high incidence of fetal growth restriction, preterm delivery, and neonatal complications such as bowel atresia, perforation, stricture, ischemia, and necrotizing enterocolitis (4,5).

Numerous studies have examined prognostic factors for outcomes of gastroschisis (6-9). It has been hypothesized that prolonged exposure to amniotic fluid may lead to inflammatory changes and damage to the exteriorized bowel (10,11). Researchers have assessed ultrasound findings, including size of abdominal wall defect, bowel wall dilation, and bowel wall thickness (6-9,12,13). While some studies have demonstrated that these findings are predictive of adverse outcomes, others report insufficient evidence to support use in clinical management (8,9,14-16). It is also theorized that elective preterm delivery may improve outcomes by preventing ongoing bowel injury (17-19). However, this theory remains unproven and there is no consensus regarding perinatal management of gastroschisis (20).

Identifying prenatal predictors and optimizing perinatal management could minimize adverse outcomes among infants with gastroschisis. The aim of this study is to identify perinatal variables associated with adverse outcomes in infants prenatally diagnosed with gastroschisis.

## Materials and Methods

A retrospective review was conducted on all inborn pregnancies complicated by gastroschisis within the five institutions of the University of California Fetal Consortium from 2007 to 2012. The University of California Fetal Consortium is a multi-institutional collaboration of the UC Medical Centers and includes UC Davis, UC Irvine, UC Los Angeles, UC San Diego, and UC San Francisco. All institutions participating in the

University of California Fetal Consortium are tertiary academic medical centers with a full complement of perinatal, neonatal, and surgical services.

Cases of gastroschisis were initially identified by ICD-9 codes. Maternal and neonatal variables were abstracted through an individual chart review at each institution. All patients included in the analysis received prenatal and postnatal care within the same institution. Infants who were transferred into a University of California Fetal Consortium institution after delivery for post-natal care were excluded. A multi-institutional review board reliance registry approved the study (IRB #10-04093). The primary outcome was a composite adverse neonatal outcome comprising neonatal death, bowel complications (intestinal atresia, stricture, or ischemia) requiring re-operation, gastrostomy, and necrotizing enterocolitis.

Demographic information was collected including maternal age, parity, zip code of residence, smoking, and drug use. Other perinatal variables collected were gestational age at delivery, preterm labor, mode of delivery, and whether delivery was electively scheduled. Findings from the last ultrasound prior to delivery were reviewed, as they were most likely to correlate with neonatal status. The perinatal sonographic variables assessed were presence of fetal bowel dilation (subjectively assessed by a physician and sonographer), intrauterine growth restriction (estimated fetal weight less than the 10<sup>th</sup> percentile), and oligohydramnios (amniotic fluid index (AFI) less than 5 cm). As gastroschisis is not usually associated with chromosomal abnormalities, genetic testing was not performed routinely in our cohort.

Adverse neonatal outcomes were collected including neonatal death, bowel complications (intestinal atresia, stricture, or ischemia) requiring re-operation, gastrostomy, and necrotizing enterocolitis. Other newborn characteristics including birth weight, small for gestational age (birth weight less than the 10<sup>th</sup> percentile for gestational age), Apgar score less than 5 at five minutes, presence of meconium at delivery, method of gastroschisis defect closure, neonatal length of stay, ventilator days, days to initiation of feeds and full feeds, total parenteral nutrition (TPN) cholestasis, presence of other neonatal anomalies, and readmission within one month were also collected.

Perinatal and neonatal variables were analyzed to determine whether they were associated with adverse outcomes in infants with gastroschisis. As there is debate regarding the need to deliver infants with gastroschisis preterm, we examined differences in neonatal outcomes based on timing of delivery (preterm <37 weeks or term ≥37 weeks). Univariate analysis was performed using Fisher's exact test for assessing the relationship between categorical variables and Wilcoxon rank sum test for comparing continuous variables between groups. Those predictors with *p*-values <0.20 on univariate analysis were included in the multivariate model. In cases where predictors were clearly associated, we selected only the variable that had the lowest *p*-value on univariate analysis. Potential predictor variables included in the models were gestational age, maternal smoking, maternal drug use, elective delivery, Apgar score less than 5 at five minutes, and institutional site. Forward stepwise regression was then utilized to identify the most significant variables. In order to assess the robustness of our stepwise selected model, a mixed effects logistic regression model was

constructed using institutional site as a random effect.  $P < 0.05$  was considered statistically significant. Statistical analyses were performed using SAS 9.3 (SAS Institute, Cary, NC).

## Results

There were 191 infants born with gastroschisis at the five University of California Fetal Consortium institutions from 2007 to 2012. Among the cohort, 87% lived in urban areas and 13% in rural areas. Of those who lived in urban areas, 64% were from areas with greater than 99% urban dwellers, while 33% were from mixed urban and rural communities.

Table 1 shows maternal and neonatal demographics of the cohort. The mean gestational age of delivery was  $363/7 \pm 1.8$  weeks. The mean maternal age was  $22 \pm 4.4$  years, and the majority of women (66%) were nulliparous. In the cohort, 15% smoked tobacco and 6% reported use of illicit drugs during pregnancy. Based on the last ultrasound prior to delivery, 25% had intrauterine growth restriction (IUGR), 7% had oligohydramnios, and 45% had bowel dilation. Of all the deliveries, 75 (39%) were scheduled electively. The cesarean delivery rate was 34%, of which 19 (29%) were elective cesarean deliveries.

The mean birth weight for all infants was  $2,469 \pm 500$  grams; 42 (22%) were small for gestational age. Meconium was present in 56% of deliveries, and 4% had Apgar scores less than 5 at five minutes. Primary closure was performed in 42% of patients. The median (interquartile range) length of NICU stay was 31 (24-45) days, ventilator days was 5 (3-9) days, days to initiation of feeds was 15 (11-21) days, and days to full feeds was 24 (21-36) days. Thirteen infants (7%) had other anomalies including cardiac (dextrocardia, pulmonary valve stenosis, atrial septal defect), neurologic (optic nerve hypoplasia, cerebral dysgenesis, absent cavum septum pellucidum, tethered spinal cord), renal (multicystic kidney, vesicoureteral reflux, hydronephrosis), severe combined immunodeficiency, arthrogryposis, and amniotic band syndrome with club feet.

Of the 191 infants in the cohort, 27 (14%; 95% CI 7.9%-17.3%) had one or more major adverse outcomes (Table 2). Three infants (1.6%; 95% CI 0%-3.3%) died after delivery with time to death ranging from two to nine days. Two of the neonatal deaths had entire liver evisceration associated with gastroschisis and pulmonary hypoplasia. The third death was due to an in utero volvulus and resultant short gut syndrome. There were no stillbirths.

Reoperation was required in 26 infants for intestinal atresia or stricture (10%) and bowel ischemia (1%). Thirteen infants (7%) required a gastrostomy tube for oral aversion or prolonged gastrointestinal dysmotility. All infants with gastrostomy were discharged home with tubes in place. Two infants (1%) had necrotizing enterocolitis complicating their hospitalization. Six infants (3%) were discharged home on total parenteral nutrition.

On univariate analysis, gestational age at delivery, spontaneous preterm labor, and birth weight were significantly different between infants without and with adverse outcomes (Table 3). We also identified differences in adverse outcomes between University of California Fetal Consortium institutional sites ( $P < 0.002$ ) which was likely attributable to one outlier institution with a 45% adverse outcome rate. When excluding the one outlier

institution, adverse outcomes were not different between institutions (adverse outcomes rate of 7-14%,  $P=0.62$ ).

On multivariate analysis, each earlier week of gestation (OR 1.4; 95% CI 1.1-1.8), maternal smoking (OR 4.3; 95% CI 1.1-10.5), and institutional site ( $p<0.001$ ) were identified as significant predictors of adverse neonatal outcomes. When site was treated as a random effect to control for site-to-site variation, neonatal outcomes worsened with each earlier week of gestation (OR 1.4; 95% CI 1.1-2.0), and maternal smoking was associated with adverse neonatal outcomes (OR 3.4; 95% CI 1.1-10.5).

The other variables of maternal drug use and mode of delivery did not differ between groups. Antenatal ultrasound findings of intrauterine growth restriction, oligohydramnios, and bowel dilation were also not predictive of adverse neonatal outcomes (Table 3). The presence of meconium, small for gestational age, five minute Apgar score, and other fetal anomalies were similar between those without and with adverse outcomes (Table 3).

In our cohort, 75 (39%) deliveries were elective. Those electively delivered had a later gestational age at delivery compared to those not electively delivered (37 0/7  $\pm$ 1.4 weeks compared with 36 0/7  $\pm$ 1.9 weeks,  $P<0.0001$ ). Infants electively delivered had higher birth weights (2,600  $\pm$ 472 grams compared with 2,384  $\pm$ 500 grams,  $P<0.01$ ) and lower rates of preterm delivery (40% compared with 73%,  $P<0.0001$ ). However, there was no difference in small for gestational age (21% compared with 22%,  $P=1.0$ ) and adverse outcomes (9% compared with 17%,  $P=0.14$ ) between the two groups.

As would be expected, those with adverse outcomes had longer NICU lengths of stay (93 [68-128] days compared with 28.5 [24-39] days,  $P<0.001$ ), more ventilator days (10 [5-16] days compared with 5 [3-9] days,  $P=0.0021$ ), and longer time to initiation of feeds (27 [25-71] days compared with 14 [11-19] days,  $P<0.001$ ). There was no association of adverse outcomes with silo placement (58% of infants without adverse outcomes had silo placement compared to 63% of those with adverse outcomes,  $P=0.83$ ).

As seen in other studies, our cohort had a high rate of preterm birth, with 115 (60%) infants delivered prior to 37 weeks. Table 4 shows the indications for preterm delivery. There were fewer adverse outcomes in infants delivered  $\geq 37$  weeks, although this difference was not statistically significant (6 [8%] adverse outcomes with delivery  $\geq 37$  weeks compared with 21 [18%] adverse outcomes with delivery  $< 37$  weeks,  $P=0.06$ ). A majority of adverse outcomes (46%) occurred in infants delivered  $< 35$  weeks compared to infants delivered  $\geq 35$  weeks (9%,  $P<0.001$ ). TPN cholestasis was higher in those who delivered prior to 37 weeks (33% with delivery prior to 37 weeks compared with 15% with delivery after 37 weeks,  $P<0.001$ ). The overall rate of TPN cholestasis within the cohort was 26%. Ventilator days, days to initiation of feeds and full feeds was not different in those who delivered before versus after 37 weeks (Table 5).

## Discussion

Much investigation on gastroschisis has focused on identifying reliable prenatal predictors to minimize risk of fetal demise and neonatal complications (6-9,12-16,21). In our cohort,

prenatal predictors such as intrauterine growth restriction, oligohydramnios, and bowel dilation on ultrasound were not found to be predictive of adverse neonatal outcomes. Neonatal variables such as the presence of meconium, small for gestational age, five minute Apgar score, and other fetal anomalies were also not predictive of adverse outcomes.

Infants in our cohort experienced bowel complications similar to those reported in other studies. Intestinal problems such as bowel atresia, stricture, or ischemia have been reported to occur in infants with gastroschisis at rates as high as 25% (22). Our adverse outcome rate of 14% comprised neonatal death, bowel complications (intestinal atresia, stricture, or ischemia) requiring re-operation, gastrostomy, and necrotizing enterocolitis. All the infants with adverse outcomes had significantly longer lengths of stay, ventilator days, and time to initiation of feeds. Despite a typical complication frequency, our mortality rate of 1.6% was significantly lower than reported previously (1,4,23). This may reflect advances in medical care. Two of the fetal deaths had liver evisceration, which is consistent with other studies that have demonstrated higher rates of mortality with liver herniation (24).

Gestational age and maternal smoking were found to be predictors of adverse neonatal outcomes. However, 28% of preterm infants were delivered following spontaneous preterm labor. The underlying etiology for spontaneous preterm labor is typically unknown, and may account in part for the worse outcomes observed in lower gestational age infants. Biologic plausibility for an association between smoking and gastroschisis include carbon monoxide exposure, vascular injury, and inflammatory changes (25, 26).

Much debate exists regarding appropriate timing and mode of delivery for the infant with gastroschisis. Proponents of early delivery believe prolonged intra-amniotic bowel exposure increases the risk of complications, and they recommend elective preterm delivery (17-19). Baud et al. found induction at 37 weeks was associated with lower rate of sepsis, bowel damage, and neonatal death compared with pregnancies managed expectantly beyond 37 weeks (27). In contrast, a randomized controlled trial of 42 pregnancies with gastroschisis demonstrated no difference in outcomes between elective delivery at 36 weeks compared to awaiting spontaneous labor (28). Our data found that infants born preterm have a higher rate of TPN cholestasis, and those born before 35 weeks are at most risk for adverse outcomes.

The primary strength of our study is that it is a large multi-institutional cohort of perinatal predictors and neonatal outcomes of gastroschisis. This study includes a large catchment area in California with patients from urban and rural areas. Data were examined within the last seven years, providing a contemporary examination of various management strategies for gastroschisis, and reflecting current advances in perinatal and neonatal technology and care.

Our study is limited in that it is based on a retrospective chart review. There was variation in availability of data, prenatal ultrasonographic surveillance, and obstetric management at each University of California Fetal Consortium institution. Although our initial analysis suggested site was predictive of adverse outcomes, we found that a single outlier site was responsible for these differences. When this site was excluded, site was not predictive of adverse outcomes. Site-specific practices are likely captured with other covariates including



mode of delivery, gestational age at delivery, and method of closure. Finally, while the study size was relatively large, it may be insufficiently powered to assess all predictors.

As the prevalence of gastroschisis continues to increase both globally and domestically, clinicians and families should be aware of potential neonatal complications. During prenatal counseling, families should be aware that infants with gastroschisis are at risk for serious complications including intestinal atresia, stricture, ischemia, necrotizing enterocolitis, feeding intolerance requiring gastrostomy, and prolonged hospital stays. The overall mortality rate for gastroschisis is low, unless liver herniation is present.

In conclusion, our data suggest ultrasound findings of bowel dilation, intrauterine growth restriction, and oligohydramnios do not warrant early delivery as they do not appear to be associated with adverse outcomes. We found no differences in outcomes with vaginal or cesarean delivery suggesting gastroschisis should not be an indication for elective cesarean deliveries. Finally, this study demonstrates an association between earlier gestational age and adverse neonatal outcomes, and it found no evidence to support routine induction of delivery.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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**Table 1**  
**Maternal and Neonatal Demographics**

| <b>Variable</b>                  | <b>n=191</b> |
|----------------------------------|--------------|
| Maternal age (y)                 | 22.2 ±4.4    |
| Nulliparous                      | 126 (66%)    |
| Smoking                          | 29 (15%)     |
| Drug use                         | 12 (6%)      |
| Gestational age at delivery (wk) | 36 3/7 ± 1.8 |
| Birthweight (g)                  | 2,469 ±500   |
| Delivery <37 weeks               | 115 (60%)    |
| Cesarean delivery                | 65 (34%)     |
| Preterm labor                    | 54 (28%)     |
| Other fetal anomalies* (n=190)   | 13 (7%)      |
| Male Gender                      | 107 (56%)    |

Data are mean ± standard deviation or n (%) unless otherwise specified.

\* Data are missing.

**Table 2****Adverse Neonatal Outcomes**

|                                      | <b>Outcome</b> | <b>Adverse outcome</b> |
|--------------------------------------|----------------|------------------------|
| Infants with adverse outcome         |                | 27 (14%)               |
| Specific adverse outcomes*           |                |                        |
| Intestinal atresia or stricture      |                | 19 (10%)               |
| Insertion of gastrostomy tube        |                | 13 (7%)                |
| Intestinal ischemia prior to closure |                | 2 (1%)                 |
| Necrotizing enterocolitis            |                | 2 (1%)                 |
| Death                                |                | 3 (1.6%)               |

Data are incidents and % of total study population (n=191).

\* Some infants had more than one adverse outcome.

**Table 3**  
**Univariate Analysis of Perinatal and Neonatal Predictors of Composite Adverse Outcomes**

| Variable   | Total<br>n=191 | No adverse outcome<br>n=164 | Adverse outcome <sup>†</sup><br>n=27 | P <sup>‡</sup> |
|--|----------------|-----------------------------|--------------------------------------|----------------|
| <b>Perinatal Predictors</b>                                    |                |                             |                                      |                |
| Gestational age (wk)   | 36 3/7 ±1.8    | 36.5 ± 1.7                  | 35.4 ±2.1                            | 0.004          |
| Maternal smoking   | 29 (15%)       | 22 (13%)                    | 7 (26%)                              | 0.14           |
| Maternal drug use  | 12 (6%)        | 8 (5%)                      | 4 (15%)                              | 0.07           |
| Intrauterine growth restriction (<10%ile) <sup>*</sup> (n=186) | 46 (25%)       | 39 (24%)                    | 7 (27%)                              | 0.81           |
| Oligohydramnios (AFI <5cm) <sup>*</sup> (n=190)                | 13 (7%)        | 10 (6%)                     | 3 (11%)                              | 0.40           |
| Bowel dilation <sup>*</sup> (n=190)                            | 86 (45%)       | 71 (44%)                    | 15 (56%)                             | 0.30           |
| Cesarean delivery  | 65 (34%)       | 54 (33%)                    | 11 (41%)                             | 0.51           |
| Elective Delivery  | 75 (39%)       | 68 (41%)                    | 7 (26%)                              | 0.14           |
| Spontaneous Preterm Labor                                      | 54 (28%)       | 40 (24%)                    | 14 (52%)                             | 0.01           |
| <b>Neonatal Predictors</b>                                     |                |                             |                                      |                |
| Delivery <37 weeks   | 115 (60%)      | 94 (57%)                    | 21 (78%)                             | 0.06           |
| Meconium   | 106 (56%)      | 92 (56%)                    | 14 (52%)                             | 0.68           |
| 5-minute Apgar score less than 5 <sup>*</sup> (n=188)          | 7 (4%)         | 4 (2%)                      | 3 (11%)                              | 0.06           |
| Birthweight (g)  | 2,469 ±500     | 2,498 ±478                  | 2,294 ±593                           | 0.04           |
| Small for gestational age                                      | 42 (22%)       | 36 (22%)                    | 6 (22%)                              | 1.00           |
| Other anomalies  | 13 (7%)        | 11 (7%)                     | 2 (7%)                               | 0.69           |
| Primary closure <sup>*</sup> (n=190)                           | 79 (42%)       | 69 (42%)                    | 10 (38%)                             | 0.83           |

Data are mean ±standard deviation or n (%) unless otherwise specified.

<sup>\*</sup> Data are missing.

<sup>†</sup> Adverse outcomes includes death, bowel complications (intestinal atresia, stricture, or ischemia) requiring re-operation, gastrostomy, and necrotizing enterocolitis.

<sup>‡</sup> Comparison between no adverse outcome group and adverse outcome group by Fisher's exact test or Wilcoxon rank sum test.

**Table 4**  
**Indications for Preterm Delivery**

| <b>Indication</b>                  | <b>n=115</b> |
|------------------------------------|--------------|
| Spontaneous Preterm Labor          | 54 (47%)     |
| Non-reassuring fetal heart tracing | 19 (17%)     |
| Intrauterine growth restriction    | 10 (9%)      |
| Oligohydramnios                    | 6 (5%)       |
| Compromised bowel*                 | 13 (11%)     |
| Other                              | 4 (3%)       |
| Unknown                            | 9 (8%)       |

Data are n (%) unless otherwise specified.

\* Compromised bowel is defined as ultrasonographic findings concerning for dilated bowel, bowel infarct, bowel perforation, or herniation of other abdominal viscera.

**Table 5**  
**Neonatal Outcomes Based on Gestational Age at Delivery**

| Outcome                     | Total n=191 | Delivery <37 weeks (n=115) | Delivery ≥37 weeks (n=76) | P <sup>‡</sup> |
|-----------------------------|-------------|----------------------------|---------------------------|----------------|
| Adverse outcome             | 27 (14%)    | 21 (18%)                   | 6 (8%)                    | 0.06           |
| Length of stay (days)       | 31 (24-45)  | 32.5 (23-47)               | 29 (24-44)                | 0.73           |
| Ventilator days             | 5 (3-9)     | 5.5 (3-9)                  | 5 (3-10)                  | 0.89           |
| Days to initiation of feeds | 15 (11-21)  | 15 (11-75)                 | 14 (11-19)                | 0.25           |
| Days to full feeds          | 24 (21-36)  | 25 (19-37)                 | 23.5 (21-75)              | 0.84           |
| TPN Cholestasis             | 49 (26%)    | 38 (33%)                   | 11 (15%)                  | <0.001         |

Data are median (interquartile range) or n (%) unless otherwise specified.

<sup>‡</sup>Comparison between no adverse outcome group and adverse outcome group by Fisher's exact test or Wilcoxon rank sum test.