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Emergent Prelabor Cesarean Birth in Solid Organ Transplant Recipients: Associated Risk Factors and Outcomes

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Condensation: Liver and kidney transplant recipients are at increased risk for emergent prelabor cesarean; delivery at a transplant center of excellence may mitigate associated risks of chronic hypertension and prevent neonatal morbidity and mortality.

Short Title: Emergent cesarean birth in kidney and liver transplant recipients

AJOG at a Glance:

- A. *Why was this study conducted?* Pregnant liver and kidney transplant recipients are at higher risk for antepartum admission and complications. The aim of this study is to characterize risk factors and outcomes of emergent prelabor cesareans in pregnant people with transplants.
- B. *Key findings* Emergent prelabor cesarean births occurred in one-third of antepartum admissions in transplant recipients and was largely due to non-reassuring fetal heart tracing. Notable risk factors for emergent prelabor cesarean include chronic hypertension and delivery outside of a transplant center. There is elevated neonatal morbidity and mortality with these unplanned births.
- C. *What does this study add to what is already known?* Given the comorbidities in solid organ transplant recipients that contribute to increased rates of emergent prelabor cesarean with associated preterm birth and neonatal morbidity, we provide additional evidence to support collaboration among maternal-fetal medicine, transplant, pediatrics, and subspecialty colleagues to care for transplant recipients and their pregnancies, i.e. Centers of Excellence.

Abstract:

BACKGROUND: Pregnancies after solid-organ transplant are at a higher risk for antepartum admission and pregnancy complications, including cesarean birth. Emergent prelabor cesarean is associated with increased maternal and neonatal morbidity in other high-risk populations, but its incidence and impact in transplant recipients is not well understood. **OBJECTIVE:** To characterize the risk factors and outcomes of emergency prelabor cesarean birth in kidney and liver transplant recipients. **STUDY DESIGN:** Retrospective cohort study of all kidney and liver transplant recipients >20 weeks' gestation enrolled in the Transplant Pregnancy Registry International between 1976 and 2019. Participants admitted antepartum who required an emergency prelabor cesarean were compared to those admitted antepartum who underwent non-emergent birth. Primary outcomes were composite severe maternal morbidity and neonatal composite morbidity. Multivariable logistic regression was conducted for neonatal composite morbidity. **RESULTS:** Of 1,979 births, 181 pregnancies (188 neonates) with an antepartum admission were included. 51 pregnancies (53 neonates, 28%) were delivered by emergent prelabor cesarean birth compared with 130 pregnancies (135 neonates, 72%) admitted antepartum who subsequently did not require emergent delivery. The most common indication for emergent delivery was non-reassuring fetal heart tracing (44 neonates, 86%). Pregnant people who underwent an emergent prelabor cesarean were less likely to birth at a transplant center (37.3% vs 41.5%, $p=0.04$) and had increased rates of chronic hypertension (33.3% vs 16.2%, $p=0.02$). There was no significant difference in severe maternal morbidity (3.9% vs 4.6%, $p=0.84$), though there was an increase in surgical site infection in the emergent prelabor cesarean cohort (3.9% vs 0%, $p=0.02$). Among those with an emergent prelabor cesarean, there was a significant increase in neonatal composite morbidity (43.4% vs 19.3%, $p<0.001$), with earlier

gestational age at delivery (33.4 vs 34.7 weeks, $p=0.02$), lower birth weight (1899g vs 2321g, $p<0.001$), lower birthweight percentile (30.3% vs 40.6%, $p=0.03$), increased NICU admission (52.8% vs 35.6%, $p=0.03$), and increased neonatal mortality (11.3% vs 1.5%, $p=0.002$). After adjusting for year of conception, race, hypertensive disorders, and fetal malformations, there was a persistent increased risk of neonatal morbidity (aOR 3.01, [1.50, 6.08], $p=0.002$) associated with emergent prelabor cesarean delivery after transplant. **CONCLUSION:** Almost one-third of kidney and liver transplant recipients admitted antepartum had an emergency prelabor cesarean birth and 63% of this cohort delivered outside of a transplant center. Pregnancies after transplantation should involve multi-disciplinary transplant-obstetrics collaboration to ensure optimal antepartum disease management, especially for pre-existing hypertension, to prevent and mitigate obstetric and neonatal morbidity in the setting of emergent cesarean birth.

Key words: antepartum admission, chronic hypertension, emergent cesarean, kidney transplant, liver transplant, maternal morbidity, neonatal morbidity and mortality, transplant center

Introduction

Pregnancies after solid organ transplant are at high risk for maternal and fetal complications including hypertensive disorders of pregnancy, pulmonary embolism, antepartum admission, postpartum hemorrhage¹⁻⁹, fetal growth restriction, prematurity, and fetal mortality.^{1-2, 10-16} Compounding these existing obstetric complications is the higher rate of cesarean birth in the transplant population. The rate of cesarean birth in kidney transplant recipients is 56.9-62.6%.^{1,10} For liver transplant recipients, the rate of cesarean birth is 44-45.8%.^{2-3, 17} Emergent cesareans are even higher risk, as emergent cesarean birth has been identified as a risk factor associated with a greater than 4-fold increase in the risk of severe maternal morbidity during childbirth¹⁸ as well as increased rates of neonatal morbidity and mortality.¹⁹ The majority of emergent cesarean births are performed in the setting of labor,²⁰ but a recent study noted that *prelabor* emergent cesarean births were particularly prevalent in transplant recipients, occurring in 9 of 14 (64%) studied cesarean births with hypertensive disorders of pregnancy being the most common indication for delivery.²¹ This study focused on anesthesia management and does not further define or characterize the emergent cesarean births nor discuss why there was a higher rate of emergent cesarean in transplant recipients. Certain other obstetric populations have been identified to be at increased risk of prelabor emergent cesarean birth due to deterioration of maternal or fetal status, including patients with advanced maternal age,²² type I diabetes,²³ and placenta previa.²⁴ Our group recently studied the indications for cesarean birth in solid organ transplant recipients and associated outcomes over five decades of clinical practice.²⁵ However, those with an emergent prelabor cesarean birth were excluded. More data is needed in this particularly high-risk population. The objective of this study is to characterize the risk factors and outcomes of prelabor emergent cesarean birth in kidney and liver transplant recipients. We

hypothesize that transplant recipients who undergo emergent cesarean birth during an antepartum admission will have higher rates of severe maternal morbidity (SMM) and neonatal composite morbidity associated with emergent prelabor cesarean birth.

Materials and Methods

This was a retrospective cohort registry study of data from the Transplant Pregnancy Registry International (TPRI). The TPRI and associated studies are institutional review board (Advarra Pro00008001) approved. Pertinent demographic and outcome data were collected via telephone interview and medical records were reviewed by trained study coordinators. All data was individually reviewed and validated for this study.

Inclusion criteria included adult kidney and liver transplant recipients with pregnancies of >20 weeks of gestational age, regardless of pregnancy outcome, and antepartum hospital admission. Patients were adults >18 years at time of delivery, though they may have received their transplant during childhood. Both kidney and liver recipients were included given the high rates of pregnancy morbidity identified in both populations and the complexity in care management pertinent to these patients¹²; given small numbers, it was not possible to analyze each organ separately. Other solid organ recipients were reviewed in the database (e.g. heart, lung, pancreas) but were excluded from this study due to small numbers. The 20-week gestational age threshold was chosen to exclude terminations and early pregnancy loss and capture deliveries at peri-viability. Antepartum admission was defined as any maternal length of stay in the hospital for all indications at any point in the pregnancy excluding admission for labor or scheduled induction of labor. Emergent prelabor cesarean was defined as an unplanned cesarean conducted emergently outside of the context of labor or induction for either maternal or

fetal indication. Indications for emergency delivery included fetal indications such as non-reassuring fetal heart tracing, abnormal doppler, and abnormal biophysical profile as well as maternal indications including uncontrolled hypertension and eclampsia. We compared pregnant patients with an antepartum admission ending in emergent prelabor cesarean delivery with patients with an antepartum admission without emergent delivery as our control group. The reason for choosing antepartum admission as the control group was based on our preliminary data review, which showed that the majority of emergent prelabor cesarean occurred during continuous fetal monitoring while inpatient; therefore, we wanted our control group to reflect a similarly high-risk population as opposed to those transplant recipients being cared for in the outpatient setting.

Pertinent risk factors for emergent prelabor cesarean were compared, including demographics, comorbidities, antepartum infection, antepartum bleeding, and measures of graft function and immunosuppression. Race was self-identified. Year of conception was studied given anticipated differences in neonatal resuscitation capabilities over time. Transplant to conception interval was also quantified in years, given previous association with graft and pregnancy outcomes.⁵ Hypertensive disorders including chronic hypertension, gestational hypertension, preeclampsia, and superimposed preeclampsia were categorized based on contemporary criteria, regardless of the originally assigned diagnosis at the time of registry entry. The primary outcomes of this study were severe maternal morbidity (SMM) and neonatal composite morbidity associated with emergent prelabor cesarean delivery. Severe maternal morbidity was defined as one or more of the 21 Centers for Disease Control severe maternal morbidity indicators.²⁶ Neonatal composite morbidity was defined as one or more of the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD)

Maternal-Fetal Medicine Units adverse outcomes.²⁷ A secondary outcome was graft loss. Graft loss for kidney recipients was defined as the need for maintenance dialysis, repeat transplant, or death with a functional graft. Graft loss for liver recipients was defined as the need for repeat transplant or death with a functional graft. Short term graft loss was defined as graft loss within 3 months after delivery. For twin deliveries, each twin was treated as a separate outcome for neonatal analysis.

Statistical analysis was conducted using R Studio version 1.2 (2019). Univariate categorical variables were analyzed using Chi-square and Fisher's exact tests. Univariate continuous variables were analyzed using the Student's t-test. Multivariable logistic regression was used to evaluate independent risk factors for neonatal morbidity. The final multivariable model was adjusted for all significant univariate differences, including year of conception, race, hypertensive disease, and delivery at a transplant center, as well as fetal malformations and gestational age. The generalized linear models (glm) base package in R was utilized and both forward and backward selection using the stepAIC function created a best-fit model with the least number of variables. Goodness of fit was evaluated by the Hosmer-Lemeshow test and by graphical evaluation of model residuals. A p-value of <0.05 was considered statistically significant.

Results

1,979 births with known mode of delivery >20 weeks of gestation between 1976 and 2019 were screened (Figure 1). 181 pregnancies (188 neonates) with an antepartum admission were included in this study, and 51 pregnancies (53 neonates, 28%, 2 sets of twins) were delivered by emergent prelabor cesarean birth. They were compared with the control group of

130 pregnancies (135 neonates, 72%, 5 sets of twins) born to women admitted to an antepartum service who did not require subsequent emergent delivery. Both cohorts had similar age, body mass index (BMI), and access to prenatal care (Table 1). Of note, the data available only denotes whether or not the patient received prenatal care but does not further clarify early or late entry to prenatal care or the care setting. Regarding allograft factors, 75% were kidney recipients and 25% liver recipients (Supplemental Table 1). Both groups were treated with similar immunosuppressive regimens and had mean transplant to conception intervals of >2 years. The majority of emergent deliveries were in the setting of fetal bradycardia during inpatient monitoring, though information regarding fetal monitoring indication and interval are not available (Supplemental Table 2). Though definitions for categorization of fetal heart tracings have changed over time, the interpretation and necessity for delivery of terminal bradycardia is not expected to be altered based on year of delivery. Other indications included umbilical cord prolapse or maternal decompensation such as worsening blood pressure and eclampsia. Indications for antepartum admission and length of stay were available for 72 of 130 antepartum control participants and 20 of 51 emergent cesarean participants. The most common indications for antepartum admission included preterm contractions without labor or rupture of membranes, graft dysfunction, and infection across both cohorts (Supplemental Table 3).

Regarding risk factors, patients who had a prelabor emergent cesarean birth had increased rates of chronic hypertension (33.3% vs 16.2%, $p=0.02$) and lower rates of superimposed preeclampsia (17.6% vs 36.2%, $p=0.02$). Incidences of gestational hypertension and preeclampsia were not different ($p>0.05$). Asian race had higher rates of emergent cesarean birth (11.8% vs. 1.5%, $p=0.007$). Transplant recipients who underwent an emergent cesarean birth

were less likely to have delivered at a transplant center (37.3% vs 41.5%, $p=0.04$) (Table 1). The majority of transplant centers were tertiary academic institutions.

For our primary outcome of severe maternal morbidity, there was no significant difference between the emergent prelabor cesarean group vs. the antepartum control group (3.9% vs 4.6%, $p=0.84$). Regarding secondary maternal outcomes, patients who underwent an emergent prelabor cesarean had increased rates of maternal surgical site infection (3.9% vs 0%, $p=0.02$) (Table 2). While the control group did include vaginal births, 76 of the 130 mothers delivered via cesarean with no surgical site infection. There were no differences in graft outcomes (Supplemental Table 1).

There was a significant increase in the primary outcome of neonatal composite morbidity in the emergent prelabor cesarean cohort (43.4% vs 19.3%, $p<0.001$). Emergent prelabor cesarean was associated with an earlier gestational age at delivery (33.4 vs 34.7 weeks, $p=0.02$), lower birth weight (1899 g vs 2321 g, $p<0.001$), lower birthweight percentile (30.3% vs 40.6%, $p=0.03$), and increased NICU admission (52.8% vs 35.6%, $p=0.03$). Neonatal morbidity from respiratory distress, sepsis, and hypoxic ischemic encephalopathy was approximately double the rate in the emergent cohort compared to the antepartum cohort (Table 3). Emergent prelabor cesarean was associated with higher neonatal mortality (11.3% vs 1.5%, $p=0.002$) (Table 3). In the emergent cesarean birth group, 6 neonates died, two neonates due to multiple fetal anomalies (years 2006 and 2007), three due to complications of prematurity (years 1994, 1986, 2007), and one due to respiratory, kidney, and heart complications (year 1997). In the antepartum group there were 2 neonatal deaths, one due to bronchopulmonary dysplasia (year 1995) and the other due to terminal bradycardia (year 2000) with absent heart rate at delivery; for the latter, the mother developed severe preeclampsia and declined recommended delivery resulting in

deteriorating maternal status. The 6 deaths in the emergent cesarean cohort had a median gestational age of 27 weeks and median birthweight of 709 grams while the 2 deaths in the antepartum cohort had a median gestational age of 25 weeks with a median birthweight of 680 grams. Neonatal mortality remained significantly elevated even after excluding the 2 neonates with significant fetal anomalies in the emergent cohort with 7.5% (4/53) compared to 1.5% (2/135) ($p=0.03$) (Table 3). There were not enough patients to conduct further statistical analysis of these numbers.

After adjusting for year of conception, race, hypertensive disorders, delivery at a transplant center, and fetal malformations, there was a persistent association of emergent prelabor cesarean after transplant with neonatal morbidity (aOR 3.01, [1.50, 6.08]). This persisted when further adjusting for gestational age (aOR 2.30, [1.05, 5.05]) (Table 4).

Discussion

Principal findings

Nearly one-third of liver and kidney transplant recipients with an antepartum admission underwent a prelabor emergent cesarean birth, the majority for non-reassuring fetal heart tracing during some form of antenatal monitoring. Emergent prelabor cesarean was associated with preterm delivery at 33 weeks and was independently associated with greater than twice the rate of neonatal morbidity in this high-risk kidney and liver transplant population. There was no association between allograft type, transplant interval, or immunosuppressive regimen with emergent prelabor cesarean and mode of delivery was not associated with peripartum rejection or short or long-term graft loss. Preexisting chronic hypertension was a significant risk factor as

was delivery outside of a transplant center. There was a statistically significant increase in maternal surgical site infection.

Results in the context of what is known

In the context of outcomes reported for emergent prelabor cesarean, a systemic review and meta-analysis found that emergent cesarean was associated with significantly increased rates of neonatal morbidity and mortality as well as maternal complications including surgical site infection, fever, urinary infection, wound dehiscence, disseminated intravascular coagulation, and reoperation compared with elective cesarean.¹⁹ We found similarly worsened neonatal outcomes with emergent prelabor cesarean after transplant, though the only significant maternal difference was surgical site infection. Transplant recipients were at a higher risk for emergent delivery independent of previously identified risk factors in non-transplant pregnancies including maternal age, diabetes, and abnormal placentation.²²⁻²⁴ A unifying theme in both transplant pregnancies and other pregnancies at risk for emergent prelabor cesarean is exacerbation of the underlying condition resulting in fetal compromise with associated preterm delivery. In those with diabetes, worsening A1c is most predictive of abnormal antenatal surveillance leading to cesarean with a 72% rate of prematurity at a mean gestational age of 35 weeks and 6 days.²³ In placenta previa, multiple early antepartum bleeds similarly portend the necessity for an emergency delivery at 34 weeks.²⁴ Our study adds to the existing literature to suggest that poor long-term vascular health due to chronic hypertension in patients after transplant and management outside of a transplant center are two modifiable risk factors that are important to consider in prevention of emergent prelabor cesarean in transplant recipients.

Clinical implications

The association with emergent prelabor cesarean and chronic hypertension but not hypertensive disorders of pregnancy suggests that medically indicated preterm delivery for those with preeclampsia may mitigate risk of an emergent cesarean that otherwise would occur in those with chronic hypertension who had a later indication for delivery at 36-39 weeks of gestation. Interestingly, superimposed preeclampsia was not associated with increased emergent cesarean delivery. In the context of chronic hypertension, the diagnosis of superimposed preeclampsia is made based on new or worsening proteinuria or presence of severe features including: thrombocytopenia, renal insufficiency, transaminitis, pulmonary edema, refractory headache or vision changes.²⁸ This may also relate to the indication for earlier delivery upon meeting the diagnosis of superimposed preeclampsia at 37 weeks or at 34 weeks if severe features. The mean gestational age at delivery of 33 to 34 weeks in both cohorts suggests that pregnancies after transplantation likely experience more complications and morbidity in the late preterm or early term period. Based on these study results, obstetric and transplant providers should thoughtfully discuss the utility of earlier delivery, depending on blood pressure control and fetal status. In light of the CHAP trial which identified benefit for more aggressive blood pressure management of chronic hypertension in pregnancy and in the setting of the findings of this study, earlier and more aggressive blood pressure management targeting normotension is especially important to mitigate the risk for emergent cesarean delivery in this population.²⁹ Delivery at a transplant center with multidisciplinary involvement including maternal fetal medicine, neonatology, and transplant teams may help determine the best delivery timing to optimize maternal, fetal, and allograft status.

Our findings also demonstrate the potential for improvement in the care of this high-risk population. We propose *Centers of Excellence* for care coordination for pregnant solid-organ

transplant recipients. A model for a *Center of Excellence* resulting in improved clinical outcomes has been shown for placenta accreta spectrum disorders³⁰⁻³². Multidisciplinary expertise lowers risks for massive hemorrhage, surgical complications, coagulopathy, and mortality in this high-risk group. The authors feel strongly that transplant recipients are a high-risk population at baseline with unique medical and surgical needs that require specialized expertise, including graft care and immunosuppression optimization, blood pressure titration, anesthesia considerations, and infection prevention. Addressing these complications could prevent emergent cesarean or mitigate its associated increased maternal and neonatal morbidity, especially at the time of antepartum admission.

Research implications

Further prospective research is required to understand if antepartum care at a transplant center can reduce maternal and neonatal morbidity, as this study was conducted retrospectively and specifically looked at one particular aspect of obstetric management. In addition, while recent studies have demonstrated no reduction in infection with postoperative antibiotics in emergent cesarean,³³ it is unclear if antibiotics in the immunosuppressed transplant population would decrease this risk of infection. More data is needed to address maternal and neonatal infection in this context.

Strengths and Limitations

A major strength of our study was the availability of 43 years of data, allowing us to investigate a cohort of 51 pregnancies (53 neonates) in this study of uncommon occurrences, emergent prelabor cesarean and a solid organ transplant. Women in the TPRI had close and consistent long-term follow-up. Study limitations include small sample size in the cohorts limiting the available analyses. Non-significant results and conclusions drawn from these

negative findings should be interpreted with caution in this context. Registry data is subject to selection and recall bias, though the reporting bias in our study is decreased by concurrent review of medical records in addition to participant survey data. However, there was still missing data on antepartum admission indications and length of stay, excluding the ability to control for these factors, though much of this information is captured by existing data on maternal and neonatal comorbidities that exist in other parts of the registry. While the availability of 43 years of data is a major strength of the study to capture a larger and more diverse study population, management and maternal and fetal resuscitation has vastly improved during that time. There are limitations when comparing deliveries across this time period and it is impossible to determine if morbidity or deaths during earlier deliveries would have had different outcomes with the current standard of care. Another limitation was the lack of more specific ethnic subgroup identification. Self-identified Asian race was associated with increased emergent cesarean but Asian is a very heterogeneous population, so this finding can only be considered preliminary without more detailed information.³⁴ Better identification of ethnic subgroups could help examine social determinants of health and structural racism that may drive risk among Asian identified pregnancies in the transplant population.

Conclusions:

Liver and kidney transplant recipients are at increased risk for an emergent prelabor cesarean birth which is associated with increased maternal surgical site infection, preterm birth, a greater than 40% rate of neonatal morbidity, and an 11% rate of neonatal mortality. We propose that pregnancies in liver and kidney transplant recipients should be cared for by multi-disciplinary teams with subspecialty-transplant-obstetrics collaboration at a transplant *Center of Excellence* to

mitigate the risk for emergent prelabor cesarean birth. This may be achieved through early recognition and management for hypertensive disease including earlier timing of delivery.

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	Emergency prelabor	Antepartum	
Demographics and risk factors	cesarean birth	admission	<i>P</i> value
	n = 51 (%)	n=130 (%)	

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Table 1: Demographics and risk factors for kidney and liver transplant recipients with antepartum admission, with or without emergency prelabor cesarean

Mode of delivery			<0.001
Emergent prelabor cesarean	51 (100)	0 (0)	
Scheduled cesarean birth	0 (0)	46 (35.4)	
Trial of labor to cesarean birth	0 (0)	30 (23.1)	
Vaginal birth	0 (0)	54 (41.5)	
Age (years), mean (SD)	29.9 (5.6)	30.3 (5.0)	0.69
Body Mass Index (kg/m ²), mean (SD)	25.7 (5.7)	26.1 (6.4)	0.80
Nulliparous	34 (66.7)	77 (59.2)	0.36
Twin gestation	2 (3.9)	5 (3.8)	0.98
Assisted reproductive technology	0 (0)	0 (0)	
Planned pregnancy	26 (51.0)	86 (66.2)	0.06
Prenatal Care	47 (92.2)	115 (88.5)	0.76
Race			0.03
Asian	6 (11.8)	2 (1.5)	0.007
Black	4 (7.8)	8 (6.2)	0.74
Other	3 (5.9)	16 (12.3)	0.28
Unknown	2 (3.9)	8 (6.2)	0.73
White	36 (70.6)	96 (73.8)	0.71
Hypertensive disease	38 (74.5)	108 (83.1)	0.02
Chronic hypertension	17 (33.3)	21 (16.2)	0.02
Gestational hypertension	1 (2.0)	7 (5.4)	0.45

Preeclampsia	11 (21.6)	33 (25.4)	0.70
Superimposed preeclampsia	9 (17.6)	47 (36.2)	0.02
Diabetes	9 (17.6)	17 (13.1)	0.24
Pregestational diabetes	7 (13.7)	7 (5.4)	
Gestational diabetes	2 (3.9)	10 (7.7)	
Urinary tract infection or pyelonephritis	11 (21.6)	20 (15.4)	0.32
Upper respiratory infection	4 (7.8)	7 (5.4)	0.53
Aspirin use	3 (5.9)	12 (9.2)	0.22
Anticoagulation	1 (2.0)	7 (5.4)	0.31
Abruption	2 (3.9)	2 (1.5)	0.33
Abnormal placentation	0 (0)	2 (1.5)	0.67
Anemia or thrombocytopenia	3 (5.9)	11 (8.5)	0.56
Antepartum bleeding	1 (2.0)	7 (5.4)	0.31
Preterm prelabor rupture of membranes	2 (3.9)	4 (3.1)	0.78

Table 2: Maternal Outcomes in kidney and liver transplant recipients with antepartum admission, with or without emergency prelabor cesarean

Pregnancy Outcomes	Emergency prelabor cesarean birth	Antepartum admission	<i>P</i> value
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	n = 51 (%)	n=130 (%)	
Severe maternal morbidity ^a	2 (3.9)	6 (4.6)	0.84
Acute myocardial infarction	0 (0)	1 (0.8)	
Blood products transfusion	1 (2.0)	1 (0.8)	
Cardiac arrhythmia	0 (0)	1 (0.8)	
Eclampsia	1 (2.0)	0 (0)	
Hysterectomy	0 (0)	1 (0.8)	
Pulmonary edema/heart failure	0 (0)	1 (0.8)	
Sepsis	0 (0)	1 (0.8)	
Postpartum hemorrhage	1 (2.0)	2 (1.5)	0.84
Intraamniotic infection	0 (0)	1 (0.8)	0.53
Surgical site infection	2 (3.9)	0 (0)	0.02
Postpartum readmission	1 (2.0)	2 (1.5)	0.84

^aSevere Maternal Mortality indicators according to the CDC: Acute myocardial infarction, aneurysm, acute renal failure, adult respiratory distress syndrome, amniotic fluid embolism, cardiac arrest/ventricular fibrillation, conversion of cardiac rhythm, disseminated intravascular coagulation, eclampsia, heart failure/arrest during surgery or procedure, puerperal cerebrovascular disorders, pulmonary edema/acute heart failure, severe anesthesia complications, sepsis, shock, sickle cell disease with crisis, air and thrombotic embolism, blood products transfusion, hysterectomy, temporary tracheostomy, ventilation

Table 3. Neonatal outcomes in kidney and liver transplant recipients with antepartum admission, with or without emergency prelabor cesarean

Neonatal outcomes	Emergency prelabor cesarean birth	Antepartum admission n=135 (%)	P value
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	n = 53 (%)		
Gestational age (weeks), mean (SD)	33.4 (3.63)	34.7 (3.27)	0.02
Birthweight (grams), mean (SD)	1899 (867)	2321 (732)	<0.001
Table 2: Pregnancy Outcomes Birthweight percentile, Mean (SD)	30.3 (25.9)	40.6 (29.1)	0.03
Sex			
Female	28 (52.8)	68 (50.4)	
Male	25 (47.2)	67 (50.0)	
Fetal malformation	5 (9.4)	6 (4.4)	0.19
NICU admission	28 (52.8)	48 (35.6)	0.03
NICU length of stay (days), mean (SD)	21.1 (10.8)	17.1 (11.1)	0.13
Neonatal composite morbidity	23 (43.4)	26 (19.3)	<0.001
Respiratory distress	11 (20.8)	17 (12.6)	
Intraventricular hemorrhage	1 (1.9)	2 (1.5)	
Sepsis	4 (7.5)	5 (3.7)	
Hypoxic ischemic encephalopathy	1 (1.9)	0 (0)	
Neonatal mortality	6 (11.3)	2 (1.5)	0.002

^aNeonatal composite morbidity included: intraventricular hemorrhage, hypoxic ischemic encephalopathy, seizure, sepsis, necrotizing enterocolitis, bronchopulmonary dysplasia, persistent pulmonary hypertension, respiratory distress syndrome, fracture, brachial plexus injury,

cardiopulmonary resuscitation, or perinatal death.

Table 4: Multivariable regression, neonatal composite morbidity associated with emergent prelabor cesarean delivery in transplant recipients

	Unadjusted OR	p-value	Adjusted OR	p-value
Model 1	3.21 (1.61, 6.45)	<0.001	3.01 (1.50, 6.08)	0.002
Model 2			2.30 (1.05, 5.05)	0.04

OR: odds ratio

Model 1: adjusted for year of conception, race, hypertensive disease, delivery at a transplant center, and fetal malformations.

Model 2: Model 1 additionally adjusted for gestational age at delivery

Figure 1: Flowchart of transplant recipient enrollment

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Figure 1. Study cohort

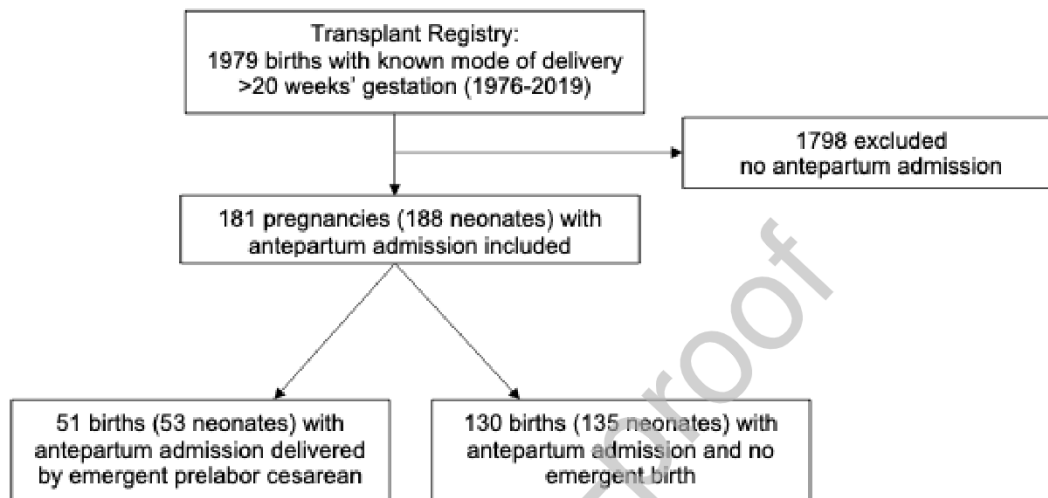


Figure 2: Visual abstract

