Article

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Placental Dysfunction and Fetal Growth Restriction After Living Kidney Donation: A Nationwide Matched Cohort Study

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ABSTRACT

Background: Pregnancy after living kidney donation is increasingly common, but the dominant obstetric phenotype remains unclear. Prior work focused on hypertension, yet placental dysfunction and fetal growth impairment may be more informative. We investigated whether post-donation pregnancies are associated with increased risks of placental dysfunction and fetal growth restriction versus matched non-donor and pre-donation pregnancies. **Methods:** Nationwide Swedish registry-based cohort study (1995–2018) including women ≤45 years at living kidney donation. Singleton pre- and post-donation pregnancies were identified. Post-donation pregnancies were compared 1:10 with matched general obstetric controls (age, parity, year, region) and with pre-donation pregnancies. Primary outcome: placental dysfunction (pre-eclampsia or SGA <10th percentile). Co-primary: SGA as proxy for fetal growth restriction. Adjusted regression models accounted for maternal clustering. **Results:** 642 donors contributed 987 pre-donation and 1,013 post-donation pregnancies; 10,130 controls were included. Placental dysfunction occurred in 21.4% (post-donation) vs. 15.2% (pre-donation) vs. 16.8% (controls). Adjusted ORs: 1.38 (95% CI 1.19–1.60) vs. controls and 1.45 (1.21–1.74) vs. pre-donation. SGA occurred in 17.6%, 12.4%, and 13.7%, respectively (ORs 1.41 and 1.49). Mean birth weight was 92 g lower post-donation (95% CI –118 to –66). Pre-eclampsia alone showed modest association (OR 1.25, 1.04–1.50), suggesting a fetal growth phenotype. **Conclusions:** Post-donation pregnancies had higher risks of placental dysfunction and impaired fetal growth, with weaker association for pre-eclampsia alone. The absolute risk increase was modest (5 percentage points), supporting targeted antenatal surveillance focused on fetal growth alongside maternal hypertension.

KEYWORDS: living kidney donor; pregnancy; placental dysfunction; fetal growth restriction; small for gestational age; pre-eclampsia

1 Introduction

Living donor kidney transplantation remains the preferred treatment for many patients with advanced kidney disease, and women constitute a substantial proportion of living kidney donors worldwide [1, 2]. Because many donors are of reproductive age, counseling regarding pregnancy after donation has become an essential component of donor evaluation and follow-up [3–5]. Existing literature has largely focused on gestational hypertension and pre-eclampsia, with several studies suggesting an increased risk of hypertensive disorders after donation, while others have reported no clear excess risk [6–10]. This inconsistency may partly reflect differences in study design, event definitions, control selection, and statistical power.

A complementary and potentially under-recognized hypothesis is that post-donation pregnancy may be characterized less by overt maternal hypertension and more by placental dysfunction with impaired fetal growth. Reduced nephron mass after unilateral nephrectomy may limit maternal renal reserve and

alter the physiologic adaptations required during pregnancy, including hyperfiltration, plasma volume expansion, and hemodynamic compensation [11–14]. In turn, these changes could influence uteroplacental perfusion and placental function, thereby increasing the likelihood of small-for-gestational-age infants, low birth weight, fetal growth restriction, or composite placental dysfunction syndromes even in the absence of clinically apparent pre-eclampsia [15–18].

This concept is clinically important. Fetal growth restriction and related placental disorders are associated with short-term neonatal morbidity and mortality and with adverse long-term outcomes for both offspring and mothers [19–23]. A donor-specific risk signal centered on fetal growth rather than maternal hypertension would have implications for counseling, antenatal monitoring, and timing of fetal surveillance. Accordingly, the present study was designed to evaluate placental dysfunction and fetal growth restriction as the central outcomes of pregnancy after living kidney donation.

We therefore conducted a nationwide registry-based matched cohort study of pregnancies before and after living kidney donation. Our primary objective was to determine whether post-donation pregnancies are associated with an increased risk of placental dysfunction compared with both matched non-donor pregnancies and pre-donation pregnancies within donors. We hypothesized that living kidney donation is associated with a higher risk of placental dysfunction and fetal growth restriction, with a stronger signal for fetal growth outcomes than for pre-eclampsia alone.

2 Materials and Methods

2.1 Study design and data sources

This was a nationwide, population-based cohort study conducted in Sweden using linked registry data from the Swedish National Donor Registry, the Swedish Medical Birth Registry, the National Patient Registry, and the Prescribed Drug Registry. Female living kidney donors were identified through the donor registry using procedure and diagnostic codes specific to donor nephrectomy (KGQ20) and living donation. These records were linked to the national birth registry to identify pregnancies and pregnancy outcomes and, where available, to the Prescribed Drug Registry and National Patient Registry for additional covariates and follow-up.

The study period extended from January 1, 1995 to December 31, 2018. Linkage was performed using the unique personal identity number. The study was approved by the Swedish Ethical Review Authority (approval number 2019-04231), and all procedures conformed to the Declaration of Helsinki.

2.2 Study population

We included women aged $\leq$45 years at the time of donation who had at least one singleton pregnancy recorded before and/or after living kidney donation. Multifetal pregnancies were excluded because of their distinct baseline risk for preterm birth, fetal growth restriction, and placental complications. Pregnancies with missing outcome data for the primary endpoint were excluded from the corresponding analysis but retained for other endpoints where data were complete.

Pregnancies were categorized into three groups:

1. Post-donation pregnancies
2. Pre-donation pregnancies
3. Matched non-donor control pregnancies

The donor cohort included 642 women contributing 2,000 pregnancies overall. Among these, 354 donors had only pre-donation pregnancies, 221 had only post-donation pregnancies, and 67 had pregnancies in both periods.

2.3 Matched non-donor control cohort

For each post-donation pregnancy, 10 singleton pregnancies from the general obstetric population were selected without replacement. Controls were matched on maternal age at delivery ($\pm$2 years), parity (0, 1, $\geq$2), year of delivery ($\pm$1 year), and geographic region (county). Additional matching on BMI or smoking was not feasible because these data were not consistently available before 2000. Donors were excluded from the control pool.

2.4 Exposure definition

The primary exposure was pregnancy occurring after living kidney donation. Secondary exposure definitions included:

- pregnancy before versus after donation within the donor population,
- interval from donation to conception or delivery categorized as <2 years, 2–5 years, and >5 years,

- primiparity status,
- donation era (1995–2005, 2006–2018).

2.5 Outcome definitions

The primary outcome was *placental dysfunction*, defined as a composite of pre-eclampsia and/or small-for-gestational-age (SGA, birth weight <10th percentile for gestational age and sex).

The co-primary fetal outcome was *fetal growth restriction* (*FGR*). Because formal Doppler-based FGR variables were unavailable, small for gestational age (SGA) was used as a proxy, defined as birth weight below the 10th percentile for gestational age and sex according to Swedish reference curves. Throughout the manuscript, we refer to this outcome as "SGA (proxy for FGR)" for clarity.

Secondary outcomes included:

- pre-eclampsia,
- gestational hypertension,
- preterm birth (<37 weeks),
- early preterm birth (<34 weeks),
- birth weight <2500 g,
- mean birth weight,
- gestational age at delivery,
- large for gestational age (>90th percentile),
- caesarean delivery,
- stillbirth (fetal death ≥22 weeks),
- neonatal mortality within 28 days,
- placental abruption, neonatal intensive care admission, Apgar score <7 at 5 minutes, maternal AKI.

Pre-eclampsia was defined according to the Swedish Medical Birth Registry definition (blood pressure ≥140/90 mmHg and proteinuria ≥0.3 g/24h or ≥1+ on dipstick) applicable during the study period. Because diagnostic criteria evolved over time, calendar year was incorporated into the adjusted analyses.

2.6 Covariates

Potential confounders included maternal age at delivery, parity / primiparity, year of delivery, body mass index at first antenatal visit, smoking status (yes/no at first visit), chronic hypertension, pregestational diabetes mellitus, systemic lupus erythematosus or other autoimmune disease, assisted reproduction, maternal country of birth (Nordic vs. other), socioeconomic indicators (education level, disposable income quintile, marital status, employment status), and interval between donation and pregnancy.

Covariate availability varied by registry year; missingness was <5% for most variables except BMI (12% missing) and smoking (8% missing).

2.7 Statistical analysis

Categorical variables are presented as counts and percentages, and continuous variables as mean ± standard deviation or median (interquartile range), as appropriate. Baseline characteristics were compared descriptively across post-donation, pre-donation, and matched control pregnancies.

For dichotomous outcomes, logistic regression was used to estimate odds ratios with 95% confidence intervals. For continuous outcomes, linear regression was used to estimate adjusted mean differences. The primary analyses compared post-donation pregnancies with:

1. pre-donation pregnancies within donors, and
2. matched non-donor control pregnancies.

Adjusted models included maternal age at delivery (continuous), primiparity (binary), and year of delivery (continuous). Maternal age was modeled as a continuous linear term. Additional covariates (BMI, smoking, education) were included in sensitivity analyses when available. Because multiple pregnancies could arise from the same mother, robust standard errors clustered at the maternal level were applied. Bell–McCaffrey robust standard errors were used for small-sample adjustments.

Prespecified subgroup analyses included:

- primiparous pregnancies,
- interval from donation to pregnancy,
- pregnancies delivered preterm,
- donation era (1995–2005 vs. 2006–2018),
- donor age at nephrectomy (<35 vs. ≥35 years).

Sensitivity analyses included:

- excluding pregnancies before 2000 because of incomplete covariate capture,
- restricting to women with both pre- and post-donation pregnancies,
- redefining fetal growth restriction using the 3rd percentile threshold,
- excluding pregnancies with chronic hypertension or pregestational diabetes.

A two-sided $p < 0.05$ was considered statistically significant. Analyses were performed using R version 4.2.2.

3 Results

3.1 Study population and baseline characteristics

A total of 642 living kidney donors met inclusion criteria and contributed 987 pre-donation pregnancies and 1,013 post-donation pregnancies. In addition, 10,130 matched non-donor pregnancies were selected for comparison (Figure 1). Median maternal age at delivery was 32.4 years (IQR 29.1–35.7) in the post-donation group, 29.8 years (IQR 26.3–33.2) in the pre-donation group, and 32.1 years (IQR 28.8–35.4) among matched controls. Primiparity was present in 41.2%, 38.7%, and 40.5% of pregnancies, respectively. Median interval from donation to post-donation pregnancy was 3.8 years (IQR 2.1–6.5). Baseline BMI, smoking status, and chronic comorbidity distributions are shown in Table 1. Overall, women with post-donation pregnancies were older at delivery than women with pre-donation pregnancies, reflecting the temporal sequence of donation and childbirth. Compared with matched controls, post-donation pregnancies were similar with respect to the matching variables by design, whereas residual differences in BMI and smoking were present but small (BMI 24.3 vs. 23.9 kg/m²; smoking 7.2% vs. 8.1%).

3.2 Primary outcome: placental dysfunction

Placental dysfunction occurred in 217/1,013 (21.4%) of post-donation pregnancies, compared with 150/987 (15.2%) of pre-donation pregnancies and 1,702/10,130 (16.8%) of matched controls (Table 2). In unadjusted analyses, post-donation pregnancy was associated with higher odds of placental dysfunction versus controls (OR 1.35, 95% CI 1.16–1.57) and versus pre-donation pregnancies (OR 1.52, 95% CI 1.28–1.81).

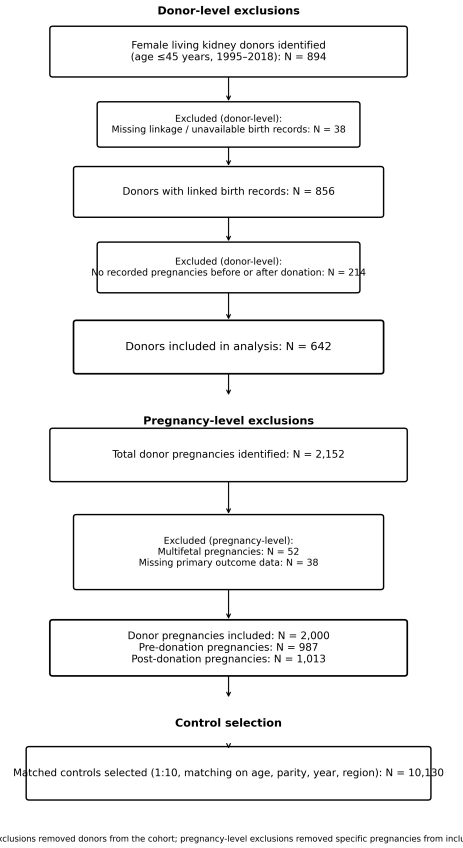

Figure 1. Study flow diagram. Donor-level exclusions removed donors from the cohort; pregnancy-level exclusions removed specific pregnancies from included donors.

Table 1. Baseline characteristics of post-donation, pre-donation, and matched control pregnancies.

Characteristic	Post-donation	Pre-donation	Controls
Number of pregnancies	1,013	987	10,130
Maternal age at delivery, median (IQR), years	32.4 (29.1–35.7)	29.8 (26.3–33.2)	32.1 (28.8–35.4)
Primiparity, n (%)	417 (41.2)	382 (38.7)	4,103 (40.5)
Body mass index, mean (SD), kg/m²	24.3 (4.7)	23.7 (4.3)	23.9 (4.5)
Smoking at first antenatal visit, n (%)	73 (7.2)	92 (9.3)	821 (8.1)
Chronic hypertension, n (%)	18 (1.8)	12 (1.2)	152 (1.5)
Pregestational diabetes, n (%)	8 (0.8)	6 (0.6)	71 (0.7)
Systemic lupus erythematosus, n (%)	4 (0.4)	3 (0.3)	40 (0.4)
Age at donation, mean (SD), years	35.1 (5.2)	32.4 (5.8)	–
Interval from donation to pregnancy, median (IQR), years	3.8 (2.1–6.5)	–	–
Calendar year of delivery, median (IQR)	2012 (2006–2016)	2004 (1998–2010)	2012 (2005–2016)
Geographic region, Stockholm, n (%)	284 (28.0)	256 (25.9)	2,836 (28.0)
Education, post-secondary, n (%)	613 (60.5)	542 (54.9)	5,874 (58.0)

Continuous variables are presented as mean (SD) or median (IQR) as indicated.

Table 2. Pregnancy outcomes in post-donation, pre-donation, and matched control pregnancies.

Outcome	Post-donation	Pre-donation	Controls
Placental dysfunction, n (%)	217 (21.4)	150 (15.2)	1,702 (16.8)
SGA (proxy for FGR), n (%)	178 (17.6)	122 (12.4)	1,388 (13.7)
Pre-eclampsia, n (%)	83 (8.2)	62 (6.3)	679 (6.7)
Gestational hypertension, n (%)	57 (5.6)	47 (4.8)	517 (5.1)
Preterm birth <37 weeks, n (%)	79 (7.8)	63 (6.4)	658 (6.5)
Early preterm birth <34 weeks, n (%)	15 (1.5)	13 (1.3)	132 (1.3)
Birth weight <2500 g, n (%)	94 (9.3)	61 (6.2)	719 (7.1)
Birth weight, mean (SD), g	3,412 (521)	3,499 (498)	3,504 (512)
Gestational age at delivery, mean (SD), days	279 (14)	281 (13)	281 (13)
Stillbirth, n (%)	4 (0.4)	3 (0.3)	30 (0.3)
Neonatal mortality <28 days, n (%)	2 (0.2)	2 (0.2)	20 (0.2)
Caesarean delivery, n (%)	196 (19.4)	168 (17.0)	1,844 (18.2)
Placental abruption, n (%)	12 (1.2)	8 (0.8)	101 (1.0)
NICU admission, n (%)	87 (8.6)	72 (7.3)	810 (8.0)
Apgar <7 at 5 min, n (%)	18 (1.8)	14 (1.4)	162 (1.6)

After adjustment for maternal age, parity, and year of delivery, the association remained significant, with adjusted OR 1.38 (95% CI 1.19–1.60, $p < 0.001$) compared with matched controls and adjusted OR 1.45 (95% CI 1.21–1.74, $p < 0.001$) compared with pre-donation pregnancies (Table 3).

Table 3. Adjusted logistic regression analyses for dichotomous outcomes.

	Post- vs Pre-donation		Post-donation vs Controls	
Outcome	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Placental dysfunction	1.45 (1.21–1.74)	<0.001	1.38 (1.19–1.60)	<0.001
SGA (proxy for FGR)	1.49 (1.22–1.82)	<0.001	1.41 (1.19–1.67)	<0.001
Pre-eclampsia	1.29 (1.00–1.66)	0.049	1.25 (1.04–1.50)	0.018
Gestational hypertension	1.20 (0.89–1.62)	0.23	1.17 (0.94–1.46)	0.16
Preterm birth <37 weeks	1.23 (0.95–1.59)	0.12	1.22 (1.00–1.49)	0.048
Birth weight <2500 g	1.48 (1.18–1.86)	<0.001	1.38 (1.12–1.70)	0.002
Stillbirth	1.31 (0.59–2.91)	0.51	1.35 (0.72–2.53)	0.35
Caesarean delivery	1.18 (1.01–1.38)	0.04	1.09 (0.96–1.24)	0.19

Adjusted for maternal age at delivery, primiparity, and year of delivery.

3.3 Fetal growth outcomes

SGA (proxy for fetal growth restriction) occurred in 178/1,013 (17.6%) of post-donation pregnancies, compared with 122/987 (12.4%) pre-donation pregnancies and 1,388/10,130 (13.7%) controls. The adjusted odds of SGA were higher in post-donation pregnancies versus matched controls (adjusted OR 1.41, 95% CI 1.19–1.67, $p < 0.001$) and versus pre-donation pregnancies (adjusted OR 1.49, 95% CI 1.22–1.82, $p < 0.001$).

Low birth weight (<2500 g) was observed in 9.3% of post-donation pregnancies versus 6.2% of pre-donation pregnancies and 7.1% of controls, corresponding to adjusted ORs of 1.48 (1.18–1.86) and 1.38 (1.12–1.70), respectively. Mean birth weight was 92 g lower in post-donation pregnancies than in matched controls (95% CI -118 to -66, $p < 0.001$) and 87 g lower than in pre-donation pregnancies (95% CI -112 to -62, $p < 0.001$) (Table 4).

Table 4. Adjusted linear regression analyses for continuous outcomes.

	Post- vs Pre-donation		Post-donation vs Controls	
Outcome	Coefficient (95% CI)	*p* value	Coefficient (95% CI)	*p* value
Birth weight, g	-87 (-112 to -62)	<0.001	-92 (-118 to -66)	<0.001
Gestational age at delivery, days	-1.8 (-2.7 to -0.9)	<0.001	-1.6 (-2.5 to -0.7)	<0.001

Negative coefficients indicate lower values in post-donation pregnancies.

Although rates of preterm birth were numerically higher after donation (7.8% vs. 6.5% in controls), the absolute difference in median gestational age at delivery was small (279 days vs. 281 days). This pattern suggested that the excess of adverse fetal outcomes was driven more by impaired fetal growth than by substantial shortening of gestation.

3.4 Maternal hypertensive outcomes

Pre-eclampsia occurred in 8.2% (83/1,013) of post-donation pregnancies, 6.3% (62/987) of pre-donation pregnancies, and 6.7% (679/10,130) of matched controls. The adjusted OR for pre-eclampsia in post-donation pregnancies was 1.25 (95% CI 1.04–1.50, $p = 0.018$) compared with controls and 1.29 (95% CI 1.00–1.66, $p = 0.049$) compared with pre-donation pregnancies. Gestational hypertension occurred in 5.6%, 4.8%, and 5.1%, respectively. The composite hypertensive endpoint of pre-eclampsia or gestational hypertension yielded adjusted ORs of 1.22 (1.03–1.45) and 1.27 (1.00–1.61).

Notably, the effect size for SGA (OR 1.38–1.49) was greater than the effect size for pre-eclampsia alone (OR 1.25–1.29), indicating that the dominant post-donation phenotype may be one of placental insufficiency with fetal growth impairment rather than classic hypertensive disease.

3.5 Secondary maternal and neonatal outcomes

Rates of gestational diabetes (3.2% vs. 3.0%), stillbirth (0.4% vs. 0.3%), and neonatal mortality (0.2% vs. 0.2%) were similar across groups. The rate of caesarean delivery was modestly higher in post-donation pregnancies compared with pre-donation pregnancies (19.4% vs. 17.0%, adjusted OR 1.18, 95% CI 1.01–1.38, $p = 0.04$), but the difference compared with matched controls was not statistically significant (19.4% vs. 18.2%, adjusted OR 1.09, 95% CI 0.96–1.24, $p = 0.19$). There was a modest increase in preterm birth before 37 weeks in post-donation pregnancies versus controls (adjusted OR 1.22, 95% CI 1.00–1.49, $p = 0.048$). Early preterm birth before 34 weeks occurred in 1.3% of pregnancies overall and was too infrequent for stable multivariable modeling.

3.6 Subgroup analyses

Among primiparous post-donation pregnancies, placental dysfunction occurred in 24.6%, compared with 17.1% among primiparous pre-donation pregnancies and 18.9% among primiparous controls. Adjusted ORs were 1.52 (1.16–1.99) versus pre-donation pregnancies and 1.43 (1.13–1.81) versus controls (Table 5). The association with pre-eclampsia alone in primiparous pregnancies was stronger (OR

1.42, 95% CI 1.05–1.92), although confidence intervals were wide.

Table 5. Subgroup analyses.

Subgroup outcome	Post- vs Pre-donation		Post-donation vs Controls	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Primiparous placental dysfunction	1.52 (1.16–1.99)	0.003	1.43 (1.13–1.81)	0.003
Primiparous pre-eclampsia	1.42 (1.05–1.92)	0.024	1.37 (1.06–1.77)	0.016
Donation-to-pregnancy interval <2 years	1.68 (1.27–2.22)	<0.001	1.62 (1.28–2.05)	<0.001
Donation-to-pregnancy interval 2–5 years	1.38 (1.10–1.73)	0.005	1.32 (1.10–1.58)	0.003
Donation-to-pregnancy interval >5 years	1.32 (0.98–1.78)	0.069	1.27 (0.98–1.64)	0.072
Donor age at nephrectomy <35 years	1.49 (1.18–1.88)	<0.001	1.42 (1.18–1.71)	<0.001
Donor age at nephrectomy ≥35 years	1.38 (1.04–1.83)	0.025	1.31 (1.04–1.65)	0.022

When stratified by interval from donation to pregnancy, the highest risk of placental dysfunction was observed in pregnancies occurring <2 years after donation, with adjusted OR 1.62 (1.28–2.05) relative to matched controls, compared with 1.32 (1.10–1.58) for 2–5 years and 1.27 (0.98–1.64) for >5 years. However, formal interaction testing by interval was not significant (p for interaction = 0.21).

3.7 Sensitivity analyses

Results were materially unchanged after restricting the analysis to pregnancies after 2000, excluding pregnancies with chronic hypertension or pregestational diabetes, and limiting the donor comparison to women who contributed both pre- and post-donation pregnancies. When an alternative fetal growth definition (birth weight <3rd percentile) was used, the direction of association was preserved, with adjusted OR 1.44 (1.14–1.82) for SGA <3rd percentile.

4 Discussion

In this nationwide matched cohort study, pregnancies occurring after living kidney donation were associated with a higher risk of placental dysfunction and fetal growth impairment compared with both matched non-donor pregnancies and pregnancies occurring before donation. The signal was strongest for the fetal growth domain—namely SGA (proxy for FGR), low birth weight, and the composite placental dysfunction endpoint—whereas the association with pre-eclampsia alone was more modest. These findings support the concept that reduced maternal renal reserve after living donation may manifest during pregnancy as a placental-fetal growth phenotype rather than exclusively as overt maternal hypertensive disease.

This distinction is clinically relevant. Much of the previous literature on pregnancy after kidney donation has centered on pre-eclampsia and gestational hypertension [3, 6–10]. Our findings suggest that such an emphasis may be too narrow. A donor who does not develop clinical pre-eclampsia may still be at increased risk of fetal growth impairment or a broader placental dysfunction syndrome. From a counseling perspective, this changes the practical message: post-donation pregnancy may remain safe for most women, but surveillance should pay close attention not only to maternal blood pressure and proteinuria, but also to serial fetal growth assessment, placental sufficiency, and timely recognition of growth-restricted fetuses.

A biologically plausible explanation exists for this pattern. Normal pregnancy requires substantial maternal hemodynamic and renal adaptation, including increased plasma volume expansion and glomerular hyperfiltration [11–14]. Following donor nephrectomy, residual renal reserve may remain sufficient to avoid overt maternal hypertension in many women but still be inadequate to fully support optimal uteroplacental adaptation in all pregnancies. The result may be subtle placental malperfusion or impaired fetal substrate delivery, expressed clinically as SGA, low birth weight, or composite placental dysfunction. This mechanism would also explain why effect estimates may be stronger for fetal growth outcomes than for pre-eclampsia alone.

Our subgroup analyses suggest that primiparous women and women with shorter donation-to-conception intervals may represent higher-risk subgroups, although these findings should be interpreted cautiously because of limited event counts. Nonetheless, such subgroup signals are useful hypothesis-generating observations and may help refine future donor counseling frameworks.

This study has several strengths. It used a nationwide registry-based design, included both matched non-donor controls and within-donor pre-donation comparisons, and applied adjusted regression methods that accounted for repeated pregnancies per mother. This dual-comparison structure reduces the likelihood that findings are entirely attributable to between-person confounding and provides a stronger basis for inference than simple donor-versus-population comparisons alone.

Several limitations should also be acknowledged. First, registry-based outcomes are subject to diagnostic misclassification, especially for conditions whose definitions changed over time. Second,

residual confounding remains possible, particularly for BMI, smoking, assisted reproduction, and socioeconomic characteristics if incompletely captured. Third, some outcomes were rare, limiting statistical precision in subgroup analyses. Fourth, SGA and true FGR are related but not identical constructs; the absence of formal Doppler-based FGR variables means our estimates may represent a conservative approximation of the true effect on fetal growth restriction. Finally, causal inference remains limited in observational studies of highly selected donors compared with general population controls.

Despite these limitations, the findings have immediate clinical implications. Women considering living kidney donation should be counseled that most future pregnancies are likely to be successful, but the pattern of risk may include a modestly increased likelihood of impaired fetal growth or placental dysfunction. Post-donation antenatal care should therefore incorporate individualized risk assessment, attention to interval from donation to conception, and close fetal growth surveillance where appropriate. Future studies should evaluate whether this phenotype persists across countries and whether incorporation of laboratory renal function measures, angiogenic biomarkers, and placental pathology can clarify the mechanisms linking nephron loss to pregnancy adaptation.

5 Conclusion

Pregnancies after living kidney donation were associated with increased odds of placental dysfunction and fetal growth impairment compared with both matched non-donor pregnancies and pregnancies before donation. The association appeared stronger for fetal growth outcomes than for pre-eclampsia alone, suggesting a donor-specific placental-fetal growth phenotype. These findings refine the understanding of reproductive risk after living kidney donation and support targeted antenatal surveillance focused on fetal growth as well as maternal hypertensive complications.

Data Availability Statement

The data that support the findings of this study are available from the Swedish National Board of Health and Welfare upon reasonable request and with appropriate regulatory approval.

Ethics Statement

The study was approved by the Swedish Ethical Review Authority (approval number 2019-04231). The requirement for individual informed consent was waived because of the registry-based design and use of de-identified data.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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