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Original Research Article

Association of pregnancy induced hypertension with fetal gender

Usman Gani[1], Farheen Qureshi[1], Bilkees Gani[2], Nighat Firdous[1], Fiza Aftab[2]*

[1]Department of Obstetrics and Gynecology, GMC Srinagar, Jammu and Kashmir, India
[2]Department of General Surgery, SKIMS SOURA, Srinagar, Jammu and Kashmir, India

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***Correspondence:**
Dr. Fiza Aftab,
E-mail: aftabfiza185@gmail.com

ABSTRACT

Background: Hypertension is a common complication during pregnancy, affecting up to 10% of pregnancies. Fetal gender has been suggested to influence the incidence and severity of pregnancy induced hypertension, though findings are inconsistent. This study aimed to investigate the relationship of pregnancy induced hypertension and its severity with fetal gender.
Methods: A total of 1500 pregnant women with singleton pregnancies diagnosed with gestational hypertension or preeclampsia were included in this prospective observational study conducted at Lal Ded Hospital, Srinagar, from November 2018 to March 2020.
Results: The fetal male/female sex ratio in the study group was 0.86 male/female, which was significantly lower than the overall hospital sex ratio of 1.07 male/female during this period. In other words pregnant women having PIH delivered more female babies. The study also found that pregnancy-induced hypertension was more common in primigravida women, with preeclampsia being more prevalent than gestational hypertension. Female fetuses had a higher incidence of intrauterine growth restriction (IUGR), while male fetuses had a higher rate of preterm deliveries. Overall, 4.1% of pregnancies resulted in intrauterine deaths, with a higher proportion of male fetuses.
Conclusions: The study highlights that female fetal gender increases the likelihood of mothers having PIH and are associated with higher IUGR rates than male fetuses while male fetal gender was associated with predominant preterm deliveries and intrauterine demise/still birth. Though many studies suggest controversial results, the study demands detailed evaluation at chromosomal level as to study the factors that predisposed the mother to pregnancy induced hypertension.

Keywords: Fetal sex, Gestational hypertension, Intrauterine growth restriction, Preeclampsia, Pregnancy-induced hypertension, Preterm delivery

INTRODUCTION

Hypertension is one of the most common medical conditions encountered during pregnancy, complicating up to 10% of pregnancies.[1] Studies have suggested a connection between fetal gender differences and the incidence and severity of preeclampsia, although findings are inconsistent. Some research has indicated that pregnant women expecting a male fetus are at a higher risk of gestational diabetes, gestational hypertension/preeclampsia, and preterm delivery, though conflicting results exist.[2-6] Women with preeclampsia (PE) and their offspring are at increased risk of developing cardiovascular diseases and stroke later in life.[7] Gestational age has also been proposed as a factor that influences the pathophysiology and outcomes of preeclampsia, with variations in acute and long-term consequences for both mother and baby. In the early 1970s, Toivanen and Hirvonen reported that pregnant women carrying a male fetus exhibited a higher prevalence

of preeclampsia, with the ratio of male to female fetuses increasing with the severity of the disease.[8] Similar findings were reported by Jaskolka et al, who noted that a male fetus was associated with an increased maternal risk of preeclampsia/eclampsia in non-Asian populations.[9] However, more recent studies suggest that women expecting a female fetus may experience earlier onset preeclampsia, whereas those carrying male fetuses tend to have a higher rate of late-onset preeclampsia.[10,11] A global meta-analysis also found preterm preeclampsia to be more prevalent among pregnancies with a female fetus compared to male foetuses.[12] In line with this, a Japanese study reported a significantly higher incidence of preeclampsia in women carrying female foetuses.[13] These studies imply the existence of sexual dimorphic differences in the occurrence of preeclampsia, although some studies have found no significant effect of fetal gender on the incidence or severity of the disease.[14,15]

Hypertensive disorders in pregnancy are classified into four categories by the National High Blood Pressure Education Program Working Group on High Blood Pressure in Pregnancy: preeclampsia, eclampsia, gestational hypertension, and chronic hypertension with superimposed preeclampsia.[16] Preeclampsia is characterized by high blood pressure and significant proteinuria, typically manifesting after 20 weeks of gestation.[17-20] If left untreated, preeclampsia can progress to eclampsia, marked by seizures.[21,22] Although the exact pathophysiologic mechanisms remain unclear, abnormal placental implantation is considered a major contributing factor, leading to poor uterine and placental perfusion, hypoxia, oxidative stress, and endothelial dysfunction.[23,24] This dysfunction manifests as maternal organ dysfunction and fetal growth restriction.[25] Preeclampsia can have severe complications, including eclampsia, HELLP syndrome, stroke, liver and kidney dysfunction, and acute respiratory distress syndrome (ARDS).[26,27] It also increases the likelihood of cesarean delivery, preterm birth, and placental abruption. The maternal risks include long-term cardiovascular diseases, while fetal risks involve intrauterine growth restriction and perinatal death.[28] Risk factors for preeclampsia include maternal obesity, prior hypertension, diabetes, and advanced maternal age, as well as certain genetic and immunological factors.[20,28] Moreover, preeclampsia is more frequent in first pregnancies and when carrying multiple foetuses.[20] Women with preeclampsia are also at increased risk of recurrence in subsequent pregnancies, especially when the disease develops early or severely.[29]

Gestational hypertension, which presents with elevated blood pressure after 20 weeks of gestation without other features of preeclampsia, may progress to preeclampsia in about one-third of cases. While the pathophysiology of gestational hypertension is not fully understood, it is believed to involve endothelial dysfunction and vasospasm, affecting uterine, placental, and other vascular systems.[30] Risk factors for gestational hypertension include maternal age, obesity, preexisting vascular conditions, and multiple gestations.[30] Severe gestational hypertension, defined by blood pressure readings ≥160/110 mmHg, warrants careful monitoring due to potential maternal and fetal complications.[30]

Chronic hypertension in pregnancy, defined as high blood pressure present before pregnancy or before 20 weeks of gestation, is associated with several pregnancy complications, including preeclampsia, fetal growth restriction, and placental abruption.[31] Maternal risks of chronic hypertension include heart failure, kidney failure, and stroke, while fetal risks involve preterm birth and stillbirth.[31] The relationship between fetal gender and pregnancy-induced hypertension (PIH) and preeclampsia remains an area of interest, with several studies identifying an association between maternal hypertension and the gender of the fetus. Most studies suggest a higher association of pregnancy-induced hypertension in women carrying female fetuses compared to male fetuses. However, no study to date has comprehensively examined the relationship between fetal gender and all hypertensive disorders of pregnancy, including the development of severe features. This study aimed to investigate the relationship of pregnancy induced hypertension and its severity with fetal gender.

METHODS

This prospective observational study, titled "Association of Pregnancy-Induced Hypertension with Fetal Gender," was conducted in the Postgraduate Department of Gynaecology and Obstetrics, Lal Ded Hospital, Government Medical College, Srinagar, from November 2018 to March 2020 (duration of one year and five months). The study was approved by the institutional ethical committee, and written informed consent was obtained from all participants.

Inclusion criteria

Pregnant women with a singleton pregnancy who presented with gestational hypertension and/or preeclampsia during the current pregnancy and attended the obstetrics outpatient department and gave birth at our facility, and who were willing to participate, were enrolled in the study.

Exclusion criteria

Chronic hypertension, eclampsia, multiple pregnancy (twins/triplets), patients who were admitted but did not give birth at our hospital were excluded.

Methods

The study was conducted on women who met the inclusion criteria. Pregnant women diagnosed with gestational hypertension or preeclampsia were enrolled. Diagnosis was made according to the International Classification of Diseases, 10th revision, clinical modification (ICD-10-

CM), and based on the American College of Obstetricians and Gynecologists (ACOG) criteria. Singleton pregnancies with a gestational age between 20 weeks 0 days and 40 weeks 6 days were included.

Gestational hypertension: New onset systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg on two occasions at least 4 hours apart after 20 weeks gestation, without associated proteinuria.

Preeclampsia: Same blood pressure criteria as gestational hypertension, but with associated proteinuria (urine dipstick protein 2+, protein-creatinine ratio >0.3, or 24-hour urine protein >300mg).

Severe features of preeclampsia: Systolic blood pressure ≥160 mmHg or diastolic ≥110 mmHg, along with other features such as thrombocytopenia, renal insufficiency, elevated liver enzymes, new onset headache/visual changes, right upper quadrant pain, or pulmonary edema.

All cases were followed until delivery, and the following data were recorded:

Type of hypertensive disorder: 1) Gestational Hypertension, 2) Preeclampsia.

Severity of hypertensive disorder: 1) Mild/non-severe, 2) Severe.

Duration of pregnancy: 1) Term, 2) Preterm.

Mode of delivery: 1) Vaginal delivery, 2) Caesarean section.

Fetal sex at birth: 1) Male, 2) Female.

Fetal outcome:1) Intrauterine growth restriction (IUGR), 2) Preterm birth, 3) Stillbirth/intrauterine death (IUD).

Participants were divided into two groups based on fetal gender. The primary outcome of the study was to compare the fetal sex ratio at birth of the study group with the overall sex ratio observed at our hospital during the study period. The total number of births and fetal gender (male or female) were obtained from the birth register of the hospital.

Statistical analysis

The recorded data were compiled and entered into a Microsoft Excel spreadsheet. Statistical analysis was performed using SPSS (Version 20.0) and Microsoft Excel. Categorical data were expressed as percentages, and continuous data were summarized as Mean ± SD. The Chi-square test or Fisher's exact test was used for the comparison of categorical variables. Graphical representation of the data was provided using bar diagrams. A p value of less than 0.05 was considered statistically significant.

RESULTS

A total of 1500 pregnant women with hypertensive disorders of pregnancy were included in the study, excluding those with eclampsia and chronic hypertension. Among these, 1006 (67.1%) had preeclampsia, and 494 (32.9%) had gestational hypertension. The distribution of patients by age group showed that 232 (15.5%) patients were aged 24 years or younger, with 164 (70%) diagnosed with preeclampsia and 68 (29.3%) with gestational hypertension. In the age group of 25-29 years, 757 patients (50.4% of the total) were identified, of whom 511 (67.5%) had preeclampsia and 246 (32.5%) had gestational hypertension. The age group of 30-34 years comprised 374 patients (25% of the total), with 242 (64.7%) diagnosed with preeclampsia and 132 (35.3%) with gestational hypertension. Finally, 137 patients (9.1% of the total) were aged 35 years or older, with 89 (65%) diagnosed with preeclampsia and 48 (35%) with gestational hypertension.

The gravidity distribution in the study group showed that 785 (52.3%) patients were primigravida, while 385 (25.7%) were gravida two, 227 (15.1%) were gravida three, 56 (3.7%) were gravida four, 38 (2.5%) were gravida five, 7 (0.5%) were gravida six, and 2 (0.1%) were gravida seven. In terms of the severity of the hypertensive disorder, 468 patients (31.2%) had severe disease, while 1032 patients (68.8%) had non-severe or mild disease. Regarding the delivery outcomes, 1378 patients (91.9%) delivered at or above 37 weeks gestation, 73 patients (4.9%) delivered between 33 and 36 weeks, 37 patients (2.5%) delivered between 29 and 32 weeks, and 12 patients (0.8%) delivered at or below 28 weeks. In terms of the mode of delivery, 798 patients (53.2%) underwent caesarean sections, while 702 patients (46.8%) had vaginal deliveries. The fetal sex distribution at birth showed that 807 babies (53.8%) were female, and 693 babies (46.2%) were male. The fetal sex ratio in the study group was 0.86 male(s) for every female (116 females per 100 males). The fetal sex ratio for cases of gestational hypertension was 0.88 male(s) for every female (113 females per 100 males), while for preeclampsia, the ratio was 0.85 male(s) for every female (118 females per 100 males). In comparison, the overall fetal sex ratio at birth in the hospital during the study period was 1.07 males for every female (107 males per 100 females). A p value of 0.001 was observed when comparing the fetal sex ratio of the study group to the overall sex ratio in the hospital.

Regarding fetal outcomes, 1006 babies (67.1%) were born at term with normal neonatal parameters, 121 babies (8.1%) were preterm, and 373 babies (24.9%) were small for gestational age (IUGR). Among the 807 female babies, 560 (69.4%) were born at term with normal neonatal parameters, 30 (3.7%) were preterm, and 217 (26.9%) were IUGR. Among the 693 male babies, 446 (64.4%) were born at term with normal neonatal parameters, 91 (13.1%) were preterm, and 156 (22.5%) were IUGR. When considering the two types of hypertensive disorders, among those with gestational hypertension, 350 female

babies (70.9%) and 232 male babies (70.9%) were born at term with normal neonatal parameters, while 30 female babies (6.1%) and 30 male babies (6.1%) were preterm, and 114 female babies (23.1%) and 114 male babies (23.1%) were IUGR. Among patients with preeclampsia, 656 female babies (65.2%) and 446 male babies (64.4%) were born at term with normal neonatal parameters, 91 female babies (9.0%) and 91 male babies (13.1%) were preterm, and 259 female babies (25.7%) and 156 male babies (22.5%) were IUGR. Out of the total 1500 babies born in the study group, 1439 (95.9%) were born alive, and 61 (4.1%) were intrauterine deaths (IUDs) or stillbirths. Among the IUDs, 35 were male (57% of the total IUDs), and 26 were female (43% of the total IUDs). In terms of birth weight, 1018 babies (67.9%) had a birth weight of 2.5 kg or above, while 482 babies (32.1%) had a birth weight of less than 2.5 kg. Of the low-birth-weight babies, 362 (24.1%) had a birth weight in the range of 2.01-2.49 kg, 99 (6.6%) had a birth weight in the range of 1.51-2.00 kg, and 99 (1.4%) had a birth weight of ≤1.5 kg. Among babies born with IUGR and preterm, 320 (88.4%) had a birth weight of 2.01-2.49 kg, 52 (52.5%) had a birth weight of 1.51-2.00 kg, and 1 (4.8%) had a birth weight of ≤1.5 kg.

Table 1: Distribution of hypertensive disorders of pregnancy by age group and severity.

Age group (years)	Total patients	Preeclampsia (%)	Gestational hypertension (%)	Severity: Severe (%)	Severity: non-severe (%)
≤24	232	164 (70)	68 (29.3)	72 (31.0)	160 (69)
25-29	757	511 (67.5)	246 (32.5)	235 (31.1)	522 (68.9)
30-34	374	242 (64.7)	132 (35.3)	123 (32.9)	251 (67.1)
≥35	137	89 (65)	48 (35)	38 (27.7)	99 (72.3)
Total	1500	1006 (67.1)	494 (32.9)	468 (31.2)	1032 (68.8)

Table 2: Fetal gender distribution and fetal sex ratio at birth.

Hypertensive disorders	Female babies (%)	Male babies (%)	Total babies (%)	Fetal sex ratio (male/female)
Gestational hypertension	262 (32.5%)	232 (33.5%)	494 (32.9%)	0.88
Preeclampsia	545 (67.5%)	461 (66.5%)	1006 (67.1%)	0.85
Total	807 (53.8%)	693 (46.2%)	1500 (100%)	0.86

Table 3: Fetal outcomes by hypertensive disorder and sex.

Fetal outcome	Gestational hypertension (%)		Preeclampsia (%)		Total (%)	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**
Term with normal neonatal parameters	350 (70.9)	232 (70.9)	656 (65.2)	446 (64.4)	560 (69.4)	446 (64.4)
Preterm	30 (6.1)	30 (6.1)	91 (9.0)	91 (13.1)	30 (3.7)	91 (13.1)
IUGR	114 (23.1)	114 (23.1)	259 (25.7)	156 (22.5)	217 (26.9)	156 (22.5)

These results suggest that while the fetal sex ratio in the study group was lower compared to the hospital's overall sex ratio, there were no significant differences in fetal outcomes by sex, though preterm deliveries and intrauterine growth restriction (IUGR) were more prevalent among certain subgroups.

DISCUSSION

The present study aimed to explore the relationship between pregnancy-induced hypertension (gestational hypertension and preeclampsia) and fetal outcomes, with a particular focus on the fetal sex ratio and its association with hypertensive disorders. The study was conducted from November 2018 to March 2020 in the Department of Obstetrics and Gynaecology at Lal Ded Hospital, an associated hospital of Government Medical College, Srinagar. During this study period, a total of 44,072 antenatal patients were admitted at various ages of gestation, out of which 33,788 delivered their babies at our hospital. Out of these, 17,477 were male births and 16,311 were female births. Among the 1500 cases of singleton pregnancies with pregnancy-induced hypertension, 494 cases had gestational hypertension and 1006 had preeclampsia, with respective incidences of 1.5% and 3%. Preeclampsia was found to be more prevalent (67.1%) compared to gestational hypertension (32.9%) in our study group. In addition, our study found that pregnancy-induced hypertension was more prevalent among primigravida women, with 52.3% of the cases being primigravida. In terms of disease severity, we found that 31.2% of the cases in the study group were classified as severe, and the remaining 68.8% were categorized as non-severe or mild. This suggests that a substantial proportion of women with pregnancy-induced hypertension were diagnosed with more serious forms of the disorder, which

could potentially lead to more adverse pregnancy outcomes.

Regarding gestational outcomes, the majority of pregnancies in the study group (91.9%) delivered at or beyond 37 weeks. Only 0.8% of pregnancies were terminated at ≤28 weeks, 2.5% were terminated between 29 and 32 weeks, and 4.9% were terminated between 33 and 36 weeks, indicating that preterm deliveries were relatively uncommon in this cohort. In our study, 53.2% of deliveries were by caesarean section, while 46.8% were vaginal deliveries, highlighting the commonality of caesarean sections in managing hypertensive pregnancies. A notable finding of this study was the relatively increased predominance of female fetuses in the study group, with 53.8% of babies born being female and 46.2% male. The fetal sex ratio at birth in our study group was 0.86 male/female (116 females per 100 males), which is lower than the overall fetal sex ratio at birth during the study period in our hospital, which was 1.07 (107 males per 100 females). This disparity in the sex ratio was statistically significant (χ^2, $p<0.005$). The sex ratio was 0.88 male/female (113 females per 100 males) in cases of gestational hypertension and 0.85 male/female (118 females per 100 males) in cases of preeclampsia. This finding suggests that pregnancy-induced hypertension may be associated with a higher likelihood of female fetuses, in agreement with some previous studies that have shown a greater risk of preeclampsia in women carrying a female fetus.[32,11] However, there is conflicting evidence in the literature regarding the fetal sex and its impact on preeclampsia risk, with some studies suggesting a higher risk in women carrying a male fetus.[9,6] Thus, further research is necessary to clarify the relationship between fetal sex and preeclampsia.

The mechanisms underlying the association between female fetal sex and an increased risk of preeclampsia are still not fully understood. One potential explanation could be gender-dependent differences in the renin-angiotensin system during early gestation. Studies have reported that women carrying a female fetus tend to have higher levels of angiotensin in early pregnancy compared to those carrying a male fetus, which may contribute to the development of preeclampsia.[33] Another potential mechanism involves differences in human chorionic gonadotropin (hCG) levels by fetal gender. Elevated hCG levels have been suggested as a predictive marker of preeclampsia, and several studies have shown that hCG levels are typically higher in women carrying a female fetus.[34-37] These findings indicate that the underlying pathophysiology is complex, and further studies are required to better understand the biological mechanisms at play. In terms of fetal outcomes, the incidence of intrauterine growth restriction (IUGR) was approximately 25% in our study, with 27% of female fetuses being diagnosed as IUGR compared to 23% of male fetuses. Statistically, female fetal gender was found to be associated with a higher incidence of IUGR (χ^2, $p<0.005$). Of the total IUGR cases in the study group, 58% were females and 42% were males. This observation is consistent with other studies that have shown that female fetuses are more likely to be diagnosed with IUGR in hypertensive pregnancies. The incidence of IUGR was similar in both gestational hypertension and preeclampsia, with 23.1% of women with gestational hypertension and 25.7% of women with preeclampsia delivering IUGR babies.

Regarding preterm delivery, the incidence in our study group was approximately 8%. Male fetuses were more commonly born preterm, with 13% of male fetuses and 3.7% of female fetuses being preterm. Out of the total preterm deliveries, 75% were males and 25% were females. This suggests that male fetal gender is associated with an increased risk of preterm delivery in hypertensive pregnancies (χ^2, $p<0.005$). Furthermore, preeclampsia was found to be associated with a higher rate of preterm deliveries compared to gestational hypertension, with 9% of women with preeclampsia delivering preterm compared to 6% of women with gestational hypertension (χ^2, $p<0.005$). The incidence of intrauterine death (IUD) or stillbirths in the study group was 4%, with 61 IUDs observed. Among these, 57% were male fetuses, and 43% were female fetuses. While males had a slightly higher proportion of IUDs, the difference was not statistically significant ($\chi^2=3.19$, $p=0.08$). When the type of hypertensive disorder was considered, the incidence of stillbirths was similar between women with gestational hypertension (4.5%) and those with preeclampsia (3.9%) ($\chi^2=0.28$, $p=0.59$), suggesting no significant association between hypertensive disorder type and stillbirth risk. Lastly, the incidence of low birth weight in our study group was approximately 32%, with 482 newborns having a birth weight of less than 2.5 kg. Among these, 77% were diagnosed with IUGR, and 23% were preterm. These findings highlight the significant association between low birth weight and hypertensive disorders of pregnancy, which are known to increase the risk of adverse neonatal outcomes.

This study has several limitations. First, the sample size was smaller compared to larger cohort studies, as data was collected from a single academic hospital, limiting generalizability. Second, being a tertiary care hospital, the study likely reflects a higher-risk population, which may not represent the general population. Lastly, our study focused only on the association between fetal sex and pregnancy-induced hypertension, without exploring the underlying causes.

CONCLUSION

Pregnancy-induced hypertension (PIH), including gestational hypertension and preeclampsia, is a significant complication affecting both maternal and fetal health. Our study supports the notion of sexual dimorphism in the maternal-fetal-placental interaction, showing that carrying a female fetus is associated with an increased risk of PIH. Additionally, PIH was linked to adverse fetal outcomes

such as intrauterine growth restriction (IUGR), preterm delivery, stillbirths, and low birth weight. Female fetal sex was significantly associated with IUGR, while male fetal sex was more likely to result in preterm delivery. However, findings from other studies, particularly in non-Asian populations, present conflicting results, suggesting that genetic and ethnic factors may play a role. Thus, while our study highlights fetal sex as a potential risk factor for PIH-related complications, the underlying mechanisms remain unclear and warrant further research. Fetal gender should be considered in risk assessments for PIH, IUGR, stillbirths, and preterm delivery, which could improve management strategies for pregnancies complicated by hypertension.

Recommendations

Future research should aim to explore the complex pathophysiological mechanisms linking fetal gender with pregnancy-induced hypertension and its complications. Larger multicenter studies with more diverse populations, including both high- and low-risk pregnancies, would help validate these findings and offer more generalizable results. Furthermore, the role of gestational diabetes mellitus (GDM) and other comorbid conditions in influencing pregnancy outcomes should be explored in conjunction with PIH. Longitudinal studies assessing genetic, hormonal, and immunological factors could provide deeper insights into the mechanisms behind the observed sexual dimorphism in pregnancy outcomes.

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