A 24-year-old nulliparous woman developed mildly elevated blood pressure (140–150/90–100 mmHg) without proteinuria (20 mg protein in a 24-hour urine collection) at 30\(^{+7}\) weeks of gestation. The fetus was small for gestational age (estimated fetal weight under the fifth percentile). At 32\(^{+7}\) weeks of gestation, the patient complained of epigastric pain, blood pressure was 180/110 mmHg, proteinuria was documented (780 mg protein in a 24-hour urine collection), schistocytes were detected in the peripheral smear, platelet count was 60,000 cells per mm\(^3\), and serum glutamic oxaloacetic transaminase was 234 U/l. The patient was diagnosed with severe preeclampsia/HELLP syndrome. Antenatal steroids were administered to induce fetal lung maturity. She and her family want to know the causes of this condition, what treatment is available, and whether there are any long-term implications of this diagnosis.

**Current therapy**

The patient described above, with new-onset hypertension (≥140/90 mmHg) and proteinuria (≥300 mg/24-hour urine) after 20 weeks of gestation, meets the criteria for the diagnosis of preeclampsia (1–3). The presence of epigastric pain, thrombocytopenia, schistocytes, and elevated hepatic enzymes is characteristic of a severe form of preeclampsia, known as HELLP (hemolysis, elevated liver enzymes, and low platelet count) syndrome (4–9). Preeclampsia is a multisystemic disorder and a leading cause of maternal and perinatal morbidity/mortality (10). Maternal complications may include convulsions ( eclampsia), intracranial hemorrhage, liver hematoma and rupture, pancreatitis, renal failure, disseminated intravascular coagulation, and maternal death. The only known treatment for preeclampsia is delivery of the fetus and placenta. Medical management consists of the administration of intravenous magnesium sulfate to decrease the risk of eclampsia (11) and antihypertensive agents (e.g., hydralazine and/or labetalol) to prevent the consequences of a hypertensive crisis (e.g., stroke). The decision to deliver a patient must balance the risks and benefits for the mother and fetus. In term gestations, when the fetus is mature, the issue is straightforward; delivery will address the maternal syndrome without major risk to the neonate (12). In preterm gestations, however, the risk to the mother of continuing the pregnancy must be balanced with the risk of preterm birth (<37 weeks of gestation), which is associated with an increased risk of short-term complications largely attributed to multiple organ immaturity (e.g., respiratory distress syndrome, intraventricular hemorrhage, necrotizing enterocolitis, neonatal sepsis) and long-term complications (e.g., chronic lung disease, neurodevelopmental disorders).

Preeclampsia is considered an inexorable disorder, and the only definitive treatment is delivery. Current medical therapy after the diagnosis of preeclampsia is aimed at preventing maternal and fetal complications (e.g., magnesium sulfate, antihypertensive agents, and antenatal steroids). Yet, there are reasons to be optimistic. Prevention of this disorder is possible. Aspirin administration in patients with a prior history of preeclampsia reduces the rate of recurrence by 10% (13). Moreover, a recent trial indicates that the combination of nitric oxide donors and antioxidants (l-arginine and vitamins E and C) may reduce the recurrence rate by 17% (14). Given the modest effect size of these interventions, a continued search for effective interventions is needed. The identification of preventive and therapeutic strategies can be guided by an improved understanding of the molecular mechanisms of disease operating in this syndrome. Development of a molecular taxonomy of disease would be a major step forward. It is now clear that preeclampsia is not a single entity but rather a syndrome with multiple etiologies. Therefore, biomarkers, preventive strategies, and treatment must be targeted to the specific mechanism of disease in each of the clusters of the syndrome.

Central to the pathophysiology of preeclampsia is ischemia of the placenta (15, 16), which leads to the release of soluble factors and micro/nanovesicles (17, 18) into the maternal circulation responsible for the clinical signs of preeclampsia: hypertension and proteinuria. These factors have been referred to as “toxins,” hence the name “toxemia of pregnancy” (19). The cause of placental ischemia is thought to be inadequate remodeling of the spiral arteries that brings maternal blood into the intervillous space of the placenta (20, 21). The mechanism responsible for the remodeling involves migration of trophoblasts from the anchoring villi into the decidua and superficial myometrium as well as the lumen and wall of the spiral arteries (21–24).

Ten years ago, Maynard et al. reported that an antiangiogenic factor, soluble VEGF-R-1 (sVEGFR-1) or soluble fms-like tyrosine kinase 1 (sFlt-1), was increased in the placentas of women with preeclampsia and that increased concentrations could recapitulate the features of the syndrome in pregnant rats (25). sVEGFR-1 plasma/serum concentrations correlated with the severity of preeclampsia (26), and the elevation could be demonstrated prior to the clinical diagnosis (27). The observation that the sera of women with preeclampsia (but not that of normal pregnant women) inhibited angiogenesis in vitro suggested that the condition is associated with an antiangiogenic state. Importantly, administration of recombinant VEGF-121 attenuated hypertension and improved renal lesions in an animal model of preeclampsia.
Preeclampsia to those of a control group. The case for SEMA3B can be strengthened by demonstrating that the administration of this protein (directly or through a vector) to pregnant animals can induce hypertension, thrombocytopenia, hepatic dysfunction, renal lesions. This should be reversible by blocking the effects of SEMA3B in vivo. Proof of a link between a trophoblast disorder and preeclampsia also requires evidence that overexpression of SEMA3B results in shallow placentation and failure of physiologic transformation of the spiral arteries. It would be important to determine whether the circulating concentrations of SEMA3B differ between patients with preeclampsia and normal pregnant women and whether such differences correlate with the severity of the disease and are detectable prior to clinical diagnosis. Demonstrating to what degree the putative involvement of SEMA3B is specific to preeclampsia is also desirable. An abnormal angiogenic profile, characterized by low concentrations of PI GF and high concentrations of the angiogenic molecules sVEGF-R-1 and sEng, was discovered in the context of preeclampsia, but we now know that such abnormalities can also be observed in patients destined to have fetal growth restriction (39) as well as fetal death (both without preeclampsia) (40, 41) and a subset of patients with spontaneous preterm labor (42). These syndromes have also been shown to feature failure of physiologic transformation of the spiral arteries, a disorder of deep placentation (43). However, even if specificity could not be proven because derangements in SEMA3B expression were to occur in other obstetric syndromes, this would be welcome news because it would expand the importance of this novel pathway in pregnancy complications. In our view, the crucial issue is the mechanism of disease, rather than the current diagnostic taxonomy of obstetric diseases. In other words, if a specific pathway (e.g., SEMA3B or others) leads to an antiangiogenic state and disorders of deep placentation and such derangement could be identified in early pregnancy (or even before), there would be opportunities for the prevention of preeclampsia and other adverse pregnancy outcomes, which have proven to be virtually intractable for more than a century.

Finally, the patient and the family referenced in the clinical vignette would like to know the implications of this diagnosis for future health and disease. Patients with preeclampsia are at a greater risk for essential hypertension (44), cardiovascular diseases (including myocardial infarction, stroke, etc.) (45), type 2 diabetes (46), and chronic renal disease later in life (47). Thus,
pregnancy can be viewed as a multisystem “stress” test, and the occurrence of preeclampsia may represent indirect evidence that vascular abnormalities may be at play. This concept has major healthcare implications, because prevention of cardiovascular disease in women can begin after the diagnosis of preeclampsia.

Acknowledgments

This work was supported, in part, by the Perinatology Research Branch, Division of Intramural Research, Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institutes of Health, Department of Health and Human Services (NICHD/NIH) and, in part, with federal funds from NICHD, NIH, under contract no. HSNS27520130006C.

Address correspondence to: Roberto Romero, Perinatology Research Branch, NICHD, NIH, DHHS, 3990 John R, 4 Brush South, Detroit, Michigan 48201, USA. Phone: 313.993.2700; Fax: 313.993.2694; E-mail: romerot@mail.nih.gov.