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Ophthalmic Artery Doppler: Technique and Clinical Applications

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Introduction

Globally, hypertensive disorders of pregnancy (HDP) complicate approximately 10% of pregnancies and are a leading cause of maternal and perinatal morbidity and mortality.[1,2] In the UK, most hospitals rely on assessing risk factors at the booking visit to identify patients at increased risk of developing preeclampsia. Routine antenatal visits are used to monitor blood pressure and perform urinalysis to identify women who have manifested HDP. The UK National Screening Committee does not yet recommend screening for preeclampsia.[3] Despite this, there is a growing interest in early prediction and prevention of HDP, particularly preeclampsia, through multivariable prediction algorithms and artificial intelligence (AI).[4] These include maternal risk factors, blood pressure, ultrasound markers (e.g. uterine artery Doppler), and biochemical tests (e.g. placental growth factor).

This report serves as a foundational white paper for integrating ophthalmic artery (OA) Doppler into routine obstetric assessment. OA Doppler provides an easy-to-assess surrogate for intracranial and systemic haemodynamic status.

Ophthalmic artery

The OA arises from the internal carotid artery as it emerges from the cavernous sinus. It enters the orbit through the optic canal, passing inferolateral to the optic nerve before crossing inferiorly to run medial to the optic nerve (Figure 1). Figures 1 and 2 show the Doppler velocimetry of the OA waveform using pulse-wave Doppler. The following features are presented: first systolic peak (PSV1), second systolic peak (PSV2), dicrotic notch, and the end diastolic velocity (EDV). The first systolic peak is formed by direct transmission from cardiac systole following the ejection of blood flow from the left ventricle into the arterial tree and up into the cranial circulation. The second systolic peak is formed by the reflection of the pulse from cardiac systole into the peripheral vasculature, back towards the heart, and its diversion into the cranial circulation at the level of the aortic arch.

The first systolic peak, therefore, provides a measure predominantly influenced by cardiac output, whereas the second systolic peak provides a measure predominantly influenced by peripheral arterial resistance. Assessing these markers together in the OA PSV-ratio allows the assessment of both cardiac output and peripheral resistance-driven maternal haemodynamics.

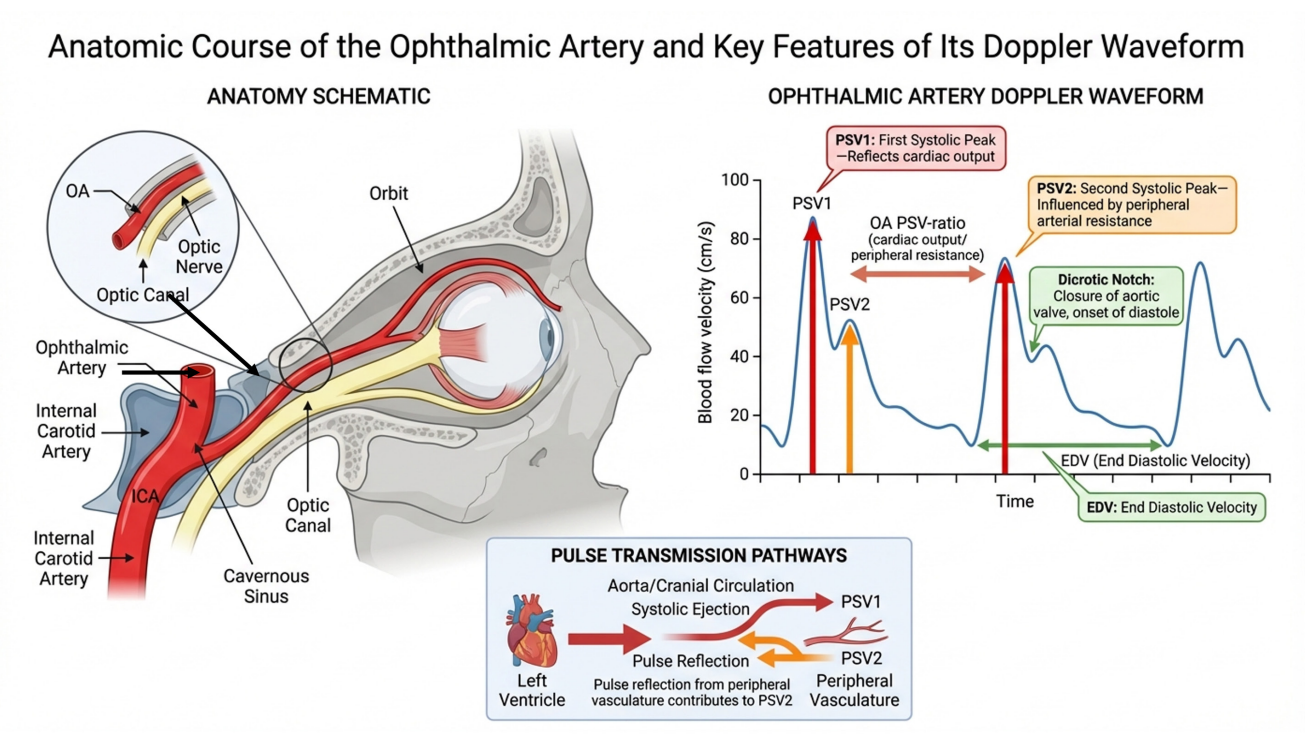

Figure 1. Anatomic course of the ophthalmic artery and key features of its Doppler waveform

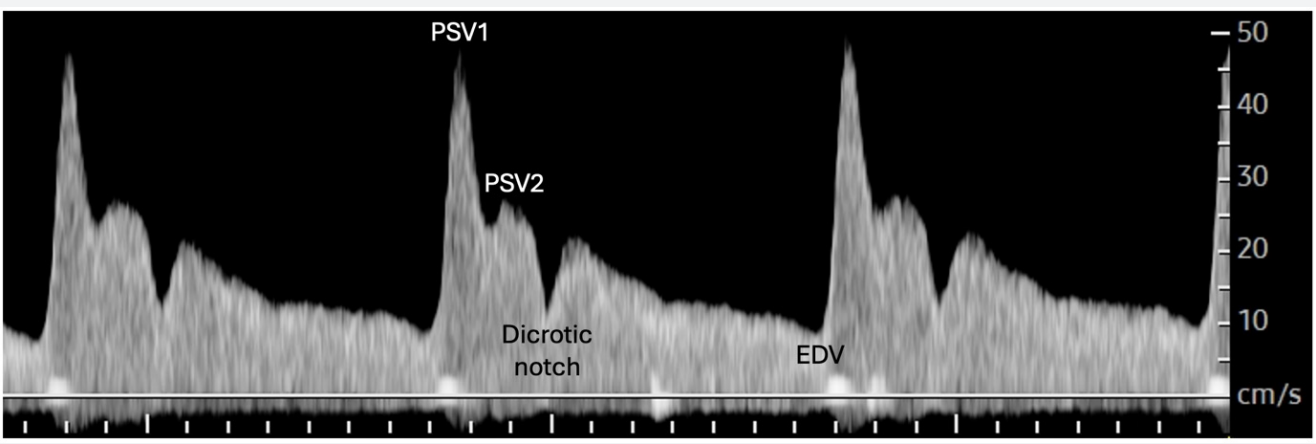

Figure 2. Ophthalmic artery pulse-wave Doppler waveform showing key features of the Doppler waveform

Ophthalmic artery Doppler

OA Doppler is a promising biomarker for the prediction of preeclampsia. It is easily obtained, cost-effective, reproducible and gives us an insight into the maternal cerebral haemodynamic adaptation. The key Doppler indices for pre-eclampsia prediction include the PSV ratio and pulsatility index (PI). OA Doppler is especially useful in improving the prediction of preterm preeclampsia in the second trimester.[5] This may be especially valuable in low-resource settings where preterm preeclampsia represents a significant burden of maternal morbidity and where serum biomarkers may be unaffordable and uterine artery Doppler may be inaccessible.

Beyond predicting preeclampsia, OA Doppler has been used in stratifying preeclampsia severity and in postnatal monitoring. In hospitalised patients with preeclampsia, PSV2 has been used to stratify women who will have an adverse outcome, although this comes with a high false positive rate.[6] Vaz de Melo et al. in their systematic review and meta-analysis, describe the use of OA Doppler parameters, in the second and third trimesters to stratify between mild and severe preeclampsia[7]. In postnatal monitoring, PSV2 may be helpful in monitoring the long-term cardiac effects of hypertensive disorders of pregnancy.[8,9]

Table 1. First trimester prediction of preeclampsia (Gana et al)[10]

Screening model	Detection Rate (Preterm PE) at 10% false positive rate	Detection Rate (Late PE) at 10% false positive rate
Maternal factors	46.3%	36.1%
Maternal factors + MAP	57.3%	44.5%
Maternal factors + MAP + UtA PI	65.9%	44.8%
Maternal factors + MAP + UtA PI + PlGF	74.6%	46.7%
Maternal factors + MAP + OA PSV ratio	63.8%	44.6%
Maternal factors + MAP + OA PSV ratio + UtA-PI + PlGF	76.7%	47.0%

Gana et al assess the use of Ophthalmic artery (OA) Doppler in the first trimester to predict the development of preterm and late preeclampsia (Table 1). They showed that a traditional screening approach simply assessing maternal factors has a poor detection rate both for preterm and late preeclampsia. On addition of maternal mean arterial blood pressure (MAP) this detection rate improves for preterm preeclampsia to 57.3%, but with the addition of uterine artery pulsatility index (UtA PI), and biochemical markers of placental hypoperfusion (placental growth restriction (PlGF)), the detection rate significantly increases to 74.6%. The addition of PSV ratio improves the detection rate to 76.7%. The PSV ratio does not significantly improve the prediction of term preeclampsia.

Table 2. Second trimester prediction of preeclampsia (Sapantzoglou et al)[11]

Screening model	Detection Rate (Preterm PE) at 10% false positive rate	Detection Rate (Late PE) at 10% false positive rate
Maternal factors	55.6%	31.0%
Maternal factors + MAP	61.1%	51.7%
Maternal factors + MAP + UtA PI	66.7%	41.1%
Maternal factors + MAP + UtA PI + PlGF	72.2%	43.1%
Maternal factors + MAP + OA PSV ratio	77.8%	53.4%
Maternal factors + MAP + OA PSV ratio + UtA-PI + sFlt-1 + PlGF	88.9%	48.3%

Sapantzoglou et al look at OA Doppler in the prediction of both preterm and late preeclampsia in the second trimester (Table 2). Compared to the first trimester the detection rate of preterm preeclampsia is generally improved. When combined with maternal factors, biochemical markers and uterine artery doppler, the detection rate at a 10% false positive rate is almost 90%. OA Doppler adds a significant improvement in the detection rate. Furthermore, OA Doppler also adds an improvement in the detection rate of late preeclampsia from 51.7% to 53.4% compared to maternal factors and blood pressure alone.

Table 3. Third trimester prediction of preeclampsia (Sarno et al)[12]

Screening model	Detection Rate (Preeclampsia - Delivery at any stage) at 10% false positive rate	Detection Rate (Preeclampsia - Delivery at <3 weeks) at 10% false positive rate
Maternal factors	25.0%	31.6%
Maternal factors + OA PSV ratio	50.0%	57.9%

Sarno et al were not looking to predict early and late preeclampsia as the screening in their study took place in the third trimester at 35–37 weeks' gestation (Table 3). Instead, they looked at the detection rate of preeclampsia and the detection rate of preeclampsia with delivery in less than 3 weeks' time. They found that OA Doppler doubles the detection rate of pre-eclampsia compared to maternal factors alone (25% to 50%) and improved the detection rate of preeclampsia with delivery <3 weeks to 57.9%.

Core measurement indices

Measured Indices

- First systolic peak velocity = PSV1
- Second systolic peak velocity = PSV 2
- End diastolic velocity = EDV

Calculated Indices

- Resistance Index = (PSV1-EDV) / (PSV1)
- Pulsatility Index = (PSV1-EDV) / (mean velocity)
- Peak systolic ratio (PSV ratio) = PSV2 / PSV1

Recording of the ophthalmic artery Doppler waveform

A trained sonographer should place the linear LM2-18 probe (Samsung Medison Co., Ltd., Seoul, Republic of Korea) on the closed upper eyelid of a patient lying supine (who has been lying supine for 5 minutes) (Figure 3). This high frequency linear probe has several features that help optimise ophthalmic artery Doppler acquisition. The high frequency allows clear visualisation of the hypoechoic optic nerve against the retrobulbar fat. The linear matrix array improves slice thickness, reducing spectral broadening and background noise in the pulse-wave Doppler. No pressure should be applied to the globe. Colour flow should be used to identify the ophthalmic artery superior and medial to the optic nerve seen as a hypoechoic band. Pulsed wave Doppler should be used to measure the blood flow waveform with the 2mm sample gate placed approximately 10-15mm from the posterior side of the globe. The pulsed wave Doppler should be optimised by angle correcting up to 20 degrees (Figure 4). At least one measurement should be taken from each eye (Box 1).[13]

The waveform can be analysed through automated and manual acquisition of key indices. This involves using the auto trace function to trace the waveform and manually selecting 2nd PSV and marking the position of the 2nd PSV within the Doppler trace. Alternatively, key parts of the Doppler trace can be marked manually. The software will then automatically calculate the core measurement indices (Figure 5 & Figure 6).

Figure 3. Probe position on the eyelid to capture the ophthalmic artery waveform

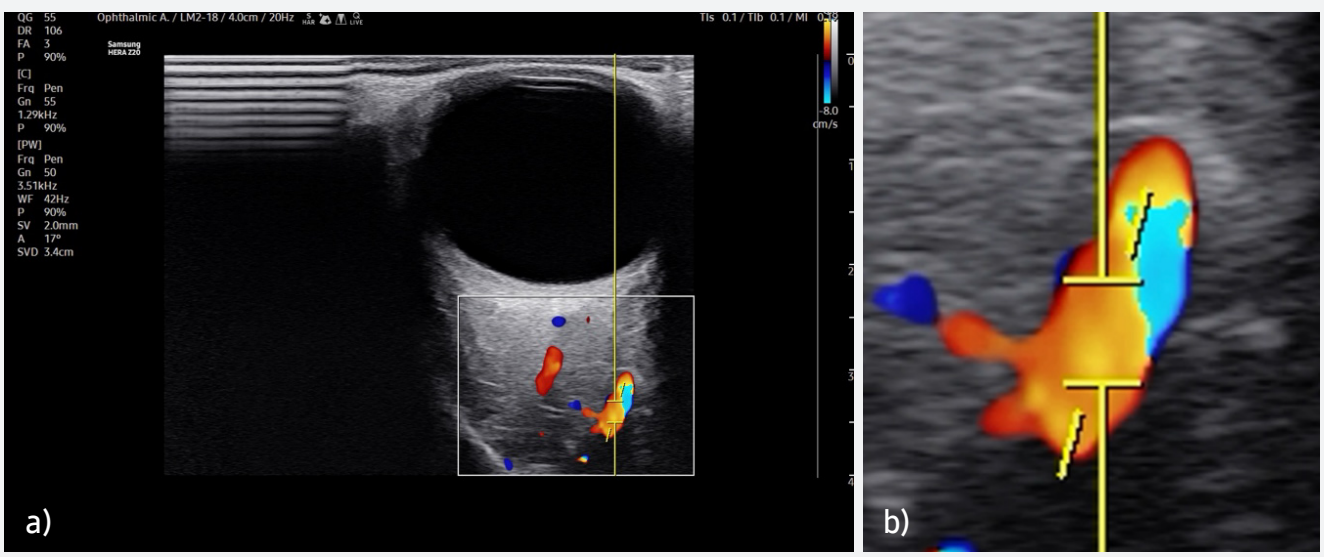

Figure 4. a) Left ophthalmic artery lying superior and medial to the optic nerve and b) angle correction of 17 degrees

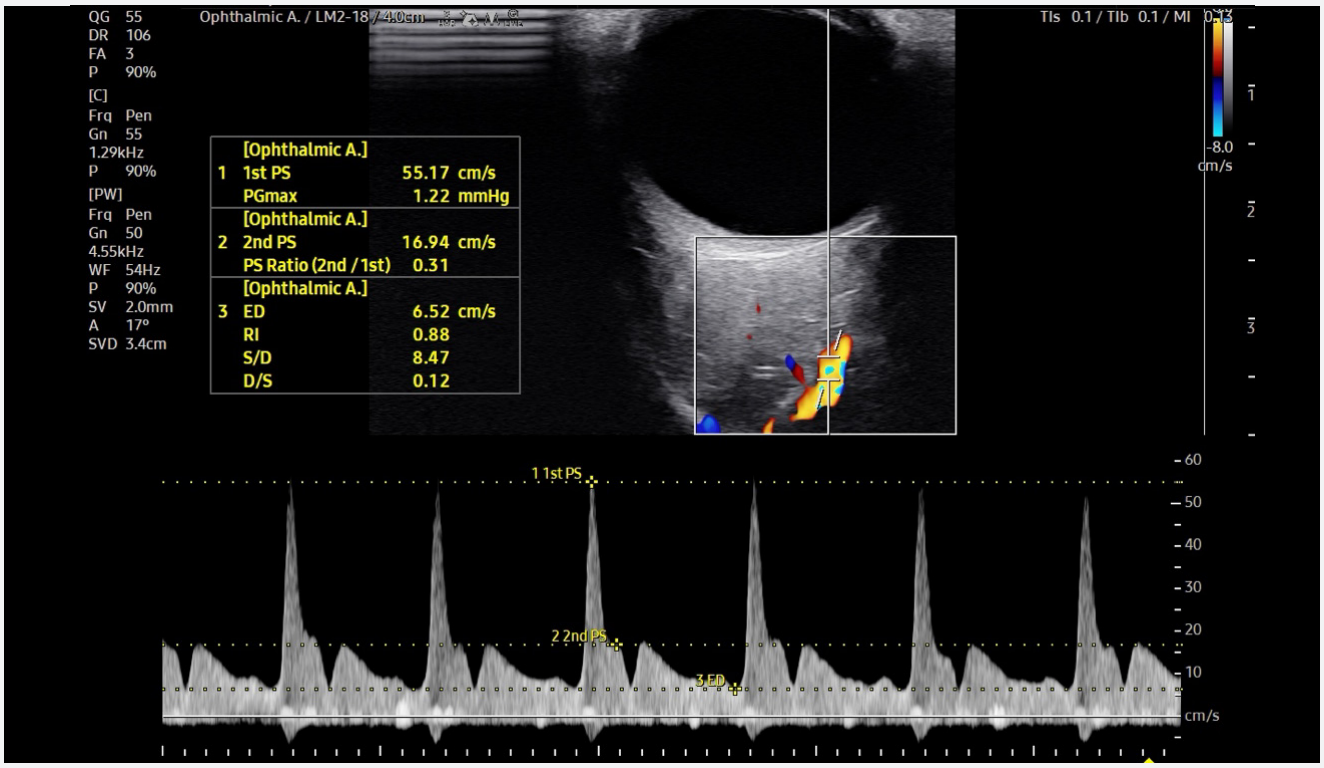

Figure 5. Doppler waveform with manual placement of first PS, second PS and EDV with calculation of the PS Ratio and RI

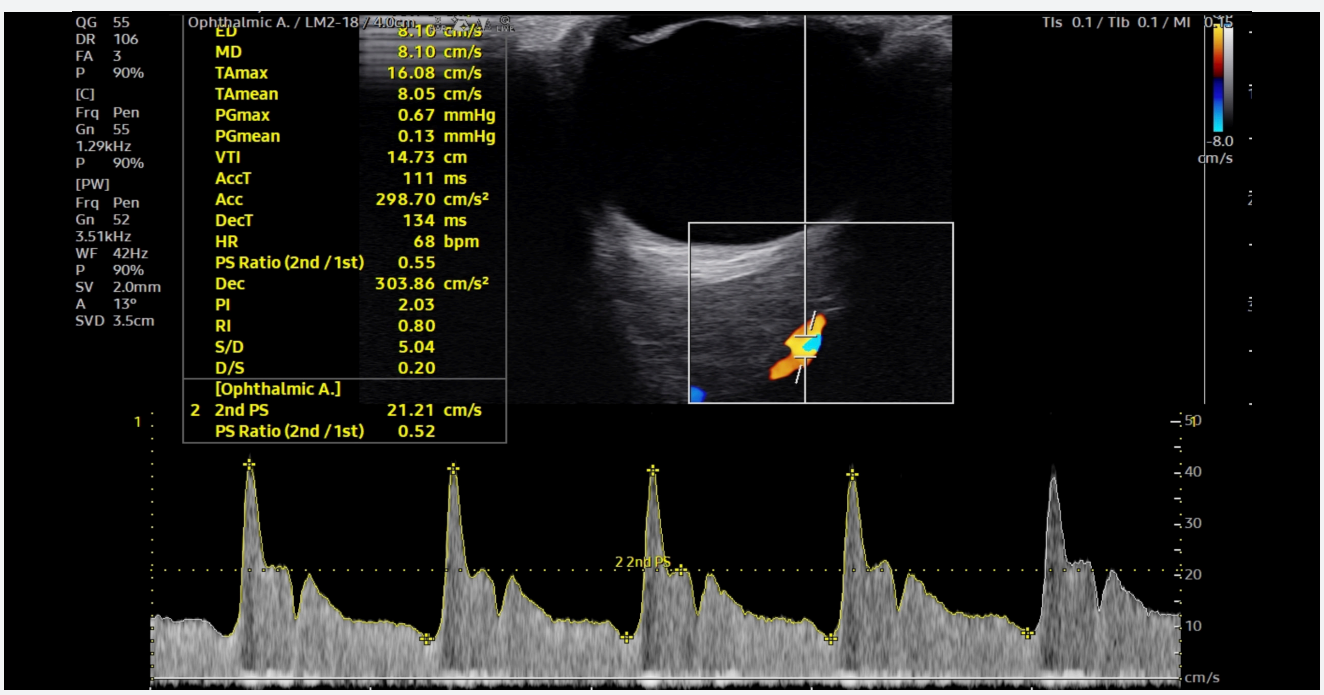

Figure 6. Doppler waveform with automatic tracing of the waveform and auto calculation PS Ratio, first PS, EDV, PI and RI

Transducer

Frequency: 2-18 MHz linear probe
Mode: Pulsed-wave Doppler

Machine settings

Wall filter: 50-100 Hz
PRF: 2-5 kHz (avoids aliasing while preserving sensitivity)
Gain: Low to moderate, just enough to visualise waveform
Angle: Optimal insonation angle is 0-20°

Acquisition protocol for pregnant patients

Patient position: Supine or semi-recumbent
Preparation:
Closed eyelid technique, apply minimal gel. Maintain gentle probe pressure to avoid altering ocular pressure
Locate the artery:
Position the probe on the medial upper eyelid
Identify optic nerve hypo echogenicity in B-mode; ophthalmic artery lies medial and superior
Capture waveform:
Align Doppler angle as close to zero as possible
Record ≥3 consistent waveforms from each eye

Box 1. Assessment of the ophthalmic artery Doppler

Interpretation of Doppler parameters

Peak Systolic Velocity (PSV)
Reflects systolic flow driven by cardiac output
End-Diastolic Velocity (EDV)
Sensitive to downstream (intracranial/orbital) resistance
Resistance Index (RI)
RI = (PSV – EDV) / PSV
Pulsatility Index (PI)
PI = (PSV – EDV) / mean velocity

Box 2. Interpretation of ophthalmic artery Doppler parameters

Safety and compliance

The HERA Z20 (Samsung Medison Co., Ltd., Seoul, Republic of Korea) with the LM2-18 probe has a specific ophthalmic artery preset which can be quickly recalled using the QuickPreset menu. The preset is configured to comply with stringent international safety guidelines, such as the FDA's recommendation for ophthalmic exams. These ensure that the acquisition of the ophthalmic artery pulse wave Doppler is captured with low thermal and mechanical indices[12] (Top right corner of Figure 4a, 5 and 6). These are prominently displayed during the scan and should be minimised due to the sensitivity of the optic tissue. By minimising these indices and because of the short time needed to acquire the measurements, the radiation safety ALARA principle (as low as reasonably achievable), can be maintained (Box 3).

Safety considerations in pregnancy

Orbital ultrasound has established safety parameters:

Mechanical Index (MI)

Maintain MI <0.23 to prevent acoustic radiation pressure effects on the lens and retina

Thermal Index (TI)

Maintain TI <1.0, ideally <0.5, especially with prolonged insonation

Exposure time

Limit Doppler sampling for each eye to <30 seconds

Gentle probe pressure

Excessive pressure can reduce ocular perfusion and distort readings

Box 3. Safety considerations in pregnancy

Conclusion

The growing evidence on the use of ophthalmic artery Doppler in predicting preeclampsia will allow us to move toward more precision-based screening and away from traditional risk-based screening, which is less resource-efficient and less personalised. Ensuring maternal cardiovascular health is at the forefront of prenatal screening will not only help us understand the risk of pregnancy complications but may also help us understand long-term cardiovascular health.

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