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Pressure Wave Analysis Is Useful to Understand the Pathophysiology of Preeclampsia, but Perhaps Not the Rapid Changes during Cesarean Delivery

IN this issue of ANESTHESIOLOGY, Dyer *et al.*[1] tested the hypothesis that continuous monitoring of cardiac output (CO) in patients with severe preeclampsia during spinal anesthesia for cesarean delivery would give better information on the uteroplacental blood flow than mean radial artery blood pressure. They found that CO, as inferred from pressure wave analysis (PWA), did not decrease significantly from baseline if the mean radial artery blood pressure was maintained at baseline levels with intermittent vasoactive treatment, concluding that spinal anesthesia was associated with clinically insignificant changes in CO. The purposes of this editorial are to describe the contributions of PWA to our understanding physiologic changes during pregnancy and preeclampsia and to question whether PWA can be used to inform us of changes during cesarean delivery.

Pressure wave analysis has been used as part of in-depth investigations of cardiovascular adaptations during pregnancy. Pressure and flow waves depend on the compliance of large and medium arteries, and vascular tone of arterioles and veins. A typical cardiac cycle is comprised of two pressure peaks, labeled P_1 and P_2 in order of timing. The decrease in arterial compliance with age has been related, by analysis of the aortic pressure and flow waves, to the progressive increase of P_2 (augmentation), which overtakes the height of P_1 (input impedance) at age 30 years.[2] Poppas *et al.*,[3] assessing pulse pressure and flow, aortic flow velocities, and left ventricular (LV) imaging during the first, second, and third trimesters of normal pregnancy, found decreased aortic input impedance starting in the first trimester and decreased augmentation in the second and third trimesters; peripheral vascular resistance decreased moderately, and CO increased. Therefore, early pregnancy produces a temporary return of the arterial system aging to that seen in normal adolescents. Mesa *et al.*[4] assessed LV function by echocardiography at the end of each trimester of normal pregnancy in 37 women. CO increased significantly, as did heart rate and stroke volume; peripheral vascular resistance decreased and LV wall thickness and mass increased from the second trimester to the end of pregnancy, thus indicating LV hypertrophy at the end of pregnancy, similar to that seen in long distance runners. Eduard *et al.*[5] studied the role of the arterial and venous systems' tone in the hemodynamic changes of normal pregnancy in the first and second trimesters and 3 months after delivery, using plethysmography, pulse wave velocity, and echocardiography. From the first trimester, heart rate and aortic distensibility increased, whereas systemic blood pressure and limb vascular resistance did not change. Lower limb venous tone increased from the first trimester, and their viscoelastic properties decreased in the third trimester, whereas no change occurred in the upper limbs. The LV diastolic diameter increased in the third trimester. These changes regressed 3 months after delivery. Therefore, the first cardiovascular change during pregnancy is the increase in arterial compliance, starting in the first trimester, with the appropriate conditioning in cardiac function to follow.

Elvan-Taşpinar *et al.*,[6] using aortic PWA and pressure wave velocity, studied the effect of preeclampsia by assessment of aortic compliance in 51 normotensive women, 38 hypertensive women without proteinuria, and 33 preeclamptic women during the third trimester of pregnancy. Aortic impedance was significantly higher in preeclamptic and hypertensive than in normotensive patients. Ejection duration and aortic pulse pressure were significantly greater in preeclamptic than in normotensive and hypertensive patients, indicating that the vascular rigidity was severe enough to increase the LV ejection time and the pressure needed to eject each stroke volume. However, the subendocardial viability ratios were not significantly different among the three groups; hence, preeclampsia reversed the high arterial compliance of pregnancy but increased LV hypertrophy. Therefore, preeclampsia encompasses a severe decrease of vascular compliance and LV hypertrophy, plus the known decreased blood volume.

Dyer *et al.*[1] used the LiDCO device (LiDCO, London, United Kingdom) to examine rapid changes in cardiovascular variables associated with spinal anesthesia, vasopressor treatment, and oxytocin. However, this method of CO assessment is not recommended during hemodynamic instability[7] and has been shown to produce CO assessment errors of greater than 33% during cardiac surgery.[8] This method is based on the aortic PWA. Murgo *et al.*[2] recorded flow and pressure waves from the aortic root, assessed their relation in their frequency domain, and then related the pattern of the impedance spectral plots to the analog shape of the pressure wave. The peak of flow aligned with P_1, and the peak of the reflected pressure wave aligned with P_2, which slows the flow wave without decreasing

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stroke volume, unless cardiac failure ensues. The algorithm used by the LiDCOplus used in this study[1] includes all of the elements of the aortic pressure wave, including the P_1 and its relation with the peak of flow. However, this device analyzes the derived aortic pressure wave by the Karamanoglu generalized transfer function from the radial pressure wave,[9] which has been found to be unable to identify P_1,[10] because the filtering effect of the transfer function removes the harmonics that identify P_1 and the foot of P_2. The algorithm used to assess CO by pulse contour analysis and calibrated by lithium dilution CO incorporates elements to establish the P_1/stroke volume relation, and because moderate changes in aortic pulse pressure do not change P_1,[2,11] the calculated CO by this device is fairly reliable in clinical situations where no rapid hemodynamic fluctuations occur, as recommended by Linton and Linton.[7] None of the above methods, including PWA, are designed to evaluate the hemodynamic changes during spinal anesthesia and cesarean delivery because of the short duration of the hemodynamic changes. Whether they can guide therapy better than routine measurement of blood pressure remains to be determined.

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