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Cerebral Doppler and fetal vasoconstriction: hemodynamics and clinical relevance

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Objective

Cerebral Doppler waveforms show a biphasic systolic contour, with a mid-systolic shoulder or even with a primary and a secondary systolic peak, P1 and P2, like an „M“. Such a systolic M-sign may appear in ophthalmic artery (OA) Doppler of pregnancies, in particular with pre-eclampsia (PE), and in middle cerebral artery (MCA) Doppler of fetuses with transitory circulatory compromise associated with intrauterine transfusion (IUT). Our aim was to study the hemodynamic principles and conditions which govern P2 appearance and timing, and to evaluate the agreement of these results with clinical observations in pregnant women and in the fetus.

Methods

The approach to study P2 appearance is based on the concept of pulse wave (PW) propagation and reflection in the arterial system. Accordingly a PW reaches the cerebral circulation twice: as primary ejection wave, generating P1, and again after reflection, return and cranial transmission, thus generating P2 [Kim 2017]. In this PW model, P2 and the P2/P1 ratio will increase with reflection intensity, and the time interval between P1 and P2 is basically given by the time of PW return, Tr. According to the principle of cardio-vascular energy optimization [Pahlevan 2014], pulsatile energy consumption is minimized, when Tr takes about 20% of the cardiac cycle: Tr/T = 0.2 (Fig.). To evaluate the agreement of these hemodynamic concepts with clinical observations, we used data from normal pregnacies and with PE [Rodriguez 2018, Avni 2010] and from fetuses after IUT [Vonzun 2022]. These maternal and fetal conditions are associated with increased arterial vasoconstriction.

Results

Rodriguez [2018] published data on maternal HR, and time of return, Tr, obtained by applanation tonometry in normal 1st and 3rd trimester pregnancies (HR 69bpm, Tr 154ms; and HR 74bpm, Tr 153ms). Converting HR to cardiac cycle time T (69bpm: 870ms; and 74bpm: 811ms), yields: Tr/T = 0.18 (1st trim.) and 0.19 (3rd trim.) respectively. Avni [2010] compared data from normal pregnancies, nP (HR 84bpm, Tr 153ms) and severe PE (HR 86bpm, Tr 133ms), yielding: Tr/T = 0.21 (nP) vs. 0.19 (PE), respectively. Thus both studies show nearly optimal PW reflection timing Tr/T in pregnant women. Similar observations have been reported in fetuses with transitory circulatory compromise after IUT. Vonzun [2022] found a highly significant association between IUT and P2 appearance in MCA Doppler (GA 28±1w) with Tr = 76±4ms. Converting mean FHR, 150bpm, to cardiac cycle time T, yields: T 400ms and T/Tr = 0.19. Again, these observations indicate nearly optimal pulsatile timing Tr/T in the fetus.

Conclusion

The agreement between optimal reflection timing: Tr/T = 0.2, given by the PW model, and clinical reflection timing obtained in pregnancies incl. PE and in fetuses after IUT provides evidence that P2 in cerebral Doppler waveforms is the result of PW reflection in the arterial system and will increase with vasoconstriction. This hemodynamic considerations show that cerebral Doppler provides information on vasoconstriction in the systemic circulation, with the potential to monitor pregnancies with PE and fetuses after IUT by OA and MCA Doppler respectively, and, furthermore, to monitor vasoactive drug effects not only in the mother, but also in the fetus.