Doppler velocimetry parameters of the equine pregnancy: practical applications of a new tool

Dr Stefania Bucca
Qatar Racing and Equestrian Club
POBox7559
Doha, Qatar

Introduction

Doppler ultrasonography is a relatively non-invasive procedure that in recent years has found two areas of investigation of reproductive function in the mare: ovarian events and feto-placental health. In the pregnant mare, Doppler technology characterizes blood flow throughout gestation, providing an insight on maternal (uterine arteries), fetal (umbilical and carotid arteries) and placental circulations (intraplacental circulation), although the latter vascular compartment has yet to be investigated. Doppler technology applied to the equine pregnancy provides an additional tool to improve our diagnostic and prognostic abilities, when assessing feto-placental compromise.

Doppler technology has become an important clinical instrument for assessing placental performance in healthy and high risk human pregnancies, where Doppler scans of maternal uterine arteries (UA), fetal umbilical circulation and other fetal vessels (i.e.: middle cerebral artery, ascending/descending aorta, renal arteries) are routinely performed at set times during gestation[1]. These parameters provide a critical, qualitative assessment of fetal health and placental vascular perfusion by identifying changes in Doppler indices. Placental dysfunction, in fact, impairs the development of the placental vascular bed and alters Doppler indices by increasing vascular resistance.

The applications of Doppler technology to the equine pregnancy are still limited, due to initial difficulties in accessing some of the relevant vascular structures. Advanced ultrasound technology, available on portable units, with user-friendly color and pulsed-wave Doppler applications, has recently generated a renewed interest in the assessment of reproductive and gestational blood flow in the mare.

Principles of Doppler Ultrasonography

Ultrasound images of flow, whether color flow or spectral Doppler, are essentially obtained from measurements of moving particles. Ultrasound scanners transmit a series of wave pulses to detect movement of blood and analyze the signal returning to the receiver. Doppler-shift is defined as the difference in frequency between received and transmitted echoes, when sound waves strike moving objects, i.e. red blood cells. The Doppler–shift is one of the factors used by the scanner to generate color signals and for computation of velocity. The changes in Doppler-shift frequency are displayed over time to produce a characteristic spectral waveform representing a cardiac cycle. Various Doppler indices can be measured (i.e. resistance index (RI), pulsatility index (PI),etc.) from a spectral waveform. In general, the RI increases when the proximal vascular conditions remain unchanged and the vascular bed distal to the point of measurement constricts. On the other hand, a low RI value indicates decreased impedance to blood flow in the vasculature distal to the point of measurement.

In order to detect flow and therefore a Doppler signal, there has to be motion in the direction of the ultrasound beam and if the flow is perpendicular to the beam, there is no detectable motion from pulse to pulse, hence the importance of the angle of insonation. The size of the Doppler signal vastly depends on the angle of insonation, and the Doppler shift increases as the Doppler ultrasound beam becomes more aligned to the flow direction. Other factors affecting the size of the Doppler signal include:

a) blood velocity: as velocity increases, so does the Doppler frequency;
b) ultrasound frequency: higher ultrasound frequencies give increased Doppler frequency, although lower ultrasound frequencies give better penetration. The choice of frequency is therefore a compromise between better sensitivity to flow and better penetration.

Several Doppler modalities are available to evaluate blood flow, but for the purpose of our gestational examinations we tend to use color and pulsed wave Doppler modes. Color Doppler mode superimposes color on the B-mode grey scale and identifies the presence and direction of flow, highlights gross circulation anomalies and provides beam/vessel angle correction for velocity measurements. Pulsed wave Doppler provides analysis of flow at specific sites in the vessel under investigation and acts as a complementary tool to color Doppler. Some manufacturers produce concurrent color flow imaging and pulsed wave Doppler, sometimes referred to as *triplex* scanning.

Assessment of Maternal Circulation

The maternal vascular compartment is assessed through Doppler interrogation of the uterine arteries (UA). Recording of abnormal UA Doppler indices suggest alterations in placental perfusion.

In the mare, the uterine arteries are easily visualized per rectum throughout gestation, employing ultrasound linear or micro-convex transducers, with frequencies ranging between 5 and 10MHz. In order to obtain consistent readings of vascular parameters, Doppler evaluation of each uterine artery is carried out about 2 to 5 cm from its origin from the external iliac artery, in close proximity to the *circumflexa ilium profunda* artery.

Doppler studies by Bollwein et al[2,3], Ousey et al [4], Bailys et al [5] and more recently Klewitz et al [6] have analyzed blood flow to the pregnant uterus of the mare throughout gestation. Most of the above studies dealt with a small number of mares, but Klewitz study included 51 pregnant mares and reported on some naturally occurring pregnancy abnormalities in this group.

The results of all the above studies uniformly indicate a progressive decrease in peripheral blood flow resistance and an increase in uterine blood flow, the latter being particularly evident during the last trimester of pregnancy. Ultimately, in normal pregnancies, haemodynamic changes in the uterine arteries progress from a high resistance/low flow pattern during the first half of gestation to a low resistance/high flow system in the second half, when placental development reaches completion and fetal demands are high. The above changes take place in response to fetal growth and development of the placental microcirculation.

Ousey reported that aged mares demonstrate a trend for reduced uterine blood flow, particularly in the last trimester of pregnancy, together with reduced placental microvillus surface densities and lighter foals at term. It was therefore suggested that a reduced uterine blood supply maybe an important contributory factor for pregnancy loss in aged mares.

Assessment of fetal circulation

Evaluation of the fetal vascular compartment in the equine pregnancy mostly relies on Doppler investigation of the fetal intracranial and umbilico-placental circulations, with the latter reflecting more specifically placental pathology. Doppler velocimetry indices of the carotid artery are currently being investigated, in order to establish fetal intracranial hemodynamic patterns, throughout gestation in the mare.

Umbilical Circulation

Equine Doppler studies of umbilical cord flow were carried out by McGladdery et al [7], Bollwein et al [4] and more recently Panzani et al [8], on small numbers of equid pregnancies. Bollwein study included 4 pregnant mares, where umbilical flow was evaluated transrectally at the placental root of the umbilical cord. Bollwein reported a gradual decrease in the umbilical arterial RI, followed by a rise during the last weeks of pregnancy, in net contrast with the other two studies. McGladdery, (six pony mares) and Panzani (six jennies) employed transabdominal ultrasonography to evaluate umbilical cord blood flow and both Authors reported a decrease in RI and PI in late gestation.

Further investigation is necessary to fully characterize umbilical cord flow, employing a standardized approach both in normal and complicated gestations.

Intracranial Circulation

The Middle Cerebral Artery (MCA), a branch of the internal carotid artery, has emerged as the vessel of choice in the Doppler assessment of human fetal intracranial circulation. MCA Doppler indices provide information on blood volume redistribution, for example, in the presence of IUGR or fetal anemia. Alterations in MCA blood flow indices are carefully monitored in human patients carrying pregnancies with a high risk of an unfavorable outcome, as they are more sensitive indicators than other fetal parameters (i.e: late cardiac decelerations), particularly when both maternal uterine and fetal MCA waveforms are altered at the same time.

In the equine fetus the MCA cannot be visualized by ultrasound, due to substantial anatomical differences with the human fetus. The carotid artery, though, can be accessed both by transrectal (when the fetus is in anterior presentation) as previously described by this Author [9] and transabdominal ultrasonography at three different sites: a) the common carotid trunk, along the fetal trachea, within the jugular groove, b) the external carotid branch, running along the lateral compartment of the ipsilateral guttural pouch and c) the internal carotid branch.

Fetal Intra-Uterine Growth Restriction (IUGR) and Fetal Hypoxia

Placental insufficiency, which leads to a reduction in nutritive supplies and fetal oxygen partial pressure, is one of the most important factors responsible for IUGR and fetal hypoxia. IUGR can lead to long-term metabolic consequences, such as an increased propensity for some of the most common diseases of adult life, whereas fetal hypoxia is the leading cause of perinatal morbidity and mortality. One of the most important sequelae of fetal hypoxia is the development of perinatal brain damage, resulting in a spectrum of neurological disabilities.

Fetal hypoxia activates a range of biophysical, cardiovascular, endocrine and metabolic responses. Fetal cardiovascular responses to hypoxia, which include modification of the heart rate, an increase in arterial blood pressure and redistribution of the cardiac output towards vital organs, are probably the most important adaptive reactions responsible for maintaining fetal homeostasis. The redistribution of blood flow towards the fetal brain is known as the “brain sparing effect”, as increased blood supply to the fetal brain is one of the compensatory mechanisms in cases of decreased placental blood flow.

Doppler assessment of the fetal cerebral and umbilico-placental circulations can detect fetal blood flow redistribution during hypoxia and quantify the degree of this redistribution. Although the brain-sparing effect attempts to compensate for the reduced oxygen delivery to the fetal brain, it has become clear that this phenomenon cannot always prevent the development of brain lesions.

The preliminary results of an ongoing study on Doppler evaluation of the fetal carotid artery will be presented.

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