Problems associated with quantitative fetal blood flow measurements.

Baumann,H.,A.Berec,F.Fallenstein,K.Vetter,A.Huch,R.Huch, Zuerich/CH.

The combination of realtime scanner and pulsed doppler technique has become a promising noninvasive method for studying blood flow in the fetal aorta and umbilical vein(1). We use an 8130 Kranzbuehler 3.5 MHz realtime scanner with a 2 MHz pulsed doppler with a sample volume of fixed size operating at a pulse repetition frequency (PRF) of 2.5 or 5.0 KHz. The angle between the doppler beam and the linear array is fixed at 50 degrees. The most important feature is the instrument's ability to display the realtime image and the doppler spectrum signal simultaneously. The maximum depth of measurement in the simultaneous mode is 15 cm for a PRF of 2.5 KHz and 7.5 cm for 5 KHz. Doppler shifts generated by flow directions towards the transducer and away from it are processed separately. Flow measurements are evaluated off line from frozen images reflecting a doppler signal record free of artefacts. The angle between doppler beam and vessel and the diameter of the vessel are determined by positioning the direction line and the calipers using the operating panel. The area of measurement can be magnified twice thus providing a resolution of .4 mm for diameter measurements. The instrument calculates a flow velocity curve from the doppler spectra and displays it on the monitor. A mean velocity over an adjustable interval of the stored section (e.g. one fetal heart cycle) and the corresponding blood flow value are also displayed. This procedure of off line processing can be repeated on the frozen image.

Before applying the equipment to clinical research we investigated its characteristics by means of an in vitro model: A plastic tube was embedded in a large water bath and perfused with a cellulose water suspension or pig blood by a roller pump in order to provide exactly predetermined flow rates between 200 and 600 ml/min. We performed regression analyses of the doppler determined flow and preset flow for both flow media, different depths of measurement and both flow directions. An excerpt of the results is shown in the table.

flow direction	**forward** y = 54.56 + 1.26x r = .998 n = 20	**reverse** y = 30.28 + 1.277x r = .998 n = 20
flow medium	**pig blood** y = 54.56 + 1.26x r = .998 n = 20	**cellulose suspension** y = 83.82 + 1.29x r = .995 n = 20
depth of measurement	**50 mm** y = 85.12 + 1.154x r = .995 n = 20	**70 mm** y = 54.56 + 1.26x r = .998 n = 20

All doppler measurements were overestimated by a positive additive constant. This is a known effect and is mainly introduced by high pass filters which remove low frequency components produced by vessel wall motions(3). The slopes of the regression lines have been found to be greater than 1, but practically identical in all series of experiments. A correction in the calculation algorithm may overcome the latter problem. Regarding the linearity expressed by a close to 1 correlation in all series, it can be concluded that - from a technical point of view - this equipment is able to measure blood flow in the human fetus.

Measurements in pregnant women however showed additional problems. The optimal angle between doppler beam and vessel is 40 to 60 degrees. This requires the vessel to appear on the monitor almost horizontally, which is sometimes difficult to accomplish since the realtime transducer and the doppler transducer are mounted to a fixed unit. An adjustment of the size of the sample volume and the possibility of continuous adjustment of its position would be an improvement.

Another source of error arose from the aliasing effect of high flow velocities on the doppler spectrum. It can be eliminated by using the higher PRF. But unfortunately the simultaneous realtime image is lost if the vessel lies deeper than 7.5 cm.

A very lively fetus makes measurements impossible. We got the impression that very often the fetus is disturbed by the equipment, perhaps by the noise of the linear array.

Other sources of error which can hardly be overcome by this method are the changing diameter caused by pressure waves in the vessel and the changing flow caused by fetal breathing movements(2), especially in the umbilical vein. We therefore suggest that for comparison of quantitative results it is not only necessary to agree on anatomically well defined points of measurement but also on states of fetal activity and the phase of pulse wave when measuring the diameter of the vessel under investigation.

1.Eik-Nes,S.H., A.O.Brubak, M.K.Ulstein: Measurement of human fetal blood flow. Br.Med.J.:280(1980)283.

2.Eik-Nes,S.H., K.Marsal, A.O.Brubak, M.K.Ulstein: Ultrasonic measurements of human fetal blood flow in aorta and umbilical vein: influence of fetal breathing movements. In: Kurjak,A.,ed.: Recent advances in ultrasonic diagnosis 2, Amsterdam (1980),233.

3.Fallenstein,F.,C.S.Kurz,A.Huch,R.Huch: Probleme bei der quantitativen nicht-invasiven Erfassung von Blutfluessen mit Hilfe der Spektralanalyse von US-Pulsed-Doppler-Signalen. In: Otto,R.C.,F.X.Jann,Hg., Ultraschalldiagnostik 82, Stuttgart (1983),177.

Klinik und Poliklinik fuer Geburtshilfe, Departement fuer Frauenheilkunde , Universitaetsspital Zuerich, Frauenklinikstrasse 10, CH-8091 Zuerich, Schweiz.