Middle Cerebral Artery Peak Systolic Velocity

Technique and Variability

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Objective. Assessment of the middle cerebral artery (MCA) peak systolic velocity (PSV) can accurately diagnose fetal anemia and has decreased the number of invasive procedures, such as amniocentesis and cordocentesis. The objective of this investigation was to evaluate the intraobserver and interobserver variability as a measure of reproducibility of MCA PSV. The technique of correctly sampling this vessel is described. ***Methods.*** The study population included 30 appropriate-for-gestational-age fetuses. In each fetus, MCA PSV was determined proximal to the transducer at 3 different locations: 2 mm after its origin from the internal carotid artery, at the midlength between its origin and division, and at its division. The peak systolic velocity was also determined at the contralateral MCA 2 mm after its origin. With each measurement (obtained at 2 different institutions), care was taken to ensure that the ultrasound beam was parallel to the artery for its entire length. The reliability of an angle corrector was also assessed. The intraobserver and interobserver reliabilities were determined from the appropriate version of the intraclass correlation. ***Results.*** Gestational age at study entry ranged from 14 to 37.5 weeks (median, 23.6 weeks). The proximal MCA, 2 mm after its origin from the internal carotid artery, had the best intraobserver and interobserver variability in both institutions. (Intraclass correlation ranged from 0.98 to 0.99.) ***Conclusions.*** Our data indicate that fetal MCA PSV is optimally measured soon after the MCA's origin from the internal carotid artery. Given the importance of clinical decision making based on this measurement, sonographers and sonologists interested in measuring MCA PSV should test their variability after a suitable period of training. ***Key words:*** Doppler ultrasonography; fetal anemia; interobserver variability; middle cerebral artery; peak systolic velocity.

Abbreviations
MCA, middle cerebral artery; PSV, peak systolic velocity

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Fetal anemia increases cardiac output and decreases blood viscosity.[1] One consequence of these changes is increased blood velocity, which, in the fetus, can be easily assessed at the level of the middle cerebral artery (MCA). Doppler ultrasonography has determined that an inverse correlation exists between fetal anemia and the highest value of the blood velocity during systole (peak systolic velocity [PSV]) of the MCA.[2–5] One prospective study evaluated MCA PSV to detect fetuses at risk for severe anemia because of red cell alloimmunization and to determine the need for invasive testing. Sensitivity in this instance was 100% (95% confidence interval, 86%–100%), and invasive procedures were avoided in 70% of cases.[3] A follow-up study was also conducted with the intention of using the determined MCA PSV value for timing regarding an invasive procedure in pregnancies at risk for fetal anemia secondary to red cell alloimmunization. Invasive procedures were avoided in 90 of 125 fetuses.[6] Other studies have confirmed that the MCA PSV can also be used to diagnose fetal anemia secondary to other causes.[7–9]

Because the use of MCA PSV assessment decreases the number of invasive procedures, such as amniocentesis and cordocentesis,[6] the clinical importance of the MCA PSV has become clear. However, it must be emphasized that good reproducibility of the PSV is essential for using the MCA PSV in clinical practice. Because PSV has generally been determined soon after the origin of the proximal MCA from the internal carotid artery (with regard to the transducer's position), the question arises of whether the blood velocity changes when it is determined in different areas of the MCA. If the velocity remains constant for the entire length of the MCA, Doppler waveforms could be determined at any position along the length of this vessel; this flexibility could facilitate assessment of this parameter in clinical practice. Therefore, we undertook the following study to assess (1) the velocity at different sites of the 2 MCAs and (2) the reproducibility of the MCA PSV at different sites of the vessel.

Materials and Methods

Sonographic Procedures

The study population consisted of 30 appropriate-for-gestational-age fetuses at 2 different institutions, the individual numbers being 14 and 16, respectively. Institutional Review Board approval for the study was obtained at both institutions. Gestational ages of the 2 study groups ranged from 14 to 36 weeks (mean ± SD, 25.8 ± 7.3 weeks) and 18.1 to 37.5 weeks (27.7 ± 5.6 weeks), respectively. In each fetus, MCA PSV was determined proximal to the transducer at 3 different locations with and without the use of an angle corrector: 2 mm after its origin from the internal carotid artery (A), at its midlength between origin and division (B), and at its division (C). The PSV was also measured at the contralateral MCA 2 mm after its origin (D) (Figure 1). With each measurement, care was taken to ensure that the ultrasound beam was parallel to the artery for its entire length.

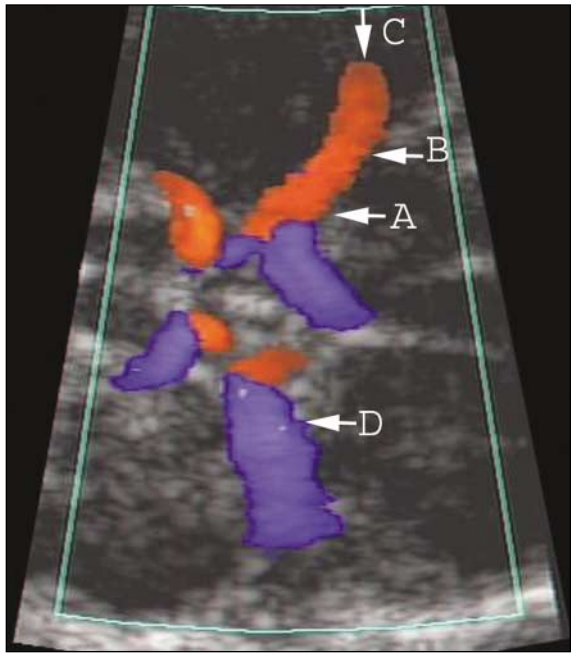
Two pairs of sonographers and sonologists performed the measurements at each institution. Several types of Doppler ultrasonographic equipment were used (Acuson Sequoia [Siemens Medical Solutions, Mountain View, CA]; HDI 5000 [Philips Medical Systems, Andover, MA]; and LOGIQ 700 [GE Healthcare, Milwaukee, WI]), but the same equipment was consistently used for each patient.

Doppler examination of the MCA was performed as reported previously[2]: An axial section of the brain, including the thalamus and the cavum septi pellucidi, was acquired during a period of fetal rest, the circle of Willis being imaged with color Doppler ultrasonography. The MCA proximal to the transducer was enlarged in such a way that it occupied more than 50% of the image and was always visualized for its entire length, the sample volume (1 mm) being superimposed on the MCA, 2 mm after its origin from the internal carotid artery. Keeping the angle between the direction of blood flow and the ultrasound beam as close as possible to 0°, it was found that the waveforms (between 15 and 30) appeared to be similar to each other, and the highest point of the waveform (PSV) was measured. Figure 2 shows the steps used to assess MCA PSV in area A. Similarly, the MCA was sampled at its midlength and division. Finally, the contralateral MCA was sampled, and the PSV was measured. Each observer sampled the area twice, taking care to ensure that the ultrasound beam was parallel to the artery for its entire length.

Statistical Analysis

The degree of agreement between observers (intraobserver variability) was calculated with data obtained from 2 different time points with

Figure 1. Circle of Willis. The letters indicate the 4 points assessed for variability.

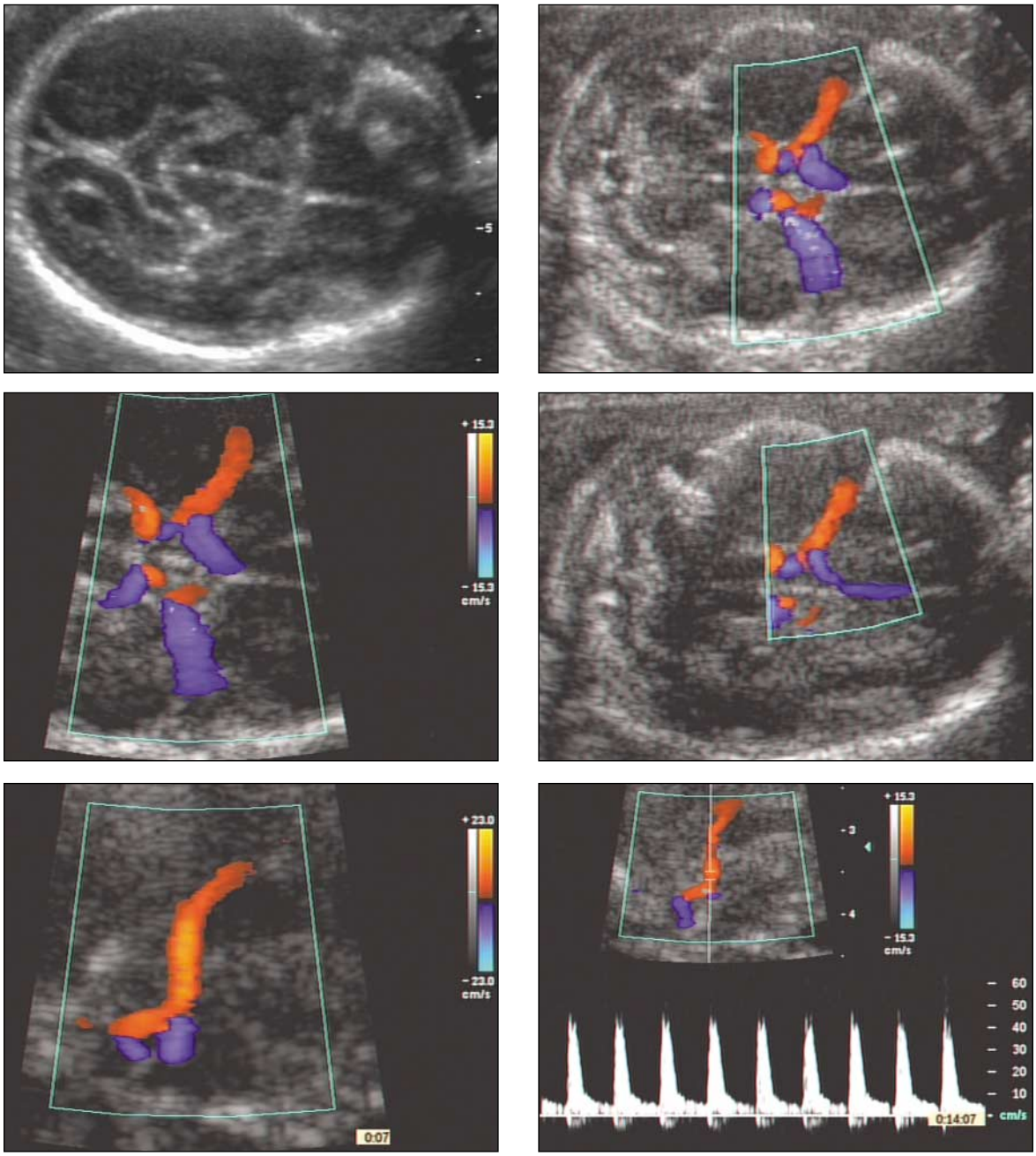


regard to the same individual and location. This was done separately for the 2 institutions. The degree of interobserver agreement between observers within the same institution was calculated with data obtained from the same individual at 1 time point. Intraobserver and interobserver agreement was calculated with different versions of intraclass correlation as described by Fleiss[10]:

$$\rho\_intra = (BMS - EMS) / (BMS + EMS),$$

where BMS and EMS represent between- and within-subject mean square errors, respectively, as obtained from 1-way analysis of variance;

Figure 2. Steps for correct MCA sampling. Top left, Axial section of the head at the level of the sphenoid bones; top right, color Doppler evidence of the circle of Willis; center left, the circle of Willis is enlarged; center right, the color box is placed around the MCA; bottom left, the MCA is zoomed; bottom right, the MCA flow velocity waveforms are displayed, and the highest point of the waveform (PSV) is measured. Note that the waveforms are similar to each other. The above sequence was repeated at least 3 times in each fetus.



$\rho\_inter = N(PMS - EMS)/\{(N \times PMS + RMS) + (N-1) \times EMS\}$,

where PMS, RMS, and EMS represent the mean squares for subjects, observers, and errors, respectively, as obtained from 2-way analysis of variance.

Comparison of the mean PSV between the 2 institutions for the same area, as well as between different areas within the same institution, was made with a 2-sample *t* test. Because the intraobserver agreement for all areas was excellent, for this analysis we used only the first measurement per observer for each area.

$P \leq .05$ indicated statistical significance.

Results

Table 1 shows the intraobserver agreement for different areas and institutions. Both institutions had a very high degree of agreement, ranging from 0.94 to 0.99. This reflected the very high reproducibility rate of the measurements when taken by a trained individual. (For areas B and C, there was insufficient data to determine the intraobserver variability because on most occasions there was only 1 measurement per case.)

In Table 2, the interobserver agreement for different areas and institutions had a high degree of agreement, ranging from 0.62 to 0.99. The highest agreement rate was observed for area A regardless of the institution or the time the measurements were taken. Although the degree of agreement for the other areas (B–D) was also high, it tended to vary on the basis of the time and institution where the measurements were taken. The data also indicate that angle-corrected measurements were more difficult to reproduce.

Table 3 shows that there was no agreement between the 2 institutions for the comparisons between A and C and B and D.

Table 4 reports the data on the comparison between the mean PSV obtained from the 2 institutions for each of the areas measured. Although no statistical differences were observed for areas A and D, there was a statistical difference in the mean PSV values between the 2 institutions for areas B and C with $P = .015$ and .003, respectively. The highest PSV values obtained from facility 2 reflect the different gestational ages of the 2 populations.

No difference was found between measurements taken with and without an angle correction for areas A and D.

Discussion

Middle cerebral artery PSV can be correctly sampled in approximately 100% of cases, and it can be used to diagnose fetal anemia due to several conditions, such as red cell alloimmunization,[2–6] parvovirus infection,[7] twin-twin-transfusion syndrome,[8] and fetomaternal hemorrhage.[9] Correction of fetal anemia is followed by a decreased MCA PSV into the normal reference range for gestational age.[11] Retrospective studies

Table 1. Intraobserver Agreement for Different Areas and Institutions

Area	Institution	Observer	Intraclass Correlation
A	1	1	0.98
A	1	2	0.99
A	2	1	0.99
A	2	2	0.94
D	1	1	0.99
D	1	2	0.97
D	2	1	0.99
D	2	2	0.99
A (angle corrected)	1	1	0.99
A (angle corrected)	1	2	0.95
D (angle corrected)	1	1	0.99
D (angle corrected)	1	2	0.98

A indicates MCA proximal to the transducer sampled 2 mm after its origin from the internal carotid artery; and D, MCA distal to the transducer sampled 2 mm after its origin from the internal carotid artery.

Table 2. Interobserver Agreement at First Measurement for Each Area and Institution

Area	Institution	Time	Intraclass Correlation
A	1	1	0.99
A	2	1	0.98
D	1	1	0.93
D	2	1	0.97
B	1	1	0.90
B	2	1	0.96
C	1	1	0.90
C	2	1	0.95
A (angle corrected)	1	1	0.92
A (angle corrected)	2	1	0.62
D (angle corrected)	1	1	0.85

A indicates MCA proximal to the transducer sampled 2 mm after its origin from the internal carotid artery; B, proximal MCA sampled at its midlength; C, proximal MCA sampled at its division; and D, MCA distal to the transducer sampled 2 mm after its origin from the internal carotid artery.

Table 3. Comparison of Mean PSV Values of Areas for the Combined Data and by Facility

Comparison Groups	Combined Data			Facility 1			Facility 2		
	Mean	Mean	*P*	Mean	Mean	*P*	Mean	Mean	*P*
A, B	43.3	43.0	NS	41.3	34.1	NS	45.1	49.9	NS
A, C	43.3	33.1	.006	41.3	25.3	.002	45.1	44.1	NS
A, D	43.3	39.4	NS	41.3	39.5	NS	45.1	39.3	NS
B, C	42.3	33.1	.05	34.1	25.3	NS	49.8	44.1	NS
B, D	42.3	39.4	NS	34.1	39.5	NS	49.9	39.3	.02
C, D	33.1	39.4	.09	25.3	39.5	.005	44.1	39.3	NS

A, indicates MCA proximal to the transducer sampled 2 mm after its origin from the internal carotid artery; B, proximal MCA sampled at its midlength; C, proximal MCA sampled at its division; D, MCA distal to the transducer sampled 2 mm after its origin from the internal carotid artery; and NS, not significant ($P > .05$).

have shown that this parameter is more accurate than amniotic fluid optical density measurement at 450 nm (ΔOD_{450}) for the diagnosis of fetal anemia.[12] Another study compared 4 different parameters previously proposed for the diagnosis of fetal anemia. The results showed that MCA PSV is the best diagnostic parameter for the detection of fetal anemia.[13] This parameter is reliable even in fetuses who have undergone a previous transfusion.[14] With appropriate training, the widespread adoption of this noninvasive Doppler parameter might reduce the number of invasive and risky procedures and save the lives of many fetuses, especially in early gestation (ie, before 20–22 weeks). However, the use of this Doppler parameter without appropriate training has the potential to do more harm than good. Therefore, it is all the more important to correctly sample the MCA when the timing or delay of an invasive procedure is predicted on the results of the PSV.

Table 4. Comparison of Mean PSV Values for Different Areas by Facility

Area	Facility 1 Mean	Facility 2 Mean	*P*
A	41.3	45.1	NS
B	34.1	49.8	.015
C	25.3	44.1	.003
D	39.5	39.3	NS
A (angle corrected)	43.1	46.3	NS

A indicates MCA proximal to the transducer sampled 2 mm after its origin from the internal carotid artery; B, proximal MCA sampled at its midlength; C, proximal MCA sampled at its division; D, MCA distal to the transducer sampled 2 mm after its origin from the internal carotid artery; and NS, not significant ($P > .05$).

The results of this study indicate that the MCA sampled at different areas provides good results for diagnosing fetal anemia. However, the distal area (C) is not an optimal point at which to assess the MCA. The reason for the high variability obtained at this focal point is the likelihood of sampling the MCA in one of its terminal branches, which have different velocity values.

The best results in terms of reproducibility are obtained when the artery is studied close to the transducer and without the use of an angle corrector (area A; interobserver variability, 0.98–0.99), whereas the use of an angle corrector gave rise to less good interobserver variability. The explanation is due to the fact that the MCA soon after its origin from the internal carotid artery is easy to sample; the contralateral MCA, with or without the use of an angle corrector, is more difficult to sample. In addition, in small fetal vessels, such as the MCA, it is more difficult to use an angle corrector as for larger vessels such as the umbilical artery in the fetus or the internal carotid artery in adults.

The results of this study corroborate those of previous studies in which the MCA was sampled soon after its origin from the internal carotid artery.[1,2] At this level, the sensitivity for detecting severe anemia was 100% (95% confidence interval, 86%–100%) with a false-positive rate of 12%.[2] Because of the importance of this Doppler parameter in clinical practice, it is vital to emphasize the steps necessary for obtaining the best results. If the criteria described in this study are used to sample the MCA, assessment of the velocity will enable correct timing with regard to the need of any invasive procedure. With the use of the MCA PSV, we have decreased the number of invasive procedures by approximately 70%.

The strength of this study derives from the observations of MCA PSV at 2 different institutions. Although several sonographers and sonologists were involved in the study, the variability between observers was very low, indicating that the velocity of the MCA is highly reproducible by trained people. However, before any sonographer or sonologist uses MCA PSV for the diagnosis of fetal anemia, a period of training is required.

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