4. Frankl O. Adenomyosis uteri. Am J Obstet Gynecol 1925; 10:680-4.
5. Bird CC, McElin TW, Manalo-Estrella P. The elusive adenomyosis of the uterus—revised. Am J Obstet Gynecol 1972;112:583-93.
6. Emge LA. Problems in the diagnosis of adenomyosis uteri. West J Surg 1956;64:291-305.
7. Israel SL, Woutersz TB. Adenomyosis—a neglected diagnosis. Obstet Gynecol 1959;14:168-73.
8. Weed JC, Geary WL, Holland JB. Adenomyosis of the uterus. Clin Obstet Gynecol 1966;9:412-21.
9. Rao BN, Persaud V. Adenomyosis uteri. West Indian Med J 1982;31:205-12.
10. Benson RC, Sneeden VD. Adenomyosis: a reappraisal of symptomatology. Am J Obstet Gynecol 1958;76:1044-61.
11. Giammalvo JT, Kaplan K. The incidence of endometriosis interna in 120 cases of carcinoma of the endometrium. Am J Obstet Gynecol 1958;75:161-6.
12. Nikkanen V, Punnonen R. Clinical significance of adenomyosis. Ann Chir Gynaecol 1980;69:278-80.
13. Kurman RJ. Benign diseases of the endometrium: adenomyosis. In: Blaustein A, ed. Pathology of the female genital tract. 2nd ed. New York: Springer Verlag, 1982: 297-9.
14. Kilkku P, Erkkola R, Groenroos M. Nonspecificity of symptoms related to adenomyosis. Acta Obstet Gynecol Scand 1984;63:229-31.
15. Olsen A, Christensen P. Adenomyosis diagnosed by hysterosalpingography. Fortschr Roentgenstr 1985;142:350-1.
16. Dodson MG. Transvaginal ultrasound. New York: Churchill Livingstone, 1991:70-2.
17. Lindgreen PG. Percutaneous needle biopsy. Acta Radiol Diagn 1982;23:653-6.
18. Lindgreen PG, Froedin L, Larsson E, Tufveson G, Wahlberg J. A new needle device for renal transplant biopsy. Transplant Proc 1986;18:98-9.
19. Weckermann D, Harzmann R. Neue Technik der urologischen Biopsie. Urologe 1988;28:100-2.
20. Emge LA. The elusive adenomyosis of the uterus. Am J Obstet Gynecol 1962;83:1541-63.

Evaluation of the fetal assessment score in pregnancies at risk for intrauterine hypoxia

Birgit Arabin, MD,[a] Rosalind Snyjders, MSc,[b] Axel Mohnhaupt, BS,[a] Volker Ragosch, MD,[a] and Kypros Nicolaides, MD[b]

Berlin, Germany, and London, England

OBJECTIVE: Our purpose was to define the diagnostic value of a new fetal assessment score that is based on each of the components of the Apgar score.

STUDY DESIGN: A fetal assessment score was established to study the main fetal vital functions: (1) cardiovascular (heart rate, color of the skin in the Apgar score), now based on fetal heart rate patterns and Doppler assessment of fetal blood flow redistribution, (2) fetal respiratory (quality of breathing in the Apgar score), now based on Doppler assessment of uteroplacental perfusion, and (3) neuromuscular function (tone and reflexes in the Apgar score), now based on fetal tone and response to external stimuli. The fetal assessment score was used in the study of 110 postdate pregnancies and 103 small-for-gestational-age infants and was compared with the traditional biophysical profile score in the prediction of perinatal outcome.

RESULTS: There were significant associations between both the fetal assessment score and the biophysical profile score with fetal distress that necessitated operative delivery, low Apgar scores, and low umbilical cord arterial blood pH. However, receiver-operator characteristic plots demonstrated that the fetal assessment score was superior to the biophysical profile score in predicting fetal distress and low Apgar values particularly in the small-for-gestational-age infants. The best single parameters in predicting fetal distress were the amniotic fluid volume in the biophysical profile score and fetal heart rate patterns and pulsed Doppler measurements in the new score.

CONCLUSION: A fetal Apgar score in which respiration is assessed by placental perfusion rather than chest movements and in which skin color is assessed by centralization of fetal blood flow may be better than the traditional biophysical profile score in predicting fetal hypoxic compromise. (Am J Obstet Gynecol 1993;169:549-54.)

Key words: Biophysical profile, perinatal outcome, uteroplacental and fetal Doppler blood flow

From the Department of Obstetrics, Gynecology, and Pediatrics, Klinikum Steglitz, Free University of Berlin,[a] and the Harris Birthright Research Centre for Fetal Medicine, Kings College Hospital Medical School.[b]
Received for publication June 16, 1992; revised March 30, 1993; accepted April 13, 1993.

Reprint requests: Birgit Arabin, MD, Univ.-Frauenklinik Steglitz, Hindenburgdamm 30, 1000 Berlin 33, Germany.

0002-9378/93 $1.00 + .20 ***6/1/47909***

The Apgar score,[1] introduced in 1952, remains the most widely used tool for assessing the immediate postnatal condition. The components of the score reflect the state of vital neonatal functions, respiratory, cardiovascular, and neuromuscular, that are known to alter in the presence of perinatal hypoxia that might have been preceded by chronic intrauterine hypoxia.

In 1980 Manning et al.[2] introduced the biophysical profile score, which used the various techniques available at that time, real-time ultrasonography, and fetal heart rate (FHR) monitoring as a screening procedure for the detection of fetal compromise. More recently, with the introduction of Doppler ultrasonography for the assessment of placental perfusion and fetal circulation, it has become possible to reproduce more closely the various components of the Apgar score in utero.

The aim of this study is to introduce a fetal assessment score and to compare this with the traditional biophysical profile score in the prediction of perinatal outcome in small-for-gestational-age (SGA) infants and in postdate pregnancies.

Patients and methods

Real-time ultrasonographic examinations, FHR monitoring, and Doppler studies of the uteroplacental and fetal circulation were performed in 103 SGA infants and 110 postdate (>290 completed days) singleton pregnancies referred to the fetal assessment unit of the Free University of Berlin. In all cases included in this study the interval between assessment and delivery was ≤3 days. Gestational age was determined from the maternal last menstrual period and confirmed by the fetal crown-rump length from an early ultrasonographic examination. The diagnosis of SGA was made by the ultrasonographic finding of a fetal abdominal diameter <5th percentile[3]; in Germany women are routinely scanned at least twice during pregnancy. In each case the data from the ultrasonographic examination and FHR monitoring were used to calculate the biophysical profile score as described by Manning et al.[2] In addition, pulsed Doppler studies (Siemens Sonoline SL 200, Erlangen, Germany) were performed for measurement of the resistance index in the uterine and umbilical arteries and the fetal common carotid artery, as previously described.[4]

Fetal assessment score. The intrauterine equivalents of the five components of the Apgar score are shown in Table I; each component was classified as normal (2 points), suspicious (1 point), or pathologic (0 points). "Heart rate" was assessed antenatally from the FHR pattern, which was analyzed with the Fischer classification[5] (normal 8 to 10, suspicious 5 to 7, pathologic <4). "Respiration" or oxygen supply, which in postnatal life is achieved by breathing but prenatally depends on placental function, was assessed by the resistance index in the uterine arteries[4] (normal resistance index <90th percentile and no early diastolic notch in the waveform, suspicious 90th to 95th percentile or notch, pathologic >95th percentile). "Color of the skin," which postnatally reflects centralization of the circulation, antenatally was assessed by the ratio of fetal carotid artery resistance index to umbilical artery resistance index (normal ratio >10th percentile, suspicious 5th to 10th percentile, pathologic <5th percentile). "Tone" was assessed from ultrasonographic observations of opening and closing of the fetal hands and bending and extending of the extremities, as in the biophysical profile score.[2] "Reflexes" were assessed by the magnitude and speed of fetal movements, as observed by ultrasonography, after vibroacoustic stimulation (normal, rapid strong movements; suspicious, slow, weak movements; pathologic, no movements).

Table I. Vital functions examined by Apgar score in neonates and fetal equivalents in fetal assessment score

Function	*Apgar score*	*Fetal assessment score*
Respiration	Breathing quality	Placental perfusion
Cardiovascular		
Heart	Heart rate	FHR
Circulation	Skin color	Cerebral-to-peripheral fetal blood flow
Neuromuscular		
Spontaneous	Tone	Tone
Reactive	Reflexes	Reflexes

The obstetricians managing the patients were not aware of the results of the fetal assessment score, and decisions were made on the basis of FHR patterns. Patient records were examined, and the following parameters were used to define fetal compromise: pathologic FHR pattern resulting in operative delivery, Apgar score <7 at 1 minute, and umbilical cord arterial blood pH < 7.20.

Statistical analysis. Receiver-operator characteristic curves were drawn for the prediction of fetal compromise by the fetal assessment score and the biophysical profile score. Significant differences of the curves of both profiles were calculated from the areas below the curves[6] with the unpaired Wilcoxon test.

Data from the SGA infants and postdate pregnancies were analyzed separately. For each score the impact of individual components was evaluated by stepwise descriminant analysis within the whole study group. F values >4 were considered to contribute significantly to the diagnostic capacity of the combined score.

Results

In the SGA infants the mean gestational age at delivery was 36 weeks (range 27 to 40 weeks), and the birth weight, which was always <10th percentile for

Table II. Associations of fetal assessment score and biophysical profile score with fetal distress necessitating operative delivery, Apgar score <7 at 1 minute, and umbilical cord arterial blood pH <7.20 in total group of 213 pregnancies (linear regression analysis)

Score	*Fetal distress*	*Apgar score <7 at 1 min*	*Umbilical cord arterial blood pH <7.20*
Fetal assessment score	$r = 0.58, p < 0.001$	$r = 0.41, p < 0.001$	$r = 0.34, p < 0.001$
Biophysical profile score	$r = 0.35, p < 0.001$	$r = 0.28, p < 0.01$	$r = 0.13$, NS

NS, Not significant.

gestation, ranged from 560 to 2850 gm (mean 2040 gm). In the postdate pregnancies the mean gestational age at delivery was 295 days (range 293 to 300 days), and the mean birth weight was 3680 gm (range 2910 to 4600 gm).

In the SGA group 57 of the 103 (55%) cases had operative deliveries because of fetal distress. The Apgar score was <7 at 1 minute in 39 (38%) and <7 at 5 minutes in 14 (14%) cases. The umbilical cord arterial blood pH was <7.20 in 22 (21%) and <7.10 in four (4%) cases. In the postdates group 38 of the 110 cases (35%) had operative deliveries because of fetal distress. The Apgar score was <7 at 1 minute in 10 (9%) and <7 at 5 minutes in two (2%) cases. The umbilical cord arterial blood pH was <7.20 in nine (8%) cases and <7.10 only once (1%).

In the SGA group the mean biophysical profile score was 8.1 (range 0 to 10) points, and in the postterm group it was 8.3 (range 4 to 10) points. The respective values for the fetal assessment score were 6.8 (range 0 to 10) points and 8.6 (range 3 to 10) points.

There were significant associations between both the fetal assessment score and the biophysical profile score and fetal distress necessitating operative delivery, low Apgar scores, and low umbilical cord arterial blood pH (Table II).

The receiver-operator characteristic plots for the prediction of fetal distress, Apgar score <7 at 1 minute, and blood pH <7.2 by the biophysical profile score and the fetal assessment score for the SGA infants and the postdate pregnancies are shown in Figs. 1 and 2, respectively. The number of cases with an Apgar score <7 at 5 minutes or blood pH <7.1 was too small for valid comparisons. As demonstrated by the receiver-operator characteristic plots, for both groups of pregnancies the new assessment score provided better prediction of fetal distress and low Apgar score ($p < 0.001$); the differences were greater in the SGA infants than in the postdate pregnancies. For the prediction of cord blood pH <7.2 there were no statistically significant differences between the two scores.

Stepwise discriminant analysis of the individual components of the two scores demonstrated that in the biophysical profile score only the FHR pattern and amniotic fluid volume contributed significantly ($F > 4$) to the diagnostic properties of the total score. In the fetal assessment score there were significant contributions from all components except for fetal tone (Table III).

Comment

Fetal assessment score as an equivalent of the Apgar score. In postnatal medicine the Apgar score has become widely accepted and has survived the test of time as a good method of assessment of the vital functions of the neonate.

In our study we used the same philosophy in creating an intrauterine Apgar score for the assessment of the fetus. Although the fetal assessment score examines and attributes equal importance to the same vital functions as the Apgar score, there are inevitable methodologic differences imposed by the physical barrier between the physician and the fetus and differences between intrauterine and extrauterine physiologic conditions.

In both the fetal assessment score and the Apgar score, neuromuscular function is assessed by observation of fetal tone and response to stimuli. In the Apgar score the observation is direct and the stimulus is touch. In the fetal assessment score observation is through ultrasonography and the stimulus is vibroacoustic.

Cardiac activity in the Apgar score is examined by auscultation; in the fetal assessment score it is assessed by FHR monitoring. Although for the latter we could have used just the FHR baseline or just FHR accelerations, there is considerable evidence that better information regarding fetal oxygenation and neonatal outcome is provided by examining all components of the FHR pattern.[7, 8] We used the Fischer score, which is widely adopted in Europe, but in the future it may well be replaced by one of the more reproducible computerized systems of analysis.

The color of the skin of the neonate as a variable in the Apgar score reflects the degree of fetal blood flow redistribution as an adaptation to hypoxia. Antenatally there is a similar redistribution or centralization in the fetal circulation during hypoxia, which can be assessed by the ratio of blood flow parameters between central and peripheral vessels that can be examined by Doppler ultrasonography. In this study we used the common carotid and umbilical arteries, respectively, but in the

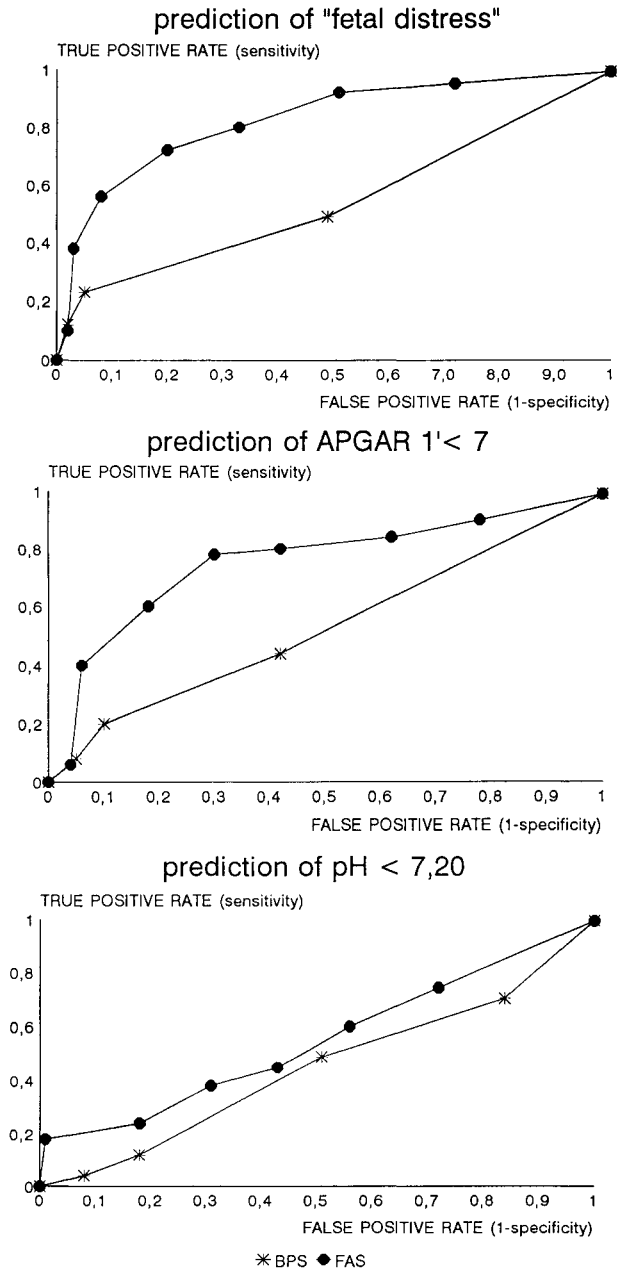

Fig. 1. Comparison of receiver-operator characteristic plots of fetal assessment score *(FAS)* (●) and biophysical profile score *(BPS)* (*) in prediction of fetal distress requiring operative delivery ($p < 0.001$), Apgar scores <7 at 1 minute ($p < 0.001$) and umbilical cord arterial blood pH <7.2 (not significant) in 103 SGA infants.

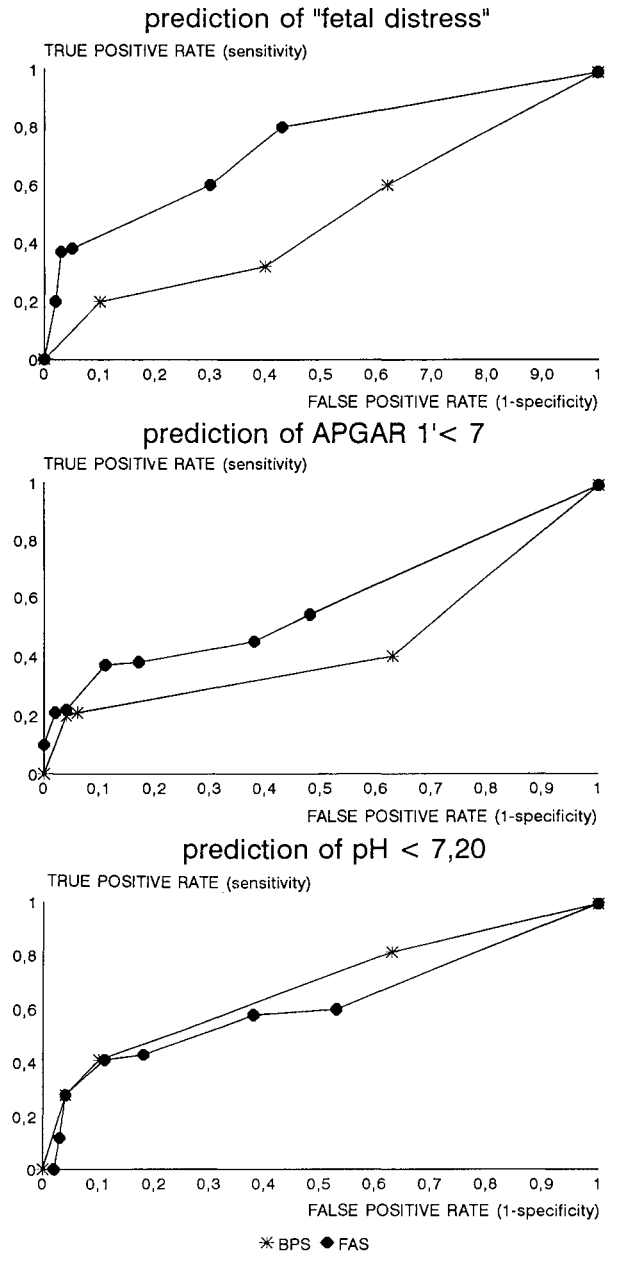

Fig. 2. Comparison of receiver-operator characteristic plots of fetal assessment score *(FAS)* (●) and biophysical profile score *(BPS)* (*) in prediction of fetal distress requiring operative delivery ($p < 0.01$), Apgar scores <7 at 1 minute ($p < 0.01$), and umbilical cord arterial blood pH <7.2 (not significant) in 110 postdate pregnancies.

future more sensitive and reproducible results may be achieved by the use of color flow imaging and the study of alternative vessels such as the middle or posterior cerebral arteries and the descending thoracic aorta or renal arteries, respectively.

Postnatally the infant relies on respiration for oxygenation, and in the Apgar score this is assessed by the presence and quality of breathing movements. In intrauterine life fetal oxygenation and blood gas exchange are primarily dependent on placental perfusion and function. Therefore in our study fetal oxygenation was assessed by Doppler measurement of resistance to flow in the uterine arteries. However, in future studies it may be preferable to include both uterine and umbilical artery Doppler results in assessing placental function because they reflect placental perfusion from both sides, respectively.

Diagnostic value for the prediction of fetal compro-

Table III. Stepwise discriminant analysis of individual components of fetal assessment score and biophysical profile score in prediction of fetal distress necessitating operative delivery, Apgar score >7 at 1 minute, and umbilical cord arterial blood pH <7.20 in total group of 213 pregnancies

Component	*Fetal distress*	*Apgar score <7 at 1 min*	*pH <7.20*
Fetal assessment score			
Placental blood flow	1.9	22.7	16.9
FHR	54.8	3.8	0.1
Fetal blood flow redistribution	41.1	4.4	1.3
Fetal reflexes	13.3	7.3	1.4
Fetal tone	3.3	2.4	2.5
Biophysical profile score			
Respiratory movements	3.3	2.1	0.1
FHR	14.4	7.9	2.7
Amniotic fluid volume	11.2	7.1	0.03
Fetal tone	0.9	0.1	0.01
Fetal movements	0.1	0.5	0.9

The cutoff value for significance is $F = 4$.

mise. The findings of this study suggest that in the assessment of postdate pregnancies and SGA infants, although both the biophysical profile score and the fetal assessment score were significantly associated with perinatal outcome, better prediction of fetal compromise may be provided by the fetal assessment score. However, it is acknowledged that the number of patients investigated in this study is relatively small in comparison to the many thousands examined by Manning et al.[9, 10] Furthermore, several studies have demonstrated a relationship of biophysical profile score and perinatal outcome in pregnancies complicated by maternal diabetes mellitus or premature rupture of membranes, in addition to SGA infants and postdate pregnancies.[11-14] Whether the fetal assessment score also provides a reliable prediction of perinatal outcome in these different types of pregnancy complications remains to be established.

The best single parameter in predicting fetal distress was the amniotic fluid volume in the biophysical profile score and FHR parameters and pulsed Doppler measurements in the fetal assessment score. Manning et al.[15] reported a close association between abnormal FHR patterns and amniotic fluid volume and concluded that FHR monitoring may be unnecessary if all other ultrasonographic parameters are normal. Conversely Vintzileos et al.[16] consider FHR monitoring an integral part of the profile because nonreactive FHR patterns are the first manifestations of fetal hypoxemia and acidemia, whereas reduction of amniotic fluid is a consequence of long-term compromise.

In our study group fetal tone and reflexes, which are indicative of neuromuscular function, were of less clinical value than cardiovascular variables. However, neuromuscular parameters may prove useful in a population with more severe fetal hypoxia or even in the prediction of neuromuscular impairment when immediate postnatal assessment has apparently normal results.

In this study we did not define "good" or "bad" scores but compared the diagnostic properties by receiver-operator characteristic analysis. In biologic systems there is no fixed limit of abnormality and normality, because it is well accepted that there are differences in sensitivity and specificity when different cutoff points are used. The primary aim of the study was therefore not to create cutoff points for normality or abnormality but to introduce the intrauterine equivalent of the Apgar score and to compare it with the biophysical profile score.

It has to be considered that not only the kind of score but also the frequency of performance is of importance for its clinical value. Because the fetal assessment score was applied in a preselected risk group it does not mean that it is useful as a screening procedure.

One criticism about biophysical profiles and even the original Apgar score relates to the lack of regard for gestational age. In normal pregnancies reference ranges with gestation are well described for FHR,[17] Doppler values,[4] fetal body and breathing movements,[18] and amniotic fluid volume.[19] Therefore in the interpretation of results from high-risk pregnancies, account should be taken of these normal changes with gestation. For fetal tone and reflexes this has not yet been established; this is one area that needs further investigation.

Comment

The end points used in our study may be considered inferior to perinatal mortality rates as used in many of the studies investigating the value of biophysical profile score. However, perinatal death is uncommon, and

modern antenatal care should be directed not only toward avoiding mortality but also preventing morbidity and long-term handicap. Similarly the use of the 1-minute Apgar score as an end point could be criticized. However, in our study the number of cases with a low Apgar score at 5 and 10 minutes was too small to allow valid statistical comparisons. Furthermore, advances in neonatal care since 1953, when the Apgar score was introduced, including intubation and resuscitation for the immature or the asphyxiated baby shortly after birth, makes it difficult to interpret the relevance of some components such as breathing quality or tone or color of the skin in the Apgar score at 5 and 10 minutes.

Previous studies have reported correlations between biophysical profile score and antenatal blood gases.[20, 21] Therefore in the short term useful information may be provided by investigating the association between the fetal assessment score and fetal blood gases obtained by cordocentesis.

It has recently been shown that there is a significant association between fetal blood pH and subsequent neurodevelopment.[22] Similarly, larger prospective trials should be performed to investigate the impact of various components of the fetal assessment score on later infant development. This implies a close cooperation between obstetricians and pediatricians.

We thank Dr. Virginia Apgar for her inspiration for the concept and design and Dr. Gabriele Kewitz for providing us with Apgar scores in the neonates. We also thank the heads of our departments, Prof. Dr. H. Versmold and Prof. Dr. H.K. Weitzel, for their interest.

REFERENCES

1. Apgar V. A proposal for a new method of evaluation of the newborn infant. Anaesth Analg Curr Res 1953;32:260-8.
2. Manning FA, Platt FD, Sipos L. Antepartum fetal evaluation: development of a fetal biophysical profile. Am J Obstet Gynecol 1980;136:787-97.
3. Hansmann M, Hackeloer BJ, Staudach A. Ultraschalldiagnostik in Geburtshilfe und Gynäkologie. Heidelberg: Springer, 1989.
4. Arabin B. Doppler blood flow measurement in uteroplacental and fetal vessels. Heidelberg: Springer, 1990.
5. Fischer WM, Stude I, Brandt H. Ein Vorschlag zur Beurteilung des antepartualen Kardiotokogramms. Z Geburtshilfe Perinatol 1976;80:116-22.
6. Hanley JA. Receiver operating characteristic (ROC) methodology: the state of the art. Crit Rev Diagn Imaging 1989;29:307-35.
7. Nicolaides KH, Sadovsky G, Visser GHA. Heart rate patterns in normoxemic, hypoxemic, and anemic second-trimester fetuses. Am J Obstet Gynecol 1989;160:1034-7.
8. Arabin B, Rüttgers H, Lorenz U, Kubli F. Course and predictive value of fetal heart rate parameters from the 27th to the 42nd week of gestation. Am J Perinatol 1988;5:272-7.
9. Manning FA, Morrison I, Lange IR, Harman CR, Chamberlain PF. Fetal assessment based on fetal biophysical profile scoring: experience in 12,620 referred high-risk pregnancies. I. Perinatal mortality by frequency and etiology. Am J Obstet Gynecol 1985;151:343-50.
10. Manning FA, Morrison I, Harman CR, Lange IR, Menticoglou S. Fetal assessment based on fetal biophysical scoring: experience in 19,221 referred high-risk patients. II. An analysis of false-negative fetal deaths. Am J Obstet Gynecol 1987;157:880-4.
11. Platt LD, Eglington GS, Sipos L, Broussard PM, Paul RH. Further experience with fetal biophysical profile score. Obstet Gynecol 1983;61:480-5.
12. Johnson JM, Harman CR, Lange IR, Manning FA. Biophysical profile scoring in the management of post-term pregnancy: an analysis of 307 patients. Obstet Gynecol 1986;72:841-6.
13. Landon MB, Grabbe SG. Fetal surveillance in the pregnancy complicated by diabetes mellitus. Clin Obstet Gynecol 1991;34:535-43.
14. Fleming AD, Salafia CM, Vintzileos AM. The relationship among umbilical artery velocimetry, fetal biophysical profile and placental inflammation in preterm premature rupture of membranes. Am J Obstet Gynecol 1991;164: 38-41.
15. Manning FA, Morrison I, Lange IR, Harman CR, Chamberlain PF. Fetal biophysical profile scoring: selective use of the nonstress test. Am J Obstet Gynecol 1987;156:709-12.
16. Vintzileos AM, Fleming AD, Scorza WE, et al. Relationship between fetal biophysical activities and umbilical cord blood gas values. Am J Obstet Gynecol 1991;165:707-13.
17. Sadovsky G, Nicolaides KH. Reference ranges for fetal heart rate patterns in normoxaemic nonanaemic fetuses. Fetal Ther 1989;4:61-8.
18. Arabin B, Riedewald S. An attempt to quantify characteristics of behavioral states. Am J Perinatol 1992;9:115-9.
19. Moore TR, Cayle JE. The amniotic fluid index in normal human pregnancy. Am J Obstet Gynecol 1990;162:1168-73.
20. Ribbert LSM, Snijders RJM, Nicolaides KH, Visser GHA. Relationship of fetal biophysical profile and blood gas values at cordocentesis in severely growth-retarded fetuses. Am J Obstet Gynecol 1990;163:569-71.
21. Vintzileos AM, Fleming AD, Scorza WE, Wolf EJ, Balducci J. Relationship between fetal biophysical activities and umbilical cord blood gas values. Am J Obstet Gynecol 1991;165:707-13.
22. Soothill PW, Ajayi RA, Campbell S, et al. Relationship between fetal acidemia at cordocentesis and subsequent neurodevelopment. Ultrasound Obstet Gynecol 1992;2: 1-4.