Association of Electronic Fetal Monitoring during Labor with Cesarean Section Rate and with Neonatal Morbidity and Mortality

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Abstract: Data from the 1980 National Natality Survey by the National Center for Health Statistics were used to assess the relation of electronic fetal monitoring (EFM) during labor with cesarean section rates and neonatal morbidity and mortality. In univariate analyses, EFM was associated with higher cesarean section rates, lower five-minute Apgar scores, and a higher rate of respiratory distress. Logistic regression analysis controlling for other risk factors for poor neonatal outcome indicated that the association of EFM with higher cesarean section rates persisted (odds ratio 1.45, 95% CI 1.16, 1.81), except in certain pregnancies at very high risk for cesarean section. EFM was associated with an Apgar score less than 6 at five minutes only if delivery was by cesarean section. EFM was not found to be independently associated with respiratory distress. Neither univariate nor multivariate analyses found an association of EFM with neonatal mortality. These results suggest that EFM may identify hypoxic infants, who are frequently delivered by cesarean section. The lack of association of EFM with beneficial neonatal outcomes is consistent either with lack of effect of EFM or with uncontrolled selection bias. (*Am J Public Health* 1988; 78:1170–1174.)

Introduction

During the past two decades, there has been a substantial increase in the use of electronic fetal monitoring (EFM) during labor; EFM was reported in 47.7 per cent of live births in the United States in 1980.[1] EFM may be direct, consisting of fetal heart rate monitoring by means of an electrode implanted in the fetal scalp, or indirect, consisting of external monitoring by Doppler ultrasound. The ultimate objective of these procedures is the prevention of perinatal morbidity and mortality by early detection of fetal hypoxia and distress. Detection of abnormality by EFM is followed by interventions aimed to relieve fetal distress, such as lateral positioning of the mother, administration of oxygen, or surgical intervention.[2]

The results of previous research on the risks and benefits of EFM are controversial. A report by the American Medical Association[3] conceded that, while appropriate use of EFM in high-risk pregnancies can decrease perinatal morbidity and mortality, inadequate data are available for conclusions with regard to low-risk pregnancies. The report also pointed out the impracticality of a randomized controlled trial, given the infrequent occurrence of intrapartum fetal distress. As most of the studies of EFM so far have been carried out in academic medical centers, there is also a need to gather data from more broadly representative samples.

The 1980 National Natality Survey (NNS), conducted by the National Center for Health Statistics (NCHS), is a nationally representative survey based on a sample of 9,941 live births in the US during 1980.[4] In order to obtain an adequate sample of low birthweight deliveries, this survey oversampled the low birthweight stratum (less than 2500 grams). A previous publication has used this data base to carry out a descriptive study of cesarean section rates in pregnancies with and without EFM.[1] The authors concluded that EFM was associated with an elevated primary cesarean section rate, although they did not carry out multivariate analyses to control for potentially confounding variables. This investigation overcomes that limitation, and furthermore looks at the relationship of EFM to pregnancy outcomes, including selected indicators of infant morbidity and mortality.

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Methods

Construction of Data File for Analysis

The NNS public use data tape consists of merged information collected from birth certificates, married mothers, hospitals, attendants at delivery, and other medical providers of radiation procedures who were identified by the mothers and medical care providers. In this analysis, we present results on variables derived from the birth certificate or from the hospital. Information collected with regard to EFM includes whether EFM was used to monitor labor, and the specific technique used (Doppler ultrasound, scalp electrode, or other methods or combinations). Specific details concerning the procedures employed in this survey are described at length elsewhere.[4] With appropriate confidentiality provisions, NCHS supplied infant death certificate information derived by matching NNS records against the National Death Index (NDI). This was added to our NNS data base.

Of the 9,941 subjects included in the data base, there were 3,003 with missing EFM information due to item or unit nonresponse. The NCHS subsequently replaced this missing information with imputed values using procedures designed to attribute the EFM exposure reported by responding sources to nonresponding sources. To avoid potential bias arising from possible misclassification of EFM exposure, these subjects were excluded from further analyses, reducing the sample to 6,938. Further exclusion criteria were applied to refine the study population and ensure comparability with other studies reported in the literature. Infants with major congenital malformations and severely premature infants (gestational age less than 28 weeks) were excluded since neither group would be expected to derive benefit from monitoring. Multiple births were excluded, as were deliveries outside hospital and planned or repeat cesarean sections. A total of 1,075 births were excluded based on these criteria, reducing the sample size to 5,863.

The dependent variables investigated were: primary cesarean section delivery; two measures of neonatal morbidity (five-minute Apgar score,[5] and respiratory distress[2]); and neonatal mortality (deaths during the first 28 days of life). For each dependent variable of interest, except neonatal mortality, imputed values were excluded from the analysis. This resulted in reduction of the sample size by from 39 to 138, or somewhat less than 3 per cent of the remaining total.

The independent variables of interest included a variety of specific complications of labor, mother's age at time of pregnancy, parity, previous live births and fetal losses, underlying medical conditions including diabetes, overall assessment of complications of pregnancy and labor, gestational age (dichotomized at $\leq$ 36 weeks and at $>$ 36 weeks), and birthweight for gestational age (defined in terms of quartiles of the range of birthweights for a given gestational age). The latter two variables controlled for the effects both of birthweight and gestational age and their interaction.

Statistical Methods

Associations between the independent and dependent variables of interest were examined using contingency table analyses. The confidence limits for odds ratios based on these tables were obtained using the Cornfield method to approximate the exact confidence limits; the computer program of Thomas was used.[6] In order to adjust for potentially confounding variables, multivariate models were then developed using multiple logistic regression analysis.[7] Potential risk factors and confounders included in the multivariate models were identified through contingency table analyses and from the literature. For the sake of brevity, the results displayed in the tables include odds ratios and confidence intervals only for EFM and for other variables with confidence intervals which exclude unity (additional data available from the author). Computation of estimated odds ratios for interactions between two variables were derived using the lack of either characteristics as the referent category.

The adequacy of each fitted logistic model was examined using the Hosmer-Lemeshow statistic[8] computed in BMD-PLR.[9] Examination of the residuals for each decile of risk showed that the models fit reasonably well over most of the range of estimated probabilities with the exception of the upper and lower deciles of risk for the model for cesarean section delivery. In the lower deciles of risk the fitted model tended to underestimate the number of cesarean sections and in the upper deciles there was tendency for it to overestimate the number. Overall, however, the model provided an adequate fit to the data.

As the data were derived from a stratified sample with unequal sampling ratios in the two strata (normal and low birthweight deliveries), we explored the possibility of including weights which would reflect this differential sampling within the strata. Weighted and unweighted logistic regression analyses were performed using GLIM[10] and the Nonlinear Regression (P3R) program available through BMDP.[9] Since the weighted analysis did not differ significantly from the unweighted analysis and national estimates were not of interest, the study was based on unweighted analyses.

For each outcome variable, a separate analysis was carried out examining its relationship to the different types of monitoring used (external or internal). The odds ratios determined for the comparison of each type of fetal monitoring to non-monitored deliveries were quite similar. Additionally, no apparent differences were noted when external monitoring was compared to internal monitoring. Consequently, the analyses presented are based only on the comparison between monitored deliveries and deliveries in which this technology was not used.

TABLE 1—Association between Primary Outcome Variables and EFM Exposure

	EFM Exposure					
	Yes		No			
Outcome measure	N	%	N	%	Odds Ratio	95% CIE
Primary Cesarean Section Delivery						
Cesarean delivery	358	12.6	229	7.7	1.72	1.44, 2.06
Other method	2492	87.4	2745	92.3		
5-minute Apgar Score						
0–5	54	1.9	28	1.0	2.01	1.24, 3.26
6–10	2782	98.1	2893	99.0		
Respiratory Distress Syndrome						
Present	176	6.3	139	4.7	1.35	1.07, 1.71
Absent	2618	93.7	2792	95.3		
Neonatal Mortality						
Neonatal death	32	1.1	23	0.8	1.46	0.82, 2.58
Alive at 28 Days	2839	98.9	2969	99.2		

CIE = Confidence Interval Estimate

Results

Electronic fetal monitoring was used in 2,871, or nearly half (49.0 per cent) of this sample of live hospital births; 28.1 per cent were by Doppler ultrasound only (external), 10.6 per cent by scalp electrode only (internal), 7.1 per cent by Doppler ultrasound and scalp electrode, and 3.1 per cent by other or unspecified methods of EFM.

Table 1 presents the univariate relations between EFM and the dependent variables in the study. EFM was related to a higher cesarean section rate, low five-minute Apgar score, and respiratory distress. The association of EFM with neonatal mortality was uncertain because of small numbers, but a somewhat larger proportion of deaths in the neonatal period occurred in monitored infants.

These relations between EFM and a variety of independent variables were quite similar to those previously reported by Placek, *et al.*[1] Primiparae and more highly educated mothers were monitored significantly more frequently as were labors with the following complications: abnormal position of the cord, abruptio placentae, premature rupture of the placental membranes, prolonged labor, toxemia, transverse lie, and inadequate pelvis. EFM was also used significantly more frequently when one or more complications of pregnancy were present, but was not clearly associated with any particular complication.

EFM and Cesarean Section

Multiple logistic regression was used to model the association of EFM with primary cesarean section delivery (Table 2). Interactions between EFM and several independent variables including placenta previa, and transverse lie or inadequate pelvis were found to contribute substantially to this model. In pregnancies complicated by placenta previa, transverse lie or inadequate pelvis, cesarean section rates were very high. However, when electronic fetal monitoring was used the odds ratio associated with these complications was greatly diminished. Thus, EFM was associated with an increased cesarean section rate only in pregnancies without these complications.

In this model each of the following variables, when present, was found to independently increase the likelihood of delivery by cesarean section: primiparity, prior fetal loss, abruptio placentae, early rupture of the placental mem-

TABLE 2—Adjusted Odds Ratios and 95% Confidence Interval Estimates (CIE) Obtained from a Multiple Logistic Regression Analysis Comparing Cesarean Section Deliveries to All other Modes of Delivery (n = 5824)

Variables	Adjusted Odds Ratio	95% CIE
EFM	1.45	1.16, 1.81
Placenta Previa	72.49	21.24, 247.37
EFM & Placenta Previa	17.09	6.02, 48.51
Transverse Lie or Inadequate Pelvis	90.70	47.51, 173.16
EFM & Transverse Lie or Inadequate Pelvis	54.86	32.62, 92.26
Birth Certificate Variables		
Primiparity	3.50	2.66, 4.60
Prior Fetal Loss	2.24	1.63, 3.09
Complications of Labor		
Abruptio Placentae	6.18	3.42, 11.17
Early Rupture of Membranes	1.89	1.37, 2.61
Prolonged Labor	5.47	3.84, 7.80
Toxemia	3.37	2.22, 5.13
Complications of Pregnancy, Underlying Medical Conditions		
One or more Complications of Pregnancy	2.13	1.58, 2.87
Maternal Diabetes	3.69	1.82, 7.46
Constant (Coefficient = −3.929; S.E. = 0.152)		

branes, prolonged labor, and toxemia, one or more complications of pregnancy, and maternal diabetes.

EFM and Five-Minute Apgar Score

Stepwise logistic regression was next used to investigate the relationship between EFM and Apgar score (Table 3). The estimated odds ratio for EFM was found to be very slightly elevated. A number of potential interactions were evaluated but only the interaction of cesarean delivery with EFM contributed to the model. The presence of both factors resulted in a significant excess risk of low Apgar score (OR = 3.90; 95% CIE = 1.98, 7.76). Several other variables contributed significantly to this model; these included birthweight as a function of gestational age, gestational age, and complications noted during labor, particularly unusual bleeding. One or more underlying medical conditions was unexpectedly associated with an odds ratio less than unity, although the upper limit of the confidence interval was close to unity.

TABLE 3—Adjusted Odds Ratios and 95% Confidence Interval Estimates (CIE) Obtained from a Multiple Logistic Regression Analysis Comparing Low (<6) to High Five-minute Apgar Score (n = 5757)

Variables		Adjusted Odds Ratio	95% CIE
EFM		1.18	0.68, 2.05
Primary C-Section		0.72	0.20, 2.56
EFM & Primary C-Section		3.90	1.96, 7.76
Birth Certificate Variables			
Gestational Age <37 wks		5.01	3.02, 8.33
Birthweight for Gestational Age*	Q3	0.83	0.33, 2.08
	Q2	1.93	0.89, 4.21
	Q1	3.48	1.69, 7.15
Complications of Labor			
One or More		2.24	1.35, 3.72
Unusual Bleeding		3.72	1.42, 9.75
Underlying Medical Conditions			
One or More		0.48	0.25, 0.93
Constant (Coefficient = −5.871; S.E. = 0.442)			

*The fourth quartile of birthweight (highest) for gestational age served as the referent group for calculation of odds ratios and 95% CIE.

EFM and Respiratory Distress Syndrome

The logistic model describing the relations between EFM and respiratory distress syndrome (RDS) is detailed in Table 4. EFM was found to be very slightly associated with RDS. Cesarean section delivery was associated with an elevated odds ratio, as were low birthweight for gestational age and shorter gestational age. Gestational age of less than 37 weeks had by far the strongest association with RDS of all the variables considered (OR = 12.09). Abnormal position of the cord and abruptio placentae were associated with elevated odds ratios as was the presence of one or more complications of pregnancy. A number of potential interactions were evaluated but none contributed to the model.

EFM and Neonatal Mortality

The model describing the association between EFM and neonatal mortality is presented in Table 5. Only 55 neonatal deaths are included in this model, so that caution is needed in interpretation of the results. The risk of neonatal death increased with diminishing birthweight for gestational age, while gestational age was again found to be the strongest predictor of outcome. The occurrence of one or more complications during pregnancy was also associated with an increased risk of neonatal death. None of the potential interactions tested were found to contribute to the model.

Discussion

The results of our study found no evidence of an association of EFM with beneficial neonatal outcomes. Our unadjusted estimates of the association of EFM with five-minute Apgar score and RDS indicated that EFM was associated with poorer outcomes; however, the estimates based on multivariate analyses indicated that some part of this negative effect was due to the confounding effects of other variables identified in previous studies: low gestational age, low birthweight for gestational age, and several complications of labor.[11,12] The odds ratios for the association of EFM with all neonatal outcomes studied remained slightly greater than one when these confounding variables were controlled. This may represent some residual confounding or other bias, which is discussed further below.

TABLE 4—Adjusted Odds Ratios and 95% Confidence Interval Estimates (CIE) Obtained from a Multiple Logistic Regression Analysis Comparing Infants Who Experienced Respiratory Distress Syndrome to Those That Did Not (n = 5725)

Variables		Adjusted Odds Ratio	95% CIE
EFM		1.13	0.87, 1.47
Primary C-Section		1.98	1.41, 2.79
Birth Certificate Variables			
Gestational Age <37 wks		12.09	9.20, 15.89
Birthweight for Gestational Age*	Q3	1.68	1.12, 2.52
	Q2	1.59	1.06, 2.40
	Q1	2.79	1.89, 4.12
Complications of Labor			
Abnormal Position of Cord		2.52	1.34, 4.74
Abruptio Placentae		2.04	1.06, 3.92
Complications of Pregnancy			
One or more		2.01	1.45, 2.79
Constant (Coefficient = −4.564; S.E. = 0.229)			

*The fourth quartile of birthweight (highest) for gestational age served as the referent group for calculation of odds ratios and 95% CIE.

The interaction of EFM with cesarean delivery in relation to Apgar score is of interest, as it indicates that monitored infants who are delivered by cesarean section have poorer Apgar scores than monitored infants delivered vaginally, or unmonitored infants regardless of method of delivery. This result seems to indicate that EFM may identify the hypoxic fetus, as cesarean section would be the method of delivery used if fetal distress were detected during monitoring which could not be resolved with less drastic intervention. In unmonitored labors, no association of cesarean section and Apgar score was found, indicating poorer ability to identify those fetuses that require rapid delivery. Schifrin and Dame reported that an abnormal fetal heart rate during the last 30 minutes of labor was associated with low five-minute Apgar score,[13] although the predictive value was only about 20 per cent. A similar result was found by Murphy, *et al*,[14] when they examined several problematic outcomes of monitored pregnancies.

Several randomized controlled trials have attempted to assess the effectiveness of EFM, and have failed to detect any benefit either in high-risk[15–17] or in low-risk pregnancies.[18,19] A large clinical trial in which policies of universal versus selective monitoring, applied in alternate months, were compared also failed to find differences in perinatal outcomes.[20] Other studies, however, have reported evidence supporting the use of EFM. One randomized trial did find that EFM in high-risk pregnancies resulted in improved neurological and biochemical status of the neonate.[21] Neutra, *et al*,[22–24] carried out an observational study in a large Boston hospital, and found that EFM was associated with a reduction in the neonatal death rate and in the prevalence of neonates with low five-minute Apgar scores in pregnancies with one or more risk factors, but not in low-risk pregnancies. Paul, *et al*,[25,26] also found some evidence of benefit of EFM in an observational study at a large hospital in California.

Critics have argued that the use of EFM has resulted in an increased rate of cesarean section as a result of efforts to achieve rapid delivery in cases where EFM indicates fetal distress.[1,27] As already discussed, EFM may produce false positive results, so that some of this excess cesarean rate may be unwarranted. Cesarean delivery may increase the risk of RDS, as suggested by our results as well as those of other investigators.[12,28–31] The reasons for this are not completely understood.

Even after controlling for all the risk factors for poor pregnancy outcome measured in this study, the odds ratios for EFM and all the neonatal outcomes in this study were somewhat greater than unity. One explanation for this finding is that in some cases EFM may have been used selectively in labors in which some abnormality had already been noted. This potential selection bias is an important limitation of the data used in this study; one cannot distinguish whether EFM was used routinely or in response to some indication of fetal distress. In view of the large percentage of births in which EFM was used, it seems unlikely that fetal distress was very frequently the initiating event for EFM.

Another potential problem is information bias. Data collected from birth certificates are often incomplete and inaccurate. Of particular concern is gestational age, which may be routinely overestimated. Infants with a low birthweight for reported gestational age may be infants in whom the gestational age was overestimated. This could account for the finding that infants in the lower quartiles of birthweight for gestational age had an elevated risk of poor neonatal outcomes.

It is also possible that some abnormalities of labor were more readily detected or more completely reported in monitored labors. In this case, controlling for complications of labor might have resulted in overcontrolling, leading to an underestimation of the beneficial effects of EFM. However, no beneficial effect of EFM was detected, even when these complications were not included in the model. It is also possible that reporting of complications differed depending on the outcome of the pregnancy. Any bias which might have been introduced in this way is difficult to evaluate.

In conclusion, it appears likely that EFM has contributed to the increasing cesarean section rate in this country[32,33] which in 1985 stood at 22.7 cesareans per 100 deliveries.[34] Although this procedure is undoubtedly much safer and freer of complications than was formerly the case, there is a certain increased risk of iatrogenic prematurity and RDS, as well as maternal morbidity and mortality. Although some evidence supports benefits of EFM to high-risk pregnancies, the bulk of the evidence from studies of lower-risk pregnancies, our study included, provide little evidence of benefit.

TABLE 5—Adjusted Odds Ratios and 95% Confidence Interval Estimates (CIE) Obtained from a Multiple Logistic Regression Analysis Comparing Neonatal Deaths to Infants Alive at 28 Days (n = 5863)

Variables		Adjusted Odds Ratio	95% CIE
EFM		1.21	0.69, 2.12
Birth Certificate Variables			
Gestational Age <37 wks		10.65	5.70, 19.89
Birthweight for Gestational Age*	Q3	3.77	0.79, 17.93
	Q2	5.78	1.29, 25.97
	Q1	14.08	3.32, 59.82
Complications of Pregnancy			
One or more		1.83	1.03, 3.43
Constant (Coefficient = −7.413; S.E. = 0.774)			

*The fourth quartile of birthweight (highest) for gestational age served as the referent group for calculation of odds ratios and 95% CIE.

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Workshop in India to Focus on Role of Women in Health Sciences and Health Care in Developing Countries

The Committee on Science and Technology in Developing Countries (COSTED), in collaboration with the Kovalevskia Foundation and the Tamil Nadu Women Doctors Association, is planning to conduct a five-day workshop, February 1–5, 1989 in Madras, India on "The Role of Women in Health Sciences and Health Care in Developing Countries," and to publish the proceedings in book form.

The workshop will discuss the present status of health science and health care programs and the training of health scientists in developing countries with special reference to constraints which hamper progress in the training of women for these programs and factors which may facilitate their active role in this activity. The workshop participation will be restricted to women health scientists, five from India, 10 from developing countries in Asia, five from Western countries, and 10 young scientists from India as observers.

COSTED will sponsor the travel of five scientists from Asia, Kovalevskia Foundation, the travel of two from Vietnam, and one from Kampuchia.

Those interested in participation in this workshop should write to: Prof. C. V. Ramakrishnan, Hon. Program Director, COSTED, Gandhi Mandap Road, Guindy, Madras-600 025, India, and include their biodata along with a short summary of their role in training health scientists and implementation of health programs.