Evaluation of Category II Fetal Heart Rate Tracings

Author, year	*Setting*	*Design/ approach*	*Subjects*	*Intervention*	*Comparator*	*Sample size*	*Outcomes*	*Risk of bias*[1]	*Results*
Hernandez Engelhart 2023	Global	Systematic review	Studies that assess inter- and intra-rater reliability and agreement of health professionals' intrapartum FHR monitoring were included and studies including other assessment of fetal well-being excluded.	Continuous FHR monitoring	-	49 studies	Reliability	High-quality review	There is great variation in reliability and agreement measures for continuous intrapartum FHR monitoring, implying that intrapartum CTG should be used with caution for clinical decision making given its questionable reliability. We found few high-quality studies and noted methodological concerns in the studies. We recommend a more standardized approach to future reliability studies on FHR monitoring.

[1] Risk of Bias Definitions
There are 4 main types of references, evaluated using a corresponding quality assessment tool:

- Guidelines: AGREE-II
  - **The overall rating is generated by averaging the scores of all 23 items and will be on a scale of 1-7,** with 7 being the highest quality
- Systematic Reviews/Meta-Analyses: AMSTAR 2
  - An overall rating of quality of the evidence will be rated as **High, Moderate, Low, or Critically Low-Quality Review**, based on 16 domains
- Randomized Controlled Trials: Cochrane Collaboration's tool
  - Each of the 7 domains will be rated as **low, high, or moderate (some concerns),** with a brief summary of the findings in the evidence table
- Observational Studies: ROBINS-I
  - For each of the 7 domains, the risk of bias will be judged as **low, moderate, serious, or critical risk of bias (or no information),** with a brief summary of the findings in the evidence table

Murphy 2023	Global	Systematic review and meta-analysis	RCTs that that compared any form of FSS to assess fetal well-being in labor	CTG and dFSS or CTG and manual fetal stimulation (abdominal or vaginal scalp stimulation)	CTG FBS or CTG alone	2 RCTs; 377 women	Perinatal death; disability in babies at or after 12 months; cesarean section rate; assisted vaginal birth; spontaneous vaginal birth; evidence of brain injury during birth	High-quality review	There is very low-certainty evidence available which makes it unclear whether stimulating the fetal scalp is a safe and objective way to confirm fetal well-being in labor. Evidence was downgraded based on limitations in study design and imprecision. Further high-quality studies of adequate sample size are required to evaluate this research question. In order to be generalizable, these trials should be conducted in different settings, including broad clinical criteria at both preterm and term gestational ages, and standardizing the method of stimulation. There is an ongoing study (FIRSST) that will be incorporated into this review in a subsequent update.
Alfirevic 2017	Global	Systematic Review	Pregnant women in labor and their infants	Continuous FHR monitoring	No monitoring or intermittent CTG	13 trials with 37,000 women	Perinatal mortality, seizures in neonatal period, cerebral palsy, caesarean section, cord blood acidosis, instrumental vaginal birth	Moderate-quality review	CTG during labor is associated with reduced rates of neonatal seizures, but no clear differences in cerebral palsy, infant mortality or other standard measures of neonatal wellbeing. However, continuous CTG was associated with an increase in caesarean sections and instrumental vaginal births. The challenge is how best to convey these results to women to enable them to make an informed decision without compromising the normality of labor.
Parer 2006	United States	Systematic review	Studies that assessed aspects of FHR patterns (eg, degree of FHR variability, depth of decelerations), and fetal acidemia, or fetal vigor	FHR patterns	-	18 articles	Association of FHR patterns with fetal acidemia (umbilical pH <7.15, base excess, 5-min Apgar <7)	Critically low-quality review	The validity of the relationship between certain FHR patterns and fetal acidemia and/or vigor, is supported by observations from the literature. In addition, four assumptions commonly used in clinical management are supported. These conclusions need to be confirmed by a prospective examination of a large number of consecutive, unselected FHR patterns, and their relationship to newborn acidemia. Pending the completion of such studies, these observations can be used to justify certain aspects of current clinical management, and may assist in standardizing the diversity of opinions regarding FHR pattern management.

Rimsza 2023	Washington	Nested prospective case-control study	Patients with singleton pregnancies at ≥37 weeks of gestation, admitted in spontaneous labor or for induction of labor	Intrapartum EFM	Control group	8580 patients	Incidence of high-risk category II EFM features in the 60 minutes before delivery; in particular, the incidence of minimal variability, recurrent late decelerations, recurrent variable decelerations, tachycardia, and >1 prolonged deceleration were compared between groups	Moderate risk of bias	Although multiple category II EFM features have been traditionally linked to acidemia, the presence of recurrent late decelerations, recurrent variable decelerations, and prolonged decelerations seemed to concern obstetricians enough to surgically intervene for nonreassuring fetal status. A clinical intrapartum diagnosis of nonreassuring fetal status in the setting of these EFM features is also associated with increased risk of acidemia, suggesting clinical validity to the diagnosis of nonreassuring fetal status.
Clark 2017	Baltimore	Case-control study	Singleton, vertex presenting fetuses at 37 weeks of gestation with EFHRM and umbilical artery blood gas measurements	Infants with arterial cord blood metabolic acidemia (base deficit [BD], >12 mM/L)	Nearest patient who was matched for multiparous or nulliparous status who delivered an infant with BD < 8 mM/L	240 patients	Mode of delivery	High risk of bias	Expert, algorithm-assisted FHR interpretation has the potential to improve standard clinical performance by facilitating significantly earlier recognition of some tracings that are associated with metabolic acidemia without increasing the rate of operative intervention. However, this improvement is modest. Of infants who are born with metabolic acidemia, only approximately one-half potentially could be identified and have delivery expedited even under ideal circumstances, which are probably not realistic in current US practice. This represents the limits of electronic FHR monitoring performance. Additional technologies will be necessary if the goal of the prevention of neonatal metabolic acidemia is to be realized.
Althaus 2005	Maryland	Case-control study	Neonates with ultrasound diagnosed cerebral white matter injury	Electronic monitoring	No electronic monitoring	125 cases and 121 controls	Ability to identify preterm infants with cerebral white matter injury	Low risk of bias	Although decreased short-term variability and increased late decelerations are associated with decreasing umbilical arterial pH and base excess, EFM is unable to identify preterm neonates with cerebral white matter injury

Triebwasser 2016	United States	Retrospective study	Singletons delivered in the second stage	Fetal monitoring features in the 30 minutes prior to delivery	-	5,388 patients	Indication for delivery; Association with fetal acidemia	Low risk of bias	The majority of deliveries for NRFS and the features that prompt that diagnosis are not associated with acidemia.
Cahill 2012	Missouri, United States	Retrospective cohort study	Singleton, nonanomalous gestations of 37 weeks or longer	Evaluation of EFM patterns in final 30 minutes prior to delivery using NICHD and non-NICHD measures	No intervention; comparison between acidemic (pH ≤ 7.10) and non-acidemic infants (pH > 7.10)	5,388 gestations	Umbilical cord arterial pH of 7.10 or less	Low risk of bias	Four NICHD-defined EFM features within the 30 minutes prior to birth demonstrated the greatest association with acidemia: repetitive prolonged decelerations (area under the curve [AUC] 0.81), baseline tachycardia (AUC 0.80), repetitive variable decelerations (AUC 0.79), and repetitive late decelerations (0.78) after adjusting for nulliparity, fever, prolonged first stage, and obesity. A non-NICHD measure, total deceleration area, demonstrated superior predictive ability for acidemia (AUC 0.83, P = .04). A non-NICHD measure of deceleration frequency and severity in the second stage performed superior to 4 NICHD EFM features for predicting fetal acidemia.
Spencer 1991	United Kingdom	Retrospective cohort study	Labors requiring fetal blood sampling	Presence of FHR acceleration at time of FBS sampling	No FHR acceleration (includes no change or deceleration)	164 cases (138 with analyzable FHR and outcome data)	Fetal scalp pH, Apgar scores, mode of delivery, umbilical artery pH Secondary: Caesarean delivery, NICU admission	Moderate risk of bias	FHR acceleration predicted normal fetal pH (≥7.20) with a specificity of 95%, NPV 91.9%; however, 6.1% of cases with acceleration still had pH <7.20. Caesarean rate was higher in non-accelerating group (p < 0.01). Apgar and neonatal outcomes did not differ. Thus, whilst an acceleration was reassuring, the absence of an acceleration at the time of fetal blood sampling was not a good predictor of fetal acidemia.

Krebs 1982	Richmond, Virginia, United States	Retrospective observational study	Laboring patients with singleton pregnancies at 34 weeks of gestation or greater	Intrapartum FHR monitoring focused on sporadic accelerations	Comparison between groups with <3 vs ≥3 FHR accelerations per 30 min	1,996 patients	1- and 5-minute Apgar scores, corrected perinatal mortality, fetal pH, mode of delivery; adverse outcomes (e.g., meconium-stained fluid, preeclampsia, emergency cesarean)	Moderate risk of bias	Fetuses with ≥3 accelerations per 30 min had significantly better Apgar scores and lower perinatal mortality. Lack of accelerations was predictive of adverse outcomes. Sensitivity was limited but specificity was high for ≥3 accelerations. Prognostic value was similar for early and late labor phases.

Management of Category I, II, and III Fetal Heart Rate Tracings

Author, year	*Setting*	*Design/ approach*	*Subjects*	*Intervention*	*Comparator*	*Sample size*	*Outcomes*	*Risk of bias*	*Results*
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Murphy 2023	Global	Systematic review and meta-analysis	RCTs that that compared any form of FSS to assess fetal well-being in labor	CTG dFSS or CTG and manual fetal stimulation (abdominal or vaginal scalp stimulation)	CTG FBS or CTG alone	2 RCTs; 377 women	Perinatal death; disability in babies at or after 12 months; cesarean section rate; assisted vaginal birth; spontaneous vaginal birth; evidence of brain injury during birth	High-quality review	There is very low-certainty evidence available which makes it unclear whether stimulating the fetal scalp is a safe and objective way to confirm fetal well-being in labor. Evidence was downgraded based on limitations in study design and imprecision. Further high-quality studies of adequate sample size are required to evaluate this research question. In order to be generalizable, these trials should be conducted in different settings, including broad clinical criteria at both preterm and term gestational ages, and standardizing the method of stimulation. There is an ongoing study (FIRSST) that will be incorporated into this review in a subsequent update.

Xodo 2022	Global	Systematic review and meta-analysis	RCTs of laboring patients with singleton gestations randomized to receive intrapartum acute tocolysis for nonreassuring FHR tracing	Intrapartum acute tocolysis	-	605 patients	Cesarean delivery	High-quality review	The cesarean delivery rate was not reduced by acute tocolysis when used for nonreassuring FHR tracing during labor. Acute tocolysis is associated with improved short-term fetal outcomes and safely increases the time-to-delivery interval.
Raghuraman 2021	Global	Systematic review and meta-analysis	RCTs comparing oxygen with room air at the time of scheduled cesarean delivery or labor in patients with singleton, nonanomalous pregnancies	Maternal oxygen administration (varied methods: nasal cannula, simple face mask, nonrebreather, Venturi)	Room air during cesarean delivery or labor	16 RCTs; 2,052 total participants (cesarean delivery: 1,128; labor: 924)	UA pH, UA PaO2, UA base excess, UA pH <7.2 and <7.1, 1- and 5-min Apgar scores, NICU admission, oxidative stress markers	High-quality review	Overall, oxygen administration was associated with no significant difference in UA pH (weighted mean difference, 0.00; 95% CI, −0.01 to 0.01). Oxygen use was associated with an increase in UA PaO2 (weighted mean difference, 2.57 mm Hg; 95% CI, 0.80-4.34 mm Hg) but no significant difference in UA base excess, UA pH less than 7.2, Apgar scores, or NICU admissions. Umbilical artery pH values remained similar between groups after accounting for the risk of bias, type of oxygen delivery device, and fraction of inspired oxygen. After stratifying by the presence or absence of labor, oxygen administration in women undergoing scheduled cesarean delivery was associated with increased UA PaO2 (weighted mean difference, 2.12 mm Hg; 95% CI, 0.09-4.15 mm Hg) and a reduction in the incidence of UA pH less than 7.2 (relative risk, 0.63; 95% CI, 0.43-0.90), but these changes were not noted among those in labor (PaO2: weighted mean difference, 3.60 mm Hg; 95% CI, −0.30 to 7.49 mm Hg; UA pH<7.2: relative risk, 1.34; 95% CI, 0.58-3.11). Suggests that studies to date showed no association between maternal oxygen and a clinically relevant improvement in UA pH or other neonatal outcomes.

Chooi 2017	Global	Systematic review	RCTs, including full texts and abstracts, comparing interventions to prevent hypotension with placebo or alternative treatment in women having spinal anesthesia for caesarean.	Prophylactic interventions	-	126 studies	Hypotension	High-quality review	While interventions such as crystalloids, colloids, ephedrine, phenylephrine, ondansetron, or lower leg compression can reduce the incidence of hypotension, none have been shown to eliminate the need to treat maternal hypotension in some women. We cannot draw any conclusions regarding rare adverse effects associated with use of the interventions (for example colloids) due to the relatively small numbers of women studied.
Bullens 2015	Netherlands	Systematic review	RCTs and observational/ case reports on intrauterine resuscitation for suspected fetal distress during term labor	Intrauterine resuscitation: tocolysis, maternal repositioning, amnioinfusion, maternal hyperoxygenation, intravenous fluids	Placebo, no intervention, or conventional treatment	15 studies: 2 RCTs on amnioinfusion, 2 RCTs on tocolysis; others are small observational or case reports	FHR patterns, fetal pH, PO_2, Apgar scores, NICU admissions, cesarean rates	Moderate-quality review	Little robust evidence to promote a specific intrauterine resuscitation technique is available. Based on our literature search, we support the use of tocolysis and maternal repositioning for fetal distress. We believe the effect of amnioinfusion and maternal hyperoxygenation should be further investigated in properly designed RCTs to make up the balance between beneficial and potential hazardous effects.
East 2013	Global	Systematic review and meta-analysis	RCTs of women with singleton pregnancies in labor with nonreassuring FHR tracings	VAS for fetal assessment	Mock or no stimulation	0 (no eligible RCTs included)	Cesarean section, operative vaginal birth, neonatal hypoxic ischemic encephalopathy, seizures, long-term infant disability, FHR responses, NICU admission	High-quality review	There are currently no RCTs that address the safety and efficacy of VAS used to assess fetal well-being in labor in the presence of a nonreassuring CTG trace. Although VAS has been proposed as a simple, non-invasive tool for assessment of fetal well-being, there is insufficient evidence from RCTs on which to base recommendations for use of VAS in the evaluation of fetal well-being in labor in the presence of a nonreassuring CTG trace.

Hofmeyr 2012	Global	Systematic review	RCTs of amnioinfusion compared with no amnioinfusion in women with babies at risk of umbilical cord compression in labor	Transcervical or transabdominal amnioinfusion with saline or Ringer's lactate during labor	No amnioinfusion (routine care or placebo)	19 studies; total ~3,000 women	Caesarean section rate, Apgar scores, FHR decelerations, NICU admission, maternal infection, length of stay, perinatal death, cord pH, meconium aspiration, birth asphyxia	High-quality review	The use of amnioinfusion for potential or suspected umbilical cord compression may be of considerable benefit to mother and baby by reducing the occurrence of variable FHR decelerations, improving short-term measures of neonatal outcome, reducing maternal postpartum endometritis and lowering the use of caesarean section, although there were methodological limitations to the trials reviewed here. In addition, the trials are too small to address the possibility of rare but serious maternal adverse effects of amnioinfusion. More research is needed to confirm the findings, assess longer-term measures of fetal outcome, and to assess the impact on caesarean section rates when the diagnosis of fetal distress is more stringent. Trials should assess amnioinfusion in specific clinical situations, such as FHR decelerations, oligohydramnios or prelabor rupture of membranes.
Simpson 2005	United States	Randomized controlled trial	Healthy nulliparous women undergoing elective oxytocin-induced labor, term singleton, vertex, with reassuring FHR	1) IV fluid bolus (500 mL vs 1000 mL), 2) maternal position changes (supine vs left vs right lateral), 3) maternal oxygen (O2) via nonrebreather mask at 10 L/min for 15 min	Baseline measures before intervention (FSpO2 and FHR characteristics)	56 women; 42 (IV fluid); 51 (positioning); 49 (O2 administration); some subjects participated in multiple arms	Differences in FSpO2 were evaluated before, during, and after each intervention	Serious risk of bias	An intravenous fluid bolus of 1,000 mL, lateral positioning, and O2 administration at 10 L/min via nonrebreather face mask are effective in increasing FSpO2 during labor.
Dellinger 2000	United States	Randomized controlled trial	All labors of women with singleton pregnancies ≥ 32 weeks of gestation electronically monitored at 2 institutions were examined	Fetal heartrate tracings	-	898 patients	Tracings	Moderate risk of bias	This simple classification system for interpreting FHR tracings accurately predicts normal outcomes for fetuses as well discriminating fetuses in true distress. Further, it identifies an intermediate group of fetuses with a condition labeled fetal stress who might benefit from additional evaluation and possibly from expeditious delivery.

Carbonne 1996	United States	Randomized controlled trial	Laboring women	Pulse oximetry	-	15 women	Fetal oxygen saturation	High risk of bias	Maternal supine position during labor is associated with a lower fetal oxygen saturation than the left lateral position.
Reddy 2021	United States	Secondary observational analysis of RCT	Laboring participants with singleton pregnancies >36 weeks	Intrapartum interventions for category II FHR: oxygen (75.4%), IV fluid bolus (29.3%), amnioinfusion (10.7%), tocolytic (2%)	No control group; comparisons between those who improved to Category I within 60 minutes and those who did not	2,251 patients	Improvement in FHR to Category I within 60 minutes	Serious risk of bias	Nearly two thirds of category II FHR tracings improved to category I within 60 minutes of intervention with a relatively low overall rate of the composite neonatal adverse outcome.
Simpson 2008	United States	Retrospective study	Pregnant women	oxytocin-induced hyperstimulation	-	56 women	Fetal oxygen saturation	Moderate risk of bias	Hyperstimulation is associated with negative effects on fetal status. The more contractions in 30 minutes, the more pronounced the effect.
Tejani 1975	United States	Retrospective observational study	Laboring patients undergoing fetal scalp blood sampling	CTG patterns with periodic changes (acceleration, early, variable, delayed decelerations); total surface area (TSA) method used to quantify pattern severity	No periodic changes or normal FHR pattern (TSA=0)	460 fetal scalp blood pH determination obtained from 216 patients	Correlation of periodic CTG changes (qualitative and TSA) with fetal scalp pH; Predictive value of baseline FHR, bradycardia, and tachycardia	Serious risk of bias	It is concluded that FHR-UC monitoring can be used to screen the innocuous from the ominous periodic change but that fetal scalp blood pH must be obtained to identify accurately the true from the false-positive ominous pattern.
Abitbol 1985	United States	Observational study	Women in early or active labor with term vertex pregnancies	Supine position during labor and continuous monitoring	Lateral position	902 women	Late FHR decelerations; fetal scalp blood pH; lower limb pulse pressure (big toe); uterine contractions; capillary pulse; systolic/diastolic pressure in femoral/popliteal arteries; mode of delivery; acid-base status	Moderate risk of bias	126 of 902 (14%) demonstrated abnormal FHR patterns; 24 (19% of those) had late decelerations only in the supine position. These decelerations were associated with reduced lower limb pulse pressure and fetal scalp acidosis, which reversed upon lateral repositioning. In 24 cases, pH improved significantly after lateral tilt. Supine aortic compression was identified as the likely cause. No upper limb pressure change was noted, ruling out systemic hypotension.

Krebs 1982	Richmond, Virginia, United States	Retrospective observational study	Laboring patients with singleton pregnancies at 34 weeks of gestation or greater	Intrapartum FHR monitoring focused on sporadic accelerations	Comparison between groups with <3 vs ≥3 FHR accelerations per 30 min	1,996 patients	1- and 5-minute Apgar scores, corrected perinatal mortality, fetal pH, mode of delivery; adverse outcomes (e.g., meconium-stained fluid, preeclampsia, emergency cesarean)	Moderate risk of bias	Fetuses with ≥3 accelerations per 30 min had significantly better Apgar scores and lower perinatal mortality. Lack of accelerations was predictive of adverse outcomes. Sensitivity was limited but specificity was high for ≥3 accelerations. Prognostic value was similar for early and late labor phases.

Adjunct Modalities for Interpretation of Fetal Heart Rate Monitoring

Author, year	*Setting*	*Design/ approach*	*Subjects*	*Intervention*	*Comparator*	*Sample size*	*Outcomes*	*Risk of bias*	*Results*
Mitchell 2025	Global	Systematic review and meta-analysis	Studies involving women in labor with a cephalic baby	1) Low FSPO2 (<30%); 2) The use of fetal pulse oximetry during labor	1) FSPO2 >30%; 2) Traditional fetal monitoring (FHR via CTG, FBS, or ECG)	47 studies, 13,071 women	Umbilical artery pH <7.15, Apgar score <7 at 5 min, NICU admission, CS for non-reassuring FHR, dystocia, base excess, UA lactate, neonatal death, HIE, CP, long-term neurodevelopment	High-quality review	FSpo2 <30% was associated with umbilical artery pH <7.15 (odds ratio [OR] 7.86, 95% confidence interval [CI] 3.29–18.75, I^2= 71%, P< 0.001), 5-min Apgar score less than 7 (OR 16.63, 95% CI 5.64–49.01, I2= 30%, P< 0.001) and NICU admission (OR 5.89, 95% CI 1.73–20.01, I^2= 0%, P< 0.005). FSpo2 monitoring combined with FHR monitoring was associated with lower odds of cesarean section for non-reassuring fetal status (OR 0.59, 95% CI 0.40–0.86, I^2= 71%, P= 0.006) without impacting 5-min Apgar scores <7 (OR 0.66, 95% CI 0.37–1.17, I^2= 0%, P= 0.160) or NICU admissions (OR 0.98, 95% CI 0.82–1.18, I^2= 0%, P= 0.840). Subgroup analysis that excluded two studies because of a lack of protocol to manage the timing of delivery for an abnormal fetal oxygen saturation and comparing fetal pulse oximetry with FHR and fetal ECG monitoring, rather than fetal pulse oximetry with FHR monitoring against FHR monitoring alone with or without the use of fetal blood sampling), found a reduction in cesarean delivery (OR 0.61, 95% CI, 0.39–0.96) associated with fetal oxygen saturation monitoring among the other studies.

Balayla 2019	Canada	Systematic review and meta-analysis	Published RCTs comparing AI-assisted with visual (human) interpretation of EFM during labor; Observational studies that reported on the degree of inter-rater reliability, irrespective of neonatal outcomes	AI-assisted EFM interpretation	Clinical (visual) interpretation of EFM	3 RCTs, 6 cohort studies (55,064 patients)	Neonatal outcomes and inter-rater reliability	Critically low-quality review	Relative to the use of clinical (visual) evaluation of the FHR, the use of AI did not change the incidence rates of neonatal acidosis, cord pH below<7.20, 5-min APGAR scores<7, mode of delivery, NICU admission, neonatal seizures, or perinatal death. With regards to the degrees of inter-rater reliability, a weighed mean Cohen's Kappa of 0.49 [0.32–0.66] indicates moderate agreement between expert observers and computerized systems. The use of AI and computer analysis for the interpretation of EFM during labor does not improve neonatal outcomes. Inter-rater reliability between experts and computer systems is moderate at best. Future studies should aim at further elucidating these findings.
Saccone 2016	Global	Systematic review and meta-analysis	RCTs comparing intrapartum fetal monitoring with cardiotocography plus ST analysis with cardiotocography alone in laboring singletons with cephalic presentation at term	Cardiotocography plus ST analysis	Cardiotocography alone	6 RCTs; 26,529 individuals	Composite of intrapartum fetal death, neonatal death, Apgar score 3 or less at 5 minutes, neonatal seizure, metabolic acidosis, intubation for ventilation at delivery, or neonatal encephalopathy	Moderate-quality review	The use of ST analysis during labor as an adjunct to the standard cardiotocography does not improve perinatal outcomes or decrease cesarean delivery.

Neilson 2015	Global	Systematic review	RCTs comparing fetal ECG waveform analysis with alternative methods of fetal monitoring during labor	Fetal ECG (ST waveform or PR interval) + CTG	CTG alone	7 RCTs; 27,403 women (ST analysis: 26,446; PR analysis: 957)	Caesarean section, cord pH <7.05 + base deficit >12 mmol/L, neonatal encephalopathy, fetal blood sampling, operative vaginal delivery, Apgar <7 at 5 min, neonatal intubation, admission to special care, perinatal death	High-quality review	The modest benefits of fewer fetal scalp samplings during labor (in settings in which this procedure is performed) and fewer instrumental vaginal births have to be considered against the disadvantages of needing to use an internal scalp electrode, after membrane rupture, for ECG waveform recordings. We found little strong evidence that ST waveform analysis had an effect on the primary outcome measures in this systematic review. There was a lack of evidence showing that PR interval analysis improved any outcomes; and a larger future trial may possibly demonstrate beneficial effects. There is little information about the value of fetal ECG waveform monitoring in preterm fetuses in labor. Information about long-term development of the babies included in the trials would be valuable.
East 2014	Global	Systematic review	All published and unpublished RCTs that compared maternal and fetal outcomes when fetal pulse oximetry was used in labor, (i) with or without concurrent use of conventional fetal surveillance	Fetal intrapartum pulse oximetry	CTG alone	7 trials with 8013 pregnancies	Cesarean rate	Moderate-quality review	The addition of fetal pulse oximetry does not reduce overall caesarean section rates. One study found a higher caesarean section rate in the group monitored with fetal pulse oximetry plus CTG, compared with fetal ECG plus CTG. The data provide limited support for the use of fetal pulse oximetry when used in the presence of a nonreassuring CTG, to reduce caesarean section for nonreassuring fetal status. A better method than pulse oximetry is required to enhance the overall evaluation of fetal well-being in labor.

Neilson2003	Global	Systematic review	Pregnant women in labor needing continuous FHR monitoring	Fetal ECG analysis + CTG (either ST waveform or PR interval analysis)	CTG alone	3 RCTs; 8,357 women	Perinatal death, neonatal encephalopathy, Apgar <7 at 5 min, metabolic acidosis (cord pH <7.05 + base deficit >12 mmol/L), neonatal intubation, NICU admission, cesarean and operative vaginal delivery, fetal blood sampling	Moderate-quality review	The use of ST waveform analysis was associated with fewer babies with severe metabolic acidosis at birth (cord pH less than 7.05 and base deficit greater than 12 mmol/L) (relative risk (RR) 0.44, 95% confidence interval (CI) 0.26 to 0.75, data from 6672 babies). This was achieved along with fewer fetal scalp samples during labor (RR 0.86, 95% CI 0.76 to 0.98) and fewer operative deliveries (RR 0.89, 95% CI 0.82 to 0.97). Apart from a trend (that did not achieve statistical significance) towards fewer operative deliveries (RR 0.87, 95% CI 0.76 to 1.01), there was little evidence that monitoring by PR interval analysis conveyed any benefit. This may reflect limitations of the technique or, alternatively, the smaller numbers available for analysis from the single trial (957 women). These findings support the use of fetal ST waveform analysis when a decision has been made to undertake continuous electronic FHR monitoring during labor. However, in most labors, technically satisfactory cardiotocographic traces can be obtained by external Fetal electrocardiogram (ECG) for fetal monitoring during labor (Review) ultrasound monitors which are less invasive than internal scalp electrodes (which are required for electrocardiographic (ECG) analysis). A better approach might be to restrict fetal ST waveform analysis to those fetuses demonstrating disquieting features on cardiotocography.

INFANT Collaborative Group 2017	United Kingdom and Ireland	Randomized controlled trial	Women in labor age 16 years or older having continuous EFM at 35 weeks of gestation or greater	Decision support software (INFANT system)	No decision support	47,062 women	Composite of poor neonatal outcome (stillbirth, early neonatal death, encephalopathy, prolonged neonatal admission); developmental assessment at 2 years.	Low risk of bias	We noted no difference in the incidence of poor neonatal outcome between the groups—172 (0·7%) babies in the decision-support group compared with 171 (0·7%) babies in the no-decision-support group (adjusted risk ratio 1·01, 95% CI 0·82–1·25). At 2 years, no significant differences were noted in terms of developmental assessment. Use of computerized interpretation of cardiotocographs in women who have continuous EFM in labor does not improve clinical outcomes for mothers or babies.
Belfort 2015	United States	Randomized controlled trial	Women with singleton pregnancies > 36 weeks of gestation attempting vaginal delivery with cervical dilation of 2-7 cm	Open fetal ECG ST-segment analysis with EFM	Masked fetal ECG monitor (conventional fetal heart-rate monitoring)	11,108 women (5,532 open group, 5,576 masked group)	Composite of intrapartum fetal death, neonatal death, 5-min Apgar ≤3, neonatal seizure, umbilical artery pH ≤7.05 with base deficit ≥12, intubation, or neonatal encephalopathy. Secondary: cesarean/operative delivery rates, maternal/neonatal complications	Moderate risk of bias	Fetal ECG ST-segment analysis used as an adjunct to conventional intrapartum electronic fetal heart-rate monitoring did not improve perinatal outcomes or decrease operative-delivery rates.

Bloom 2006	United States	Randomized controlled trial	Nulliparous women at term and in early labor	Open fetal pulse oximetry	Masked fetal pulse oximetry	5341 women	Cesarean delivery	Low risk of bias	There was no significant difference in the overall rates of cesarean delivery between the open and masked groups (26.3% and 27.5%, respectively; P = 0.31). The rates of cesarean delivery associated with the separate indications of a nonreassuring FHR (7.1% and 7.9%, respectively; P = 0.30) and dystocia (18.6% and 19.2%, respectively; P = 0.59) were similar between the two groups. Similar findings were observed in the subgroup of 2168 women in whom a nonreassuring FHR was detected before randomization. The condition of the infants at birth did not differ significantly between the two groups.
Amer-Wåhlin 2001	Sweden	Randomized controlled trial	Women in labor with term, singleton, cephalic fetuses	Cardiotocography (CTG) with automatic ST-waveform analysis (STAN S21 monitor)	Cardiotocography alone (CTG)	4,966 women	Primary: Umbilical-artery metabolic acidosis (pH < 7.05, base deficit >12 mmol/L). Secondary: Operative delivery for fetal distress, Apgar scores, NICU admission, neonatal encephalopathy, perinatal death.	Moderate risk of bias	The CTG+ST group showed significantly lower rates of umbilical-artery metabolic acidosis than the cardiotocography group (15 of 2159 [0·7%] vs 31 of 2079 [2%], relative risk 0·47 [95% CI 0·25–0·86], p=0·02) and of operative delivery for fetal distress (193 of 2519 [8%] vs 227 of 2447 [9%], 0.83 [0.69–0.99], p=0.047) when all cases were included according to intention to treat. The differences were more pronounced after exclusion of 291 in the CTG+ST group and 283 in the CTG group with malformations or inadequate recording. Intrapartum monitoring with cardiotocography combined with automatic ST-waveform analysis increases the ability of obstetricians to identify fetal hypoxia and to intervene more appropriately, resulting in an improved perinatal outcome.

Garite 2000	United States	Randomized controlled trial	Patients with term singleton pregnancies in active labor with cephalic presentation and cervical dilation to at least 2 cm and at the -2 station	Continuous fetal pulse oximetry (Nellcor FS14 sensor) in addition to electronic FHR monitoring	Electronic FHR monitoring alone	1,010 patients	Cesarean delivery due to nonreassuring fetal status	Moderate risk of bias	The study confirmed its primary hypothesis of a safe reduction in cesarean deliveries performed because of nonreassuring fetal status. However, the addition of fetal pulse oximetry did not result in an overall reduction in cesarean deliveries. The increase in cesarean deliveries because of dystocia in the study group did appear to result from a well-documented arrest of labor. Fetal pulse oximetry improved the obstetrician's ability to more appropriately intervene by cesarean or operative vaginal delivery for fetuses who were actually depressed and acidotic. The unexpected increase in operative delivery for dystocia in the study group is of concern and remains to be explained.
Bloom 1999	United States	Randomized controlled trail	Consenting gravidas with uncomplicated pregnancies at or beyond 36 weeks of gestation	Women with fetuses with at least one epoch of arterial oxyhemoglobin saturation below 30%	Women with fetuses without such an episode	129 fetuses	Fetal compromise	Moderate risk of bias	Transient fetal arterial oxyhemoglobin saturation values below 30% are common during normal labor and did not predict fetal compromise. Fetal arterial oxyhemoglobin saturation values less than 30% for 2 minutes or longer might be associated with fetal compromise.
Westgate 1993	England	Randomized controlled trial	Women with high-risk labor (>34 weeks of gestation, singleton gestations)	ST waveform plus cardiotocogram monitoring	Cardiotocogram only	2,400 women	Operative delivery for fetal distress, fetal blood sampling frequency, Apgar scores at 1 and 5 min, cord artery pH, base deficit, birth asphyxia, special care admission	Moderate risk of bias	Statistical trend (p=0.09) indicating a reduction in metabolic acidemia, along with a 46% reduction in operative deliveries (p=0.001) in the ST waveform plus cardiotocogram group.

Grant 1989	Ireland	Randomized controlled trial	Liveborn children (at 4 years old) who participated in the Dublin Randomised Trial of Intrapartum Monitoring	Electronic FHR monitoring, with scalp blood sampling when indicated	Intermittent auscultation without EFM	13,079 children	Cerebral palsy diagnosis at age 4	Moderate risk of bias	Compared with intermittent intrapartum monitoring, intensive monitoring has little, if any, protective effect against cerebral palsy.
MacDonald 1985	Ireland	Randomized controlled trial	Women in labor	Electronic FHR monitoring, with scalp blood sampling when indicated	Intermittent auscultation without EFM	12,964 women	Stillbirths and neonatal deaths; neonatal seizures; Apgar scores; mode of delivery; acid-base status of fetal blood; rates of cesarean and forceps deliveries; neonatal trauma; infections; maternal and neonatal outcomes	Moderate risk of bias	No significant difference in perinatal mortality (9 vs. 8 per 1000). Seizure rate was lower in the electronic monitoring group (0.5 vs. 1.1/1000, $p < 0.05$). Higher rates of operative deliveries (e.g., cesareans) in the electronic monitoring group. No major long-term outcome differences observed.
Porreco 2004	United States	Observational study	Nulliparous women in labor whose progress was monitored with fetal pulse oximetry	Fetal heartrate patterns	-	274 patients	Shoulder dystocia	Low risk of bias	Significantly nonreassuring FHR patterns predict cesarean delivery for dystocia among nulliparous patients with normally oxygenated fetuses in a setting of a standardized labor management protocol. This confirms the observations in the randomized controlled trial of fetal pulse oximetry in the United States and may provide insight into the treatment of nonprogressive labor in contemporary practice.
Seelbach-Gobel 1999	Germany	Multicenter study	Deliveries monitored by fetal pulse oximetry	Fetal pulse oximetry	-	400 deliveries	Fetal compromise	Low risk of bias	An arterial oxygen saturation of 30% was confirmed as the critical boundary for fetal compromise during labor. The development of acidosis seems to be predictable by the duration of hypoxemia, as indicated by fetal arterial oxygen saturation ≤30%.

McCoy 2025	United States	Retrospective cohort study	Patients with EFM and umbilical cord gas data	Deep learning analysis of EFM data to predict fetal acidemia	Standard clinical interpretation of EFM (historical benchmark, not concurrent control)	10,182 patients	Fetal acidemia (umbilical artery pH <7.20, <7.15, <7.10, <7.05); base excess	Moderate risk of bias	The application of deep learning methods to intrapartum EFM analysis achieves promising performance in predicting fetal acidemia. This technology could help improve the accuracy and consistency of EFM interpretation.
Gorenberg 2003	-	Secondary analysis	-	Fetal oxygen saturation data	-	1 RCT	Low fetal oxygen episodes	Moderate risk of bias	This study confirms previous findings that fetal oxygen saturation of <30% is associated with declining fetal arterial pH. There appears to be an association between adverse neonatal outcomes and >10 epochs of <30%.
Dildy 1996	-	Secondary analysis	-	Fetal oxygen saturation	-	-	Oxygen saturation	Low risk of bias	FHR monitoring is sensitive but nonspecific for detecting fetal compromise. Additional clinical information is needed to discern those fetuses not at risk for development of intrapartum acidosis to avoid unnecessary intervention. Fetal oxygen saturation monitoring is a new technique currently under development.
Johnson 1989	England	Case report	1 subject: 29-year-old primigravida at term	Continuous fetal oxygen monitoring via pulse oximeter	-	1 woman	Oxygen saturation, FHR, labor progression, fetal pH, presence of meconium, and neonatal status.	N/A	Fetal oxygen saturation dropped to 20% during labor, preceding deceleration in FHR. Recovery occurred after position change. Cesarean was performed. No lasting harm.

Abbreviations: *CTG*, cardiocartography; *dFSS*, digital fetal scalp stimulation; *ECG*, electrocardiogram; *EFHRM*, electronic fetal heart rate monitoring; EFM, electronic fetal monitoring; *FBS*, fetal blood sampling; *FHR*, fetal heart rate; *FSPaO2*, fetal oxygen saturation; *FSS*, fetal scalp stimulation; *NICU*, neonatal intensive care unit; *NRFS*, non-reassuring fetal status; *PaO2*, partial pressure of oxygen in arterial blood; *RCT*, randomized controlled trial; *STAN*, ST-waveform analysis; *TSA*, total surface area; *UA*, umbilical artery; *VAS*, vibroacoustic stimulation