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Online version at http://www.minervamedica.it

Minerva Obstetrics and Gynecology 2021 mese;73(0):000–000
DOI: 10.23736/S0026-4784.20.04690-0

REVIEW

LABOR AND DELIVERY

STAN: a reappraisal of its clinical usefulness

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ABSTRACT

The automatic analysis of fetal ECG in labor has been introduced as an adjunct of traditional cardiotocography with the aim to improve the identification of fetuses with intrapartum hypoxia. Several randomized controlled trials and meta-analyses have produced conflicting results, with the most recent randomized controlled trial not demonstrating any improvement in either neonatal outcomes or reduction in operative birth rates. The objective of this review article is to present the state of art about the use of STAN technology in labor ward.

(*Cite this article as:* Cagninelli G, Dall'Asta A, Di Pasquo E, Morganelli G, Degennaro VA, Fieni S, *et al.* STAN: a reappraisal of its clinical usefulness. Minerva Obstet Gynecol 2021;73:000-000. DOI: 10.23736/S0026-4784.20.04690-0)

KEY WORDS: Fetal monitoring; Cardiotocography; Review.

Intrapartum fetal heart rate monitoring by means of cardiotocography (CTG) has the aim of identifying fetal hypoxia occurring during labor and preventing the occurrence of adverse perinatal outcomes.[1]

Several classifications of the CTG trace have been proposed by the main scientific societies.[2-6]

Following its introduction traditional cardiotocography has been shown to yield a good sensitivity but a very low positive predictive value in detecting intrapartum fetal acidemia. Overall, the routine use of this technique for intrapartum fetal surveillance in the general population compared with intermittent auscultation has been demonstrated to increase the number of operative deliveries bot not to decrease the occurrence of cerebral palsy or adverse perinatal outcomes. The interpretation of the CTG trace both in the 1st stage or the 2nd stage of labor is acknowledged to be associated with a low intra- and interobserver agreement whatever classification system is used.[7, 8] Another limitation of the CTG trace is represented by the poor quality of the FHR signal which is recorded through the external transducer under those circumstances which may affect the transmission of the ultrasound Doppler signal through the maternal abdomen. These include maternal obesity or active pushing during the second stage of labor.[3, 9, 10]

Assessment of fetal wellbeing in labor using ST-segment waveform analysis from the fetal electrocardiogram has been proposed in 2000 as an adjunct to conventional FHR monitoring with the scope of improving the ability to recognize the cases of true fetal acidemia and to decrease the number of unnecessary operative deliveries. Early animal studies conducted before this technology was introduced in clinical practice observed that changes in the ST-segment of the fetal ECG indicated fetal hypoxia occurring during labor.[11, 12]

Since then, several studies have been conducted to verify whether the use of STAN yielded a measurable benefit in labor and perinatal outcomes.

Randomized controlled trials and meta-analyses have produced conflicting results, with the most recent randomized controlled trial not demonstrating any improvement in either neonatal outcomes or reduction in operative birth rates. A recent observational study[13] showed that the implementation of intrapartum ST-segment waveform resulted in a substantial reduction in rates of umbilical artery metabolic acidosis as well as a significant reduction in operative birth rates, and incidence of neonatal encephalopathy. The objective of this review article is to discuss the evidence and present the state of art about the use of STAN technology in labor ward.

Pathophysiology

Fetal electrocardiography (ECG) is the graphic record of the electrical activity of the myocardial cells and STAN analyses the changes in the fetal ECG complex. More specifically, the ST segment is the graphic expression of the isoelectric phase of the myocardial cells which occurs just after the myocardial contraction (depolarization) and prior to the myocardial relaxation (repolarization), while the T wave represents the ventricular repolarization that allows the myocardial fibers to contract again following the impulse generated by the sinus node.[14] The repolarization process is energy consuming; in conditions of normal oxygen supply there is a positive energy balance in the myocardial cells, while during hypoxia the energy balance becomes negative, and the cells are required to shift to an anaerobic metabolism in order to produce energy.[15]

In response to an ongoing hypoxic stress, the fetus primarily attempts to protect the central organs as myocardium, brain and adrenal glands by reducing fetal movements and by abolishing FHR accelerations to decrease the myocardial workload. If these responses are insufficient to maintain oxygenation of central organs, a massive release of catecholamines (adrenaline and noradrenaline) allows to obtain more oxygenated blood from the placental bed by increasing the fetal heart rate and to divert oxygen to the central organs by peripheral vasoconstriction. Furthermore, the "catecholamines surge" and the consequent activation of beta-adrenoreceptors mediate for the breakdown of the glycogen to glucose (glycogenolysis).[16] This process is finalized to increase the availability of the main metabolic substrate at heart level and to use this to produce the energy which is required to maintain the function of the "sodium-potassium pump" and to preserve myocardial integrity.

During intrapartum hypoxia, not only lactic acid but also the potassium ions, which are stored within the glycogen molecule, are released within the myocardial cells leading to myocardial hyperkalemia.[17] An increased concentration of potassium ions in the myocardial cells will produce "tall" or "tented" T waves at the ECG recording. If the height of the T wave becomes significantly higher than the baseline T wave recorded under condition of normal oxygen supply the ST analyzer would generate a "ST event." Depending on the duration of intrapartum hypoxia, this could be either an "episodic" T/QRS event (if hypoxia lasts less than 10 minutes) or a "baseline" T QRS Event (if hypoxia lasts more than 10 minutes)[15] (Table I).[18]

As mentioned before, ST Segment reflects the "refractory period" after the myocardial contraction (depolarization) and prior to myocardial relaxation (repolarization); thus, under normal conditions cell membrane should not allow transfer of ions and the ST segment will have a stable baseline (iso-electric). If there is a primary or secondary dysfunction of the myocardial cell a leakage of anions and cations across the membrane occurs and the ST segment of the ECG complexes would no longer be stable shifting

TABLE I.—*ST events and cut off value that define an ST change as significant, indicating obstetric intervention.*[18]

Events	Intermediary CTG	Abnormal CTG
Episodic T/QRS rise (duration <10 minutes)	Increase >0.15 from baseline	Increase >0.10 from baseline
Baseline T/QRS rise (duration >10 minutes)	Increase >0.10 from baseline	Increase >0.05 from baseline
Biphasic ST	3 episodes of biphasic ST grade 2 or 3.	>1 episode of biphasic ST grade 2 or 3.

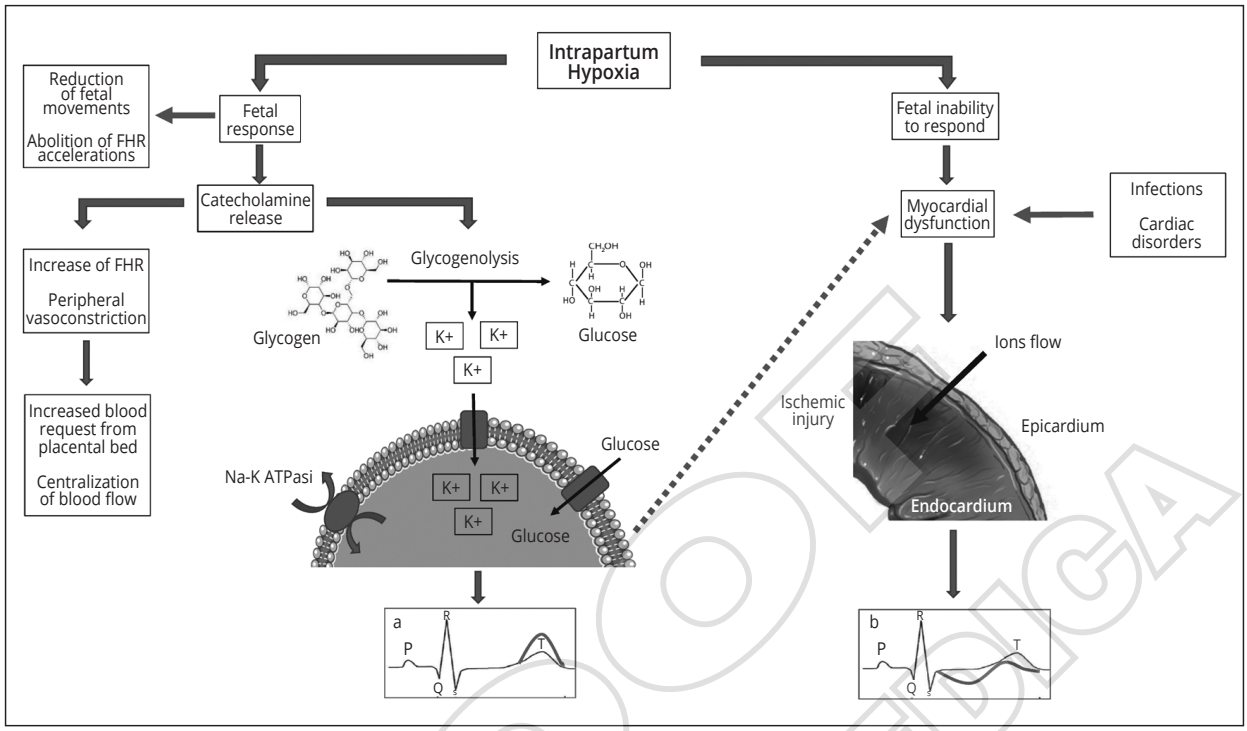

Figure 1.—The effects of intrapartum hypoxia on fetal heart and their correlation with ECG changes.
a: increased concentration of K+ in the myocardial cells produces "tall" or "tented" T waves at the fetal ECG; b: endocardium is affected by the ischemic injury more deeply and sooner compared with the external part (epicardium).

upwards or downwards and leading to "biphasic ST Events" (Figure 1).

As during intrapartum hypoxia, the internal part of the heart (endocardium) is more deeply and sooner affected by the ischemic injury compared with the external part (epicardium), the ions flow is directed out to in resulting in the downward leaning of the ST segment; depending on the type of ST depression biphasic grade 1, 2 and 3 ST events may also be produced on the ECG[15, 19] (Figure 2).

In conclusion, while the amplitude of the T wave reflects the degree of metabolic acidosis, a biphasic ST event may be observed in case of inability of the fetal myocardium to respond to acute hypoxic stress whereby it has had no time to respond to hypoxia shifting to anaerobic metabolism or when the fetal heart has a reduced capacity to respond, due to chronic stress situations and lack for already used resources.

Biphasic ST-changes of the fetal ECG have also been associated with infections, or cardiac disorders like malformations, or hypertrophic cardiomyopathy which may occur in fetuses of diabetic mothers.[1, 15, 20, 21]

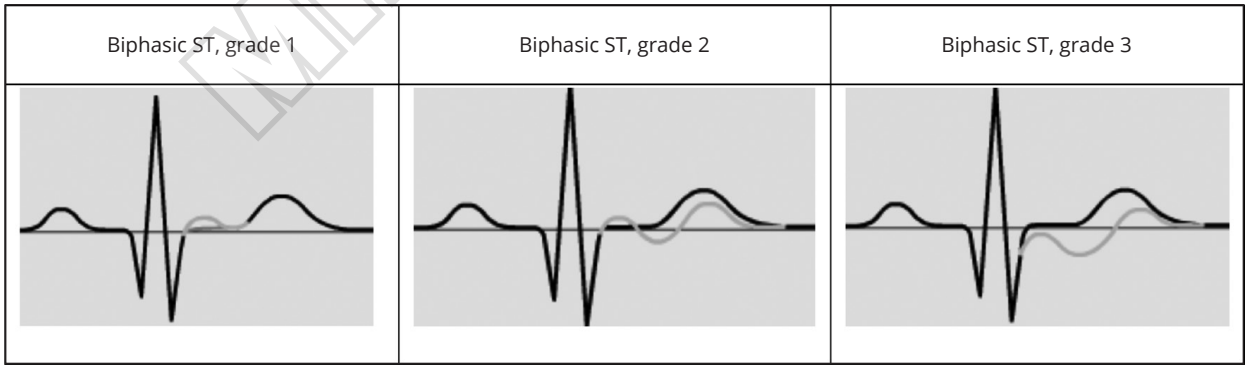

Figure 2.—Types of biphasic ST. Biphasic ST grade 2 or grade 3 are defined as significant.

How to perform and interpret the ST-analysis

Electrical signals from the fetal heart are captured through the placement of a scalp electrode that allows the simultaneous recording of the conventional CTG monitoring and the analysis of the fetal ECG parameters and that is connected to a skin electrode on the maternal thigh.

As soon as it is applied, ST-analyzer calculates the initial reference baseline T/QRS ratio. From this moment, the machine analyses every 30 ECG complexes (*i.e.* if baseline fetal heart rate (FHR) is 150 bpm, there would be five analyses in 1 minute) and compares them with the original baseline T/QRS ratio. Each of them is recorded on the ST analyzer monitor as a cross (X). Continuous data are needed to obtain reliable ST information. Gaps in the T/QRS ratios for more than 4 minutes may result in missed ST events.

Good signal quality is required to make an accurate assessment of the fetal conditions and poor signal quality warrants appropriate measures.[18, 22]

It is important to ensure a good contact between the fetal scalp and the fetal electrode and, for this reason, the internal probe is usually applied during the first stage of labor as soon as this is permitted by cervical dilatation.

The ST analysis is targeted to detect the hypoxia of the central organs (heart and brain) and its use should be restricted to monitor an apparently healthy term fetus.

Before starting ST analysis, it is an essential prerequisite to document on the standard CTG trace that the fetus has no evidence of preexisting hypoxic or non-hypoxic injury. In presence of a loss of variability or cycling, or of unstable or abnormal heart rate baseline (including cases when the baseline even in in the normal range is not appropriate for the given gestational age) or prolonged decelerations or more in general in case of a pathological CTG trace according to the FIGO or other guidelines the fetus may have suffered a critical damage or exhausted the reserves to respond to an ongoing hypoxic stress; hence, it is unlikely that STAN machine may show further changes at fetal ECG.[15, 18, 22]

Other limitations to the use of this technology in labor ward include prematurity, growth restriction, maternal diabetes or fetal infections.

The premature or growth restricted fetus due to the lower myocardial reserves of glycogen and due to the lack of enzymes which are necessary to utilize it is not a good candidate for the ST analysis during labor. For opposite reasons the use of STAN is not suitable to fetuses of diabetic mothers who may present a hypertrophic cardiomyopathy due to increased glycogen reserves and this may alter the ions flow across the cardiac wall. Finally, in cases of suspected fetal infections or chorioamnionitis the use of STAN does not seem appropriate as the ST analysis is not devised to highlight signs of inflammatory injury but rather of hypoxia of the central organs.

Contraindications to STAN monitoring include those clinical circumstances where the application of a fetal scalp electrode is not advisable such as maternal infectious diseases (*e.g.* HIV, HBV, HCV, HSV in active phase), or suspected fetal coagulative disorders.[18]

The STAN guidelines are based on the combined interpretation of the CTG pattern and the ST changes;[18] the preliminary classification of the actual CTG trace is essential whenever a ST event is highlighted on the STAN monitor. Such principles for the interpretation of the FHR in combination with ST Analysis have been adapted from the International Federation of Gynecology and Obstetrics (FIGO) guidelines that classify the CTG into 4 FHR patterns: "normal," "intermediary" (or "suspicious"), "abnormal" (or "pathological"), and "(pre)terminal."[3]

Once the CTG trace has been classified, the type or magnitude of the recorded events (T/QRS rise >0.05, 0.10 or 0.15 or grade 2 and 3 biphasic events) has to be considered.

A normal CTG is highly predictive of the absence of fetal metabolic acidosis and therefore, according to the STAN clinical guidelines, an ST-event in presence of a normal CTG does not lead to any intervention (except continuous monitoring).[22]

A recent study has confirmed that the occurrence of certain ST events among fetuses with normal CTG is not associated to neonatal acidemia but may herald abnormalities of the electrolyte's levels.

In particular the cord blood sodium levels were negatively associated with T/QRS ratio magnitude.[23] On contrary, the occurrence of a ST-event in the presence of an intermediary or abnormal CTG requires intervention in relation to the type and magnitude of the ST changes.[24]

Appropriate intervention should also take into account the clinical picture (meconium-stained amniotic fluid, intrapartum bleeding, intrauterine growth-restriction, suspected chorioamnionitis) and may include intrauterine resuscitation maneuvers or immediate delivery (within 20 min) if there is evidence of acute fetal compromise. During second stage with active pushing, intervention means that immediate operative delivery is recommended unless spontaneous delivery is anticipated within the next five to 10 minutes.

Finally, a (pre)terminal CTG represents an indication for immediate delivery irrespective of ST events.[18, 22]

Comparison of the perinatal outcomes in women submitted to CTG monitoring *vs.* CTG+STAN

Randomized controlled trials

Since 1993, six RCTs comparing conventional CTG monitoring and CTG associated with the ST analysis of the fetal ECG have been performed with the aim to compare the accuracy in predicting an adverse labor outcome (Table II).[25-31]

The first RCT by Westgate *et al*. (Plymouth Trial)[25] included 2434 high-risk pregnancies based on a history of preeclampsia, antepartum hemorrhage, growth restriction, diabetes, previous cesarean delivery, abnormal antenatal or early labor external cardiotocography, induced or augmented labor, presence of meconium, epidural analgesia or breech presentation with a gestational age >34 weeks. The primary outcome was the rate of operative delivery for fetal distress. Secondary outcomes included fetal blood sampling pH, metabolic acidosis, Apgar score at 5 minutes ≤7, birth asphyxia, admission to NICU. The CTG+ST analysis arm was associated with a 46% reduction (P<0.001, odds ratio 1.85 [1.35-2.66]) in the incidence of operative deliveries for "fetal distress," and also a trend towards a lower rate of metabolic acidosis (P=0.09, odds ratio 0.38 [0.13-1.07]) and a 5-minute Apgar Score<7 (P=0.12, odds ratio 0.62 [0.35-1.08]) were recorded.[25]

Similarly, another study from Sweden enrolled 4966 women with fetuses in cephalic presentation and gestational age >36 weeks, who were randomly assigned to the 2 groups (CTG+ST group *vs.* CTG group). The primary outcome was the rate of umbilical-artery metabolic acidosis (pH<7.05 and base deficit >12 mmol/L). Secondary outcomes included operative delivery for fetal distress. Consistently with the results by Westgate *et al*. the CTG+ST group showed significantly lower rates of umbilical-artery metabolic acidosis (15 of 2159 [0.7%] *vs.* 31 of 2079 [2%], P=0.02) and operative delivery for fetal distress (193 of 2519 [8%] *vs.* 227 of 2447 [9%], 0.83 [0.69-0.99], P=0.047) compared to the cardiotocography group.[26]

Conversely, more recent evidence from four RCTs[27-30] yielded different results compared to the above mentioned RCTs. Among them, the largest RCT so far conducted,[30] including 11,108 women demonstrated that the use of the STAN did not reduced operative delivery rates.

In the Dutch RCT[29] that included 5681 women with a singleton pregnancy high-risk and gestation >36 weeks, the prevalence of metabolic acidosis was lower in the CTG plus ST arm (0,7%) compared with CTG only arm (1%) (RR=0.70, range 0.38-1.28), however no significant difference was demonstrated.[29]

Similarly, in the Finnish RCT, which included 1483 women in active labor at term gestation, no difference in the incidence of metabolic acidosis was found between the STAN and CTG group as define by umbilical cord artery blood pH<7.05 and base deficit calculated in extracellular fluid compartment >12 mmol/L. (1.7 *versus* 0.7%). Consistently, no difference was found in the incidence of neonatal acidemia (5.8 *versus* 4.7%), cesarean section (6.4 *versus* 4.7%) and operative vaginal delivery (9.5 *versus* 10.7%).[27]

Another RCT from France was conducted with the aim to evaluate the rate of operative delivery for fetal distress. Seven hundred ninety-ninewomen at term with abnormal cardiotocography or meconium-stained amniotic fluid (7%) were enrolled, and no difference in the incidence

TABLE II.—*Summary of RCTs.*

Authors and year	Country	N. of included subjects	Primary outcome	Main results (CTG *vs.* CTG+ST analysis)
Westgate *et al.*, 1993[25]	United Kingdom	2434	Total operative delivery rate, fetal distress and metabolic acidosis (umbilical artery (pH<7.05 and BDecf>12 mmol/L)	Metabolic acidosis: 13/1215 *vs.* 5/1219 OR=0.38; 95% CI: 0.13-1.07; P=0.09 Operative delivery for fetal distress: 111/1215 *vs.* 61/1219 OR=0.51, 95% CI: 0.37-0.70; P<0.001
Amer-Wahlin *et al.*, 2001[26]	Sweden	4966	Metabolic acidosis (umbilical artery pH<7.05 and BDecf >12 mmol/L)	Metabolic acidosis: 31/2079 *vs.* 15/2159 OR=0.46; 95% CI: 0.25-0.86; P=0.02 Operative delivery for fetal distress: 227/2447 *vs.* 193/2519 RR=0.83; 95% CI: 0.69-0.99; P=0.047
Ojala *et al.*, 2006[27]	Finland	1483	Umbilical artery pH<7.10	Metabolic acidosis: 5/722 *vs.* 12/714 RR=2.43; 95% CI: 0.86-6.85; P=0.093 Cesarean delivery: 35/739 *vs.* 47/733 RR=1.35; 95% CI: 0.86-2.07; P=0.12 Operative vaginal delivery: 79/739 *vs.* 70/733 RR=0.89; 95% CI: 0.66-1.21, P=0.53
Vayssière *et al.*, 2007[28]	France	799	Operative deliveries for fetal distress	Operative delivery: 221/400 *vs.* 216/399 RR=0.98; 95% CI: 0.86-1.11
Westerhuis *et al.*, 2010[29]	the Netherlands	5681	Metabolic acidosis (umbilical artery pH<7.05 and BDecf>12 mmol/L)	Metabolic acidosis: 30/2840 *vs.* 20/2827 RR=0.70; 95% CI: 0.38-1.28 Operative delivery: 822/2840 *vs.* 789/2827 RR=0.96; 95% CI: 0.87-1.06
Belfort *et al.*, 2015[30]	USA	11108	Composite outcome (intrapartum fetal death, neonatal death, 5 minutes Apgar Score ≤3, umbilical artery pH≤7.05 with BD blood ≥12 mmol/L, intubation or ventilation at delivery, neonatal encephalopathy)	Primary composite outcome: 40/5576 *vs.* 52/5532 RR=1.31; 95% CI: 0.87-1.98; P=0.20 Operative delivery: 22.0% *vs.* 22.8%, P=0.31
Turnbull *et al.*, in progress[31]	Australia		Emergency cesarean section	

of operative delivery for non-reassuring fetal state was demonstrated between the CTG only and the CTG+ST group.[28]

Finally, in 2018 a new RCT has been started (RCT "Stan Australian Randomized controlled Trial- START")[31] and its results are yet to be reported. Overall, 1818 laboring women with singleton pregnancy in cephalic presentation >36 weeks of gestation will be included. Based on the hypothesis combined CTG and STAN monitoring may reduce the frequency of emergency cesarean section due to intrapartum fetal distress,[32] the study aimed to compare emergency cesarean section rate neonatal acidemia and additional labor and perinatal outcomes between women submitted to CTG+STAN *versus* women submitted to CTG monitoring only.

Meta-analysis of randomized controlled trials

Due to the conflicting results arising from the RCT, several meta-analysis (MA) of RCTs[33-39] including two by the Cochrane collaborative group[38, 39] have been conducted in order to sum-

marize the existing evidences on the role of STAN analysis in adjunction to conventional CTG for intrapartum fetal monitoring. The main results are illustrated in Table III.[33-39]

Four MAs[33-36] investigated the role of the use of ST analysis+ CTG in reducing of the overall rate of operative deliveries but only two MAs demonstrated a significant reduction of this outcome.[33, 35] On note, heterogeneities in the incidence of operative vaginal delivery for fetal distress were noted among the studies and a significant reduction of operative vaginal delivery for fetal distress was only observed in the MA by Becker *et al*.[33] (RR=0.86, 95% CI: 0.76-0.97).

On the other hand, more discordant results have been reported when analyzing the occurrence of metabolic acidosis; these discordant results are probably due to the different definitions of metabolic acidosis adopted and in the multiple data sets. While Blix *et al*.[34] reported a significant reduction in metabolic acidosis (36%, OR=0.64, 95% CI: 0.46-0.88) all other meta-analysis failed in demonstrating a significant reduction in the incidence of metabolic acidosis. In addition, Blix *et al*. reported that CTG+ST analysis reduced operative vaginal delivery rate by 8% (RR=0.92, 95% CI: 0.86-0.99). On note, only Blix *et al*. used correct and revised data from the Dutch and the Sweden trial.

In their MA Saccone *et al*.[36] used two different definitions of metabolic acidosis: 1) pH <=7.05 and extracellular fluid base deficit (BDecf) ≥12 mmol/L; and 2) pH<7.05 and BDecf>12 mmol/L.

These definitions excluded the Plymouth RCT[25] in the first case and the trial by Belfort *et al*.[30] in the latter case. Irrespectively from the

TABLE III.—*Summary of meta-analysis considered comparing CTG plus ST-analysis with CTG alone.*

Authors and year	Metabolic acidosis definition used	Metabolic acidosis	Operative delivery (Operative vaginal delivery+ Cesarean section)	Operative vaginal delivery for fetal distress
Becker *et al*., 2012[33]	Umbilical cord pH<7.05 and base deficit in the extracellular fluid (BDecf)>12 mmol/L.	RR=0.72, 95% CI: 0.43-1.19, N.=15338	RR=0.94, 95% CI: 0.89-0.99, N.=15.338	RR=0.86, 95% CI:, 0.76-0.97, N.=15338
Potti and Berghella, 2012[37]	Umbilical arterial pH <7.05 and base deficit >12 mmol/L.	RR=0.80, 95% CI: 0.44-1.47, N.=14574	Not performed	Not performed
Neilson 2013,[38]	Cord artery pH<7.05 and base deficit >12 mmol/L (blood).	RR=0.78, 95% CI: 0.44-1.47, N.=14574	Not performed	Not performed
Oloffson *et al*., 2014[35]	cord artery pH<7.05 and base deficit in the extracellular fluid (BDecf)>12.0 mmol/L.	RR=0.61, 95% CI: 0.41-1.07, N.=14586	RR=0.93, 95% CI: 0.88-0.99, N.=14539	Not performed
Neilson 2015, [39]	Cord artery pH <7.05 and base deficit >12 mmol/L	RR=0.72, 95% CI: 0.43-1.20, N.= 25682	Not performed	Not performed
Saccone *et al*., 2016[36]	Definition 1: umbilical arterial pH ≤7.05 and base deficit in the extracellular fluid (BDecf) ≥12 mmol/L. Definition 2: umbilical arterial pH<7.05 and extracellular fluid base deficit (BDecf)> than 12 mmol/L.	Definition 1: RR=0.74, 95% CI: 0.54-1.02, N.=24,095 Definition 2: RR=0.81, 95% CI: 0.44-1.46, N.=15302	RR=0.93, 95% CI: 0.86-1.01, N.=26.446	Not performed
Blix *et al*., 2016[34]	pH<7.05 and base deficit in extracellular fluid (BDecf)>12 mmol/L.	OR=0.64, 95% CI:, 0.46-0.88, N.=26,493	RR=0.96, 95% CI: 0.91-1.02, N.=26,446 Operative delivery for fetal distress: RR=0.88, 95% CI: 0.75-1.03, N.=26,446	RR=0.87, 95% CI: 0.74-1.03, N.=26,446

definition used, a nonsignificant reduction in the incidence of metabolic acidosis was reported.

Due to these contrasting results, the debate about the clinical advantages of the routinely use of ST analysis in adjunct to conventional fetal heart monitoring in labor is still ongoing.

The role of the training in the use STAN method

The STAN technology requires a human being to interpret the CTG trace according to the STAN guidelines; for this reason, most failures are due to human errors in CTG interpretation.

Several observational studies have investigated if training and implementation in the use of STAN technology may impact on the main adverse outcomes.

Among the available studies, the largest included 42146 women recruited between 2001 and 2011 with the primary aim to longitudinally evaluate the rates of metabolic acidosis and operative deliveries following the implementation of the ST-analysis as an adjunct to conventional intrapartum fetal heart rate monitoring at a large tertiary maternity unit in Finland. A longitudinal reduction in the incidence of metabolic acidosis from the first 2 years and the following 9 years of enrolment (1% *vs*. 0.25%, P=0.0035) was demonstrated.

Cesarean deliveries also decreased by 18% (17.2% *vs*. 14.1%, RR=0.82; 95% CI: 0.77-0.87). The benefits of the method may not be evident in the early stages of adoption, since a learning period is necessary, and the results have been observed improve over time.[40]

Consistently, in Netherland, another study was conducted between 2000 and 2013 to evaluate the change in frequency of perinatal intervention and adverse neonatal outcome after the implementation of ST waveform analysis. 19,664 medium-and high-risk singleton pregnancies with fetuses in cephalic presentation, gestational age of ≥36 weeks, and the intention to deliver vaginally were included in this retrospective longitudinal study.[13]

With the implementation of ST analysis between 2000 and 2010, a reduction of the metabolic acidosis rate from 2.5% in the first years to 0.4% in more recent years (P<0.001) has been shown, which represents an 84% decrease. A decrease in the total number instrumental vaginal deliveries from 13.8% to 10.3% (P<0.001) has been also observed.[13]

Furthermore, several other studies also correlated the learning curve with the reduction of the rate of metabolic acidosis in the umbilical artery.[13, 41-43]

Novel perspectives

Albeit in the presence of several RCTs, MAs and cohort and observational studies, to date no study has evaluated the performance of the STAN method according to the new classification system proposed by FIGO (FIGO 2015).[3]

In 2020 a simulation study investigated the performance of the new FIGO classification system from 2015 (FIGO 2015) (Table IV)[3] *vs*. the CTG classification system used in the STAN interpretation algorithm from 2007 (STAN 2007) (Table V),[18] which is based on the FIGO system from 1987.[44]

In this study, CTG traces and ST events of 44 cases with metabolic acidosis were retrospectively classified according to the old (STAN 2007) and the new (FIGO 2015) classification system by three experts in consensus and the time from the first significant CTG plus ST event till delivery was calculated for both systems in each case. STAN2007 system was found to have a higher sensitivity (73% *versus* 43%, P=0.0002) and alarmed for metabolic acidosis in mean

TABLE IV.—*FIGO 2015 CTG Classification.*[3]

Variables	Normal	Suspicious	Pathological
Baseline	110–160 bpm	Lacking at least one characteristic of normality, but with no pathological features	<100 bpm
Variability	5–25 bpm		Reduced variability, increased variability, or sinusoidal pattern
Decelerations	No repetitive decelerations		Repetitive late or prolonged decelerations during >30 min or 20 min if reduced variability, or one prolonged deceleration with N5 min

TABLE V.—*STAN 2007 CTG Classification.*[18]

	Normal CTG	Intermediary CTG	Abnormal CTG	Preterminal CTG
Baseline Heart Frequency	110-150 bpm	100-110 bpm 150-170 bpm Short bradycardia episode (<100 bpm for ≤3 minutes)	150-170 bpm and reduced variability >170 bpm Persistent bradycardia (<100 bpm for >3 minutes)	Total lack of variability (2 bpm) and reactivity with or without decelerations or bradycardia
Variability Reactivity	Accelerations 5-25 bpm	>25 bpm (saltatory pattern <5 bpm >40 minutes with absence of accelerations	<5 bpm for >60 minutes Sinusoidal pattern	
Decelerations	Early uniform decelerations Uncomplicated variable decelerations with a duration of <60 sec and loss of <60 beats	Uncomplicated variable decelerations with a duration of <60 sec and loss of >60 beats A combination of several intermediary observations will result in an abnormal CTG	Complicated variable decelerations with a duration of >60 sec Repeated late uniform decelerations	

34 minutes earlier than the FIGO 2015 system (P=0.002). There were no cases where FIGO 2015 indicated a significant CTG plus ST event and STAN 2007 did not.[45]

In 2019 Rosen *et al.*[46] conducted a study to identify the predominant FHR patterns in connections with ST events in those cases of cord artery metabolic acidosis which had been overlooked by the more recent 2015 FIGO classification system. With the *post-hoc* analysis of 44 cases with umbilical cord artery metabolic acidosis retrieved from a European multicenter database, 3 specific FHR patterns in connection with an ST event have been identified to become indications for obstetric intervention: 1) an acute and instantaneous rise in beat to beat variations (alarm reactions); 2) a reduced beat to beat variation after a previous increase in the second stage of labor; and 3) repeated decelerations in second stage with recovery phase <2 minutes. At the light of these findings, a revision of the STAN guidelines taking into account these specific CTG has been proposed and is currently underway to achieve an improved clinical performance of STAN technology in the management of labor.

Conclusions

STAN technology is claimed to support traditional CTG in improving the identification of true fetal hypoxia during labor and reducing the rate of unnecessary operative deliveries. However, to date there is no strong evidence supporting the extensive implementation of the technique in the clinical practice. This may result from differences in the studies conducted so far, and also from the limited experience in the use of STAN among the practitioners involved in the labor ward practice. Further investigations are warranted in order to clarify the advantages – if any – of the ST analysis and to evaluate whether the implementation of new guidelines can improve the labor outcome of patients undergoing ST analysis as an adjunct to CTG.

References

1. Amer-Wahlin I, Kwee A. Combined cardiotocographic and ST event analysis: A review. Best Pract Res Clin Obstet Gynaecol 2016;30:48–61.

2. ACOG. ACOG Practice Bulletin No. 106: Intrapartum fetal heart rate monitoring: nomenclature, interpretation, and general management principles. Obstet Gynecol 2009;114:192–202.

3. Ayres-de-Campos D, Spong CY, Chandraharan E; FIGO Intrapartum Fetal Monitoring Expert Consensus Panel. FIGO consensus guidelines on intrapartum fetal monitoring: cardiotocography. Int J Gynaecol Obstet 2015;131:13–24.

4. National Institute for Health and Care Excellence. Intrapartum care: NICE guideline CG190 Interpretation of cardiotocograph traces. NICE; 2017 [Internet]. Available from: https://www.nice.org.uk/guidance/cg190/resources/interpretation-of-cardiotocograph-traces-pdf-248732173 [cited 2021, Jan 22].

5. SOGC - BCPHP fetal health surveillance: antepartum and intrapartum Consensus Guideline. BCPHP; 2008 [Internet]. Available from: http://www.perinatalservicesbc.ca/Documents/Guidelines-Standards/Maternal/FHSConsensusGuideline.pdf [cited 2021, Jan 22].

6. Intrapartum Fetal Surveillance. Clinical Guideline - Fourth Edition. RANZCOG; 2019 [Internet]. Available from: https://ranzcog.edu.au/RANZCOG_SITE/media/RANZCOG-MEDIA/Women%27s%20Health/Statement%20and%20guidelines/Clinical-Obstetrics/IFS-Guideline-4thEdition-2019.pdf?ext=.pdf [cited 2021, Jan 22].

7. Clark SL, Hankins GD. Temporal and demographic trends in cerebral palsy—fact and fiction. Am J Obstet Gynecol 2003;188:628–33.

8. Donker DK, van Geijn HP, Hasman A. Interobserver variation in the assessment of fetal heart rate recordings. Eur J Obstet Gynecol Reprod Biol 1993;52:21–8.

9. Brocato B, Lewis D, Mulekar M, Baker S. Obesity's impact on intrapartum electronic fetal monitoring. J Matern Fetal Neonatal Med 2019;32:92–4.

10. Ghi T, Morganelli G, Bellussi F, Rucci P, Giorgetta F, Rizzo N, *et al.* Cardiotocographic findings in the second stage of labor among fetuses delivered with acidemia: a comparison of two classification systems. Eur J Obstet Gynecol Reprod Biol 2016;203:297–302.

11. Westgate JA, Bennet L, Brabyn C, Williams CE, Gunn AJ. ST waveform changes during repeated umbilical cord occlusions in near-term fetal sheep. Am J Obstet Gynecol 2001;184:743–51.

12. Rosén KG, Dagbjartsson A, Henriksson BÅ, Lagercrantz H, Kjellmer I. The relationship between circulating catecholamines and ST waveform in the fetal lamb electrocardiogram during hypoxia. Am J Obstet Gynecol 1984;149:190–5.

13. Landman AJ, Immink-Duijker ST, Mulder EJ, Koster MP, Xodo S, Visser GH, *et al.* Significant reduction in umbilical artery metabolic acidosis after implementation of intrapartum ST waveform analysis of the fetal electrocardiogram. Am J Obstet Gynecol 2019;221:63.e1–13.

14. Kashou AH, Basit H, Malik AS. Segment. StatPearls; 2019 [Internet]; 2019. Available from: https://www.ncbi.nlm.nih.gov/books/NBK459364/ [cited 2021, Jan 22].

15. Rosen KG, Martendal A. The green book of neoventa part I – The physiology of fetal surveillance. Mölndal: Neoventa Medical AB; 2014.

16. Chandraharan E. Applying fetal physiology to interpret CTG traces. In: Chandraharan E, editor. Handbook of CTG Interpretation: from patterns to physiology. Cambridge: Cambridge University Press; 2017.

17. Penn WO. The deposition of potassium and phosphate with glycogen in rat livers. J Biol Chem 1939;128:297–307.

18. Amer-Wahlin I, Arulkumaran S, Hagberg H, Marsál K, Visser GH. Fetal electrocardiogram: ST waveform analysis in intrapartum surveillance. BJOG 2007;114:1191–3.

19. Amer-Wåhlin I, Marál K. ST analysis of fetal electrocardiography in labor. Semin Fetal Neonatal Med 2011;16:29–35.

20. Rosen KG. Intrapartum fetal monitoring and fetal ECG-time for a change. Arch Perinat Med 2001;7:7–12.

21. Rosen KG, Martendal A. The green book of neoventa part II – Fetal surveillance and assessment of fetal reactions. Mölndal: Neoventa Medical AB;2014.

22. Carillo AP, Chandraharan E. ST-Analyzer (STAN). In: Chandraharan E, editor. Handbook of CTG interpretation: from patterns to physiology. Cambridge: Cambridge University Press; 2017.

23. Vettore M, Straface G, Tortora D, Parotto M, Greco P, Ugwumadu A, *et al.* Fetal ST baseline T/QRS rise in normal CTG does not predict neonatal acidemia. J Matern Fetal Neonatal Med 2019;1–6.

24. Demaegd H, Bauters E, Page GH. Foetal scalp blood sampling and ST-analysis of the foetal ECG for intrapartum foetal monitoring: a restricted systematic review. Facts Views Vis ObGyn 2020;11:337–46.

25. Westgate J, Harris M, Curnow JS, Greene KR. Plymouth randomized trial of cardiotocogram only versus ST waveform plus cardiotocogram for intrapartum monitoring in 2400 cases. Am J Obstet Gynecol 1993;169:1151–60.

26. Amer-Wåhlin I, Hellsten C, Norén H, Hagberg H, Herbst A, Kjellmer I, *et al.* Cardiotocography only versus cardiotocography plus ST analysis of fetal electrocardiogram for intrapartum fetal monitoring: a Swedish randomised controlled trial. Lancet 2001;358:534–8.

27. Ojala K, Vääräsmäki M, Mäkikallio K, Valkama M, Tekay A. A comparison of intrapartum automated fetal electrocardiography and conventional cardiotocography—a randomised controlled study. BJOG 2006;113:419–23.

28. Vayssière C, David E, Meyer N, Haberstich R, Sebahoun V, Roth E, *et al.* A French randomized controlled trial of ST-segment analysis in a population with abnormal cardiotocograms during labor. Am J Obstet Gynecol 2007;197:299.e1–6.

29. Westerhuis ME, Visser GH, Moons KG, van Beek E, Benders MJ, Bijvoet SM, *et al.* Cardiotocography plus ST analysis of fetal electrocardiogram compared with cardiotocography only for intrapartum monitoring: a randomized controlled trial. Obstet Gynecol 2010;115:1173–80.

30. Belfort MA, Saade GR, Thom E, Blackwell SC, Reddy UM, Thorp JM Jr, *et al.*; Eunice Kennedy Shriver National Institute of Child Health and Human Development Maternal–Fetal Medicine Units Network. A randomized trial of intrapartum fetal ECG ST-segment analysis. N Engl J Med 2015;373:632–41.

31. Turnbull D, Salter A, Simpson B, Mol BW, Chandraharan E, McPhee A, *et al.* Comparing the effect of STan (cardiotocographic electronic fetal monitoring (CTG) plus analysis of the ST segment of the fetal electrocardiogram) with CTG alone on emergency caesarean section rates: study protocol for the STan Australian Randomised controlled Trial (START). Trials 2019;20:539.

32. Wilkinson C, Kuah S, Bryson K, Mayes E, Matthews G, Mol B, *et al.* A pilot randomised trial of STan fetal monitoring compared with CTG monitoring alone. J Paediatr Child Health 2017;53:3.

33. Becker JH, Bax L, Amer-Wåhlin I, Ojala K, Vayssière C, Westerhuis ME, *et al.* ST analysis of the fetal electrocardiogram in intrapartum fetal monitoring: a meta-analysis. Obstet Gynecol 2012;119:145–54.

34. Blix E, Brurberg KG, Reierth E, Reinar LM, Øian P. ST waveform analysis versus cardiotocography alone for intrapartum fetal monitoring: a systematic review and meta-analysis of randomized trials. Acta Obstet Gynecol Scand 2016;95:16–27.

35. Olofsson P, Ayres-de-Campos D, Kessler J, Tendal B,

Yli BM, Devoe L. A critical appraisal of the evidence for using cardiotocography plus ECG ST interval analysis for fetal surveillance in labor. Part I: the randomized controlled trials. Acta Obstet Gynecol Scand 2014;93:556–68, discussion 568–9.

36. Saccone G, Schuit E, Amer-Wåhlin I, Xodo S, Berghella V. Electrocardiogram st analysis during labor: A systematic review and meta-Analysis of randomized controlled trials. Obstet Gynecol 2016;127:127–35.

37. Potti S, Berghella V. ST waveform analysis versus cardiotocography alone for intrapartum fetal monitoring: a meta-analysis of randomized trials. Am J Perinatol 2012;29:657–64.

38. Neilson JP. Fetal electrocardiogram (ECG) for fetal monitoring during labour. Cochrane Database Syst Rev 2013;CD000116.

39. Neilson JP. Fetal electrocardiogram (ECG) for fetal monitoring during labour (SUMMARY OF FINDINGS FOR THE MAIN COMPARISON). Cochrane Database Syst Rev 2015;17:406–11.

40. Timonen S, Holmberg K. The importance of the learning process in ST analysis interpretation and its impact in improving clinical and neonatal outcomes. Am J Obstet Gynecol 2018;218:620.e1–7.

41. Norén H, Blad S, Carlsson A, Flisberg A, Gustavsson A, Lilja H, *et al.* STAN in clinical practice—the outcome of 2 years of regular use in the city of Gothenburg. Am J Obstet Gynecol 2006;195:7–15.

42. Norén H, Carlsson A. Reduced prevalence of metabolic acidosis at birth: an analysis of established STAN usage in the total population of deliveries in a Swedish district hospital. Am J Obstet Gynecol 2010;202:546.e1–7.

43. Kessler J, Moster D, Albrechtsen S. Intrapartum monitoring of high-risk deliveries with ST analysis of the fetal electrocardiogram: an observational study of 6010 deliveries. Acta Obstet Gynecol Scand 2013;92:75–84.

44. FIGO Subcommittee on Standards in Perinatal Medicine. Guidelines for the use of fetal monitoring. Int J Gynecol Obs 1987;25:159–67.

45. Olofsson P, Norén H, Carlsson A, Rosén KG. Identifying newborns with umbilical cord blood metabolic acidosis by intrapartum cardiotography combined with fetal ECG ST analysis (STAN): comparison of the new and old FIGO systems to classify cardiotocograms. J Matern Fetal Neonatal Med 2020;33:404–9.

46. Rosén KG, Norén H, Carlsson A. FHR patterns that become significant in connection with ST waveform changes and metabolic acidosis at birth. J Matern Fetal Neonatal Med 2019;32:3288–93.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions.—All authors read and approved the final version of the manuscript.

History.—Article first published online: November 30, 2020. - Manuscript accepted: November 23, 2020. - Manuscript received: September 29, 2020.