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# Does a physiology-based interpretation of cardiotocography allow to dispense with second-line methods? A cross-sectional online survey

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## A B S T R A C T

**Context:** Second line methods are used to help obstetricians to identify abnormalities that reflect foetal acidosis. Since the use of a new technique of cardiotocography (CTG) interpretation based on the pathophysiology of the foetal period, the use of second-line tests has been questioned.

**Objective:** To evaluate the impact of specific training in CTG physiology-based interpretation on professional attitudes towards the use of second-line methods.

**Methods:** This cross-sectional study included 57 French obstetricians divided into two groups: the trained group (obstetricians who had already participated in a training course in physiology-based interpretation of CTG) and the control group. Ten medical records of patients who had abnormal CTG tracings and underwent foetal blood sampling pH measurement during labour were presented to the participants. They were given three choices: use a second-line method, continue labour without using second-line method, or perform a caesarean section. The main outcome measures was the median number of decisions to use second-line method.

**Results:** Forty participants were included in the trained group and 17 in the control group. The median number of recourses to second-line method was significantly inferior for the trained group (4/10 s-line methods) than for the control group (6/10,  $p = 0.040$ ). Regarding the 4 records for which a caesarean section was the real outcome, the median number of decisions of continuing labour was significantly superior in the trained group than in the control group ( $p = 0.032$ ).

**Conclusions:** Participation in a training course in physiology-based interpretation of CTG could be associated with a less frequent use of second-line method at the cost of more frequently continuing labour with the risk compromising foetal and maternal well-being. Additional studies are required to determine whether this change in attitude is safe for the foetal well-being.

## Keywords:

CTG interpretation  
Second-line methods  
Practices  
Training  
Caesarean delivery

## 1. Introduction

Electronic foetal monitoring was invented in the 1960s, and cardiotocography (CTG) has since become the primary means of monitoring foetal well-being during labour in developed countries [1,2]. CTG interpretation has an excellent negative predictive value but carries the drawback of a mediocre positive predictive value [3]. Thus, the interpretation of an abnormal CTG is challenging, and misinterpretations are frequent with the implicit risk of performing excessive operative deliveries or conversely, to wrongly abstain from an intervention that would have been necessary to preserve foetal well-being [4,5]. CTG is therefore an imperfect tool to be used alone to make

decisions with potentially serious consequences, often in emergency situations. In this context, second-line methods have found their use in cases of abnormal CTG and they allow us to differentiate abnormalities that reflect foetal acidosis from those that do not have an impact on foetal well-being [6].

This rationale has recently been challenged. Some authors have suggested that foetal monitoring does not inherently have a low positive predictive value and that its diagnostic performance could be improved by a paradigm shift in its interpretation [7]. Their claim is that CTG should not be interpreted on a pattern recognition basis but with a pathophysiological approach instead to identify the characteristics of the compensatory response of the foetus [8–10]. Indeed, traditionally, the interpretation of the CTG is taught by learning distinct criteria of concern (baseline heart rate, absence of accelerations, short-term variability, presence of decelerations) and by the

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recognition of different patterns of decelerations (early, variable or late; typical or atypical) [11]. The new paradigm is based on pathophysiology studies, especially in animals, and promotes the teaching of explanations of the foetal response to various phenomena occurring during labour [8,12]. One of the main purposes of this method is to differentiate between tracings that correspond to a physiological adaptation of the foetus and those that have a decompensatory meaning and require immediate operative deliveries. The underlying implicit goal is to sufficiently improve the positive predictive value of the CTG interpretation to dispense with second-line methods [13–15]. Since 2017 and the publication of the “Handbook of CTG Interpretation: From Patterns to Physiology”, this method of interpretation has been widely promoted, particularly through specific training courses [8]. Recent literature suggests that this type of analysis has a highest discrimination capacity for neonatal acidemia than the others CTG guidelines [16]. However, there are no existing studies to determine the value of these teachings on clinical decision-making.

The objective of this study was to evaluate the impact of specific training in CTG physiology-based interpretation on professional attitudes towards the use of second-line methods.

## 2. Methods

### 2.1. Study design and participants

We conducted a national cross-sectional study based on an online survey. French obstetricians were invited to participate during congresses and through national networks. Participants could be licenced obstetricians or specialized residents in their fourth year or higher and were required to have had regular practice in obstetrics in the previous year. This study was approved by the local ethics committee (Aix-Marseille University 2021–04–08–06).

### 2.2. Questionnaire

The questionnaire was divided into two parts:

The first part included questions about the participant: level of experience, place of work, frequency of use of second-line methods in the maternity hospital where he worked (frequent or infrequent), participation in specific training in physiology-based CTG interpretation and the type of training.

The second part focused on clinical cases. Ten medical records of patients who delivered in our unit and for whom foetal scalp blood sampling was performed during labour were presented with the following information: medical history, notable events during pregnancy, detailed description of the labour with a partograph and CTG. If the complete CTG was too long to be transmitted in its entirety, CTG at the beginning of labour and then at the onset of CTG abnormalities was transmitted. Patients gave their consent for the use of anonymized data from their records. All presented information was anterior to the decision to perform foetal scalp blood sampling: information about what happened after this decision was hidden from the participants on the partograph and the CTG. For each medical record, the participants were given three options: (i) perform a second-line method, (ii) continue labour without performing second-line method, or (iii) perform a caesarean section without performing second-line method.

After completion of the questionnaire, the participants received an email in which the real outcomes (foetal scalp blood sampling, mode of delivery, neonatal status) were presented for each medical record. They could not modify their answers after their completion of the questionnaire.

### 2.3. Selection of medical records

Ten medical records of term pregnant women who delivered in our unit between 2019 and 2020 and presented CTG abnormalities for whom FBS was used were carefully selected amongst forty records. Four reviewers were involved in this selection process and had access to the entire record (before and after foetal scalp blood sampling, including the neonatal status). The four reviewers were experienced obstetricians, including one expert in the court.

They were given the same instructions:

For patients for whom a caesarean section was performed, the record could be retained only if the foetal scalp blood sampling was less than 7.20 and if the reviewers deemed that caesarean section was the only reasonable decision to preserve foetal well-being. The record could not be retained if one or more reviewers deemed that another reasonable solution existed to avoid or delay a caesarean section (e.g., begin expulsive efforts, modify oxytocin administration). According to these criteria, four records of patients for whom a caesarean section was performed after foetal scalp blood sampling were retained and presented to the participants.

For patients who had a vaginal delivery, the record could be retained only if the foetal scalp blood sampling was greater than 7.20, if the delivery occurred at least one hour after the foetal scalp blood sampling and if the reviewers deemed that continuing the labour had been a reasonable decision based on the neonatal status. According to these criteria, six records were selected.

The four reviewers had to agree that a medical record met the required criteria for it to be selected. In any case of disagreement amongst the reviewers, the medical record was not retained for presentation. Their judgement was based on the entire medical record, including the neonatal status after delivery.

### 2.4. Groups and endpoints

The participants were divided into two groups: the trained group (obstetricians who participated in a training course in physiology-based interpretation of CTG) and the control group (no participation in such a course declared).

The primary endpoint was the difference between groups in the median number of second line method that the participants would have performed.

The secondary endpoints were the median number of decisions to continue labour without second-line method when the real outcome was a caesarean section and the median number of decisions to perform a caesarean section when the real outcome was a vaginal delivery.

### 2.5. Statistical analyses

The number of participants was calculated to detect an arbitrary median difference between groups of one recourse to second-line method amongst the ten presented records. Given a two-sided test with 90% statistical power and 95% confidence interval (CI), 44 participants needed to be included. Based on this number and with the assumption that 10 to 15 more obstetricians would agree to participate after each monthly reminder, we decided to allow access to the online questionnaire for four months (July to October 2020).

Professional characteristics of the participants and attitudes towards the presented cases were compared between the two groups. Qualitative variables are presented as counts (percentages) and were compared between groups using the  $\chi^2$  test or Fisher's exact test when appropriate. Continuous variables are presented as the median (interquartile range [IQR]) and were compared using Student's *t*-test or the Mann–Whitney U test when appropriate.

All of the statistical analyses were two-tailed, and the results were taken to be statistically significant when P values <0.05 were

obtained. The analyses were performed using IBM SPSS Statistics version 20.0 (IBM Corporation, Armonk, New York, US).

### 3. Results

#### 3.1. Characteristics of the participants

The participants' characteristics are reported in Table 1. Fifty-seven obstetricians answered the questionnaire: 40 had already participated in specific training in physiology-based CTG interpretation and were included in the trained group, and 17 participants were included in the control group. The level of experience was the same in both groups ( $p = 0.623$ ). The majority of participants were residents (in their fourth year or higher) and worked in a university hospital. Participants in the trained group either participated in a two-day master class (27.5%), had a shorter training course (72.5%) or read a book on physiology-based CTG interpretation (25.0%). Fifty percent of the participants of the trained group followed least two different types amongst the aforementioned trainings. Most of the participants in the trained group declared using this teaching in their daily practice (95.0%).

#### 3.2. Attitudes towards clinical cases

The participants' decisions towards the clinical cases are summarized in Table 2. amongst the ten medical records, the median number of recourses to second-line method was significantly inferior for the trained group (4 [2–6] second-line method on 10 records) than for the control group (6 [4–7];  $p = 0.040$ ). The median number of decisions to continue labour without using second-line method was significantly superior in the trained group than in the control group (3 [2–5] vs. 2 [1–3];  $p = 0.015$ ). The median number of decisions to perform a caesarean section without using second-line method was similar between groups (2 [1–4] vs. 2 [1–3.5];  $p = 0.788$ ). amongst the 4 records for which a caesarean section was in fact performed after the foetal scalp blood sampling, the median number of decisions of continuing labour without using second-line method was significantly superior in the trained group than in the control group (1 [0–1] decision of continuing labour on 4 records vs. 0 [0–1];  $p = 0.032$ ). amongst the 6 records for which the patient actually delivered vaginally after the result of the foetal scalp blood sampling, the median number of decisions of performing a caesarean section without using

**Table 2**

Comparison of attitudes towards clinical cases between the two groups.

	Control group <i>n</i> = 17	Training group <i>n</i> = 40	P value
Responses to the ten clinical cases, median (IQR)			
Continue labour without using a second-line method	2 (1 – 3)	3 (2 – 5)	0.015*
Perform a second-line method	6 (4 – 7)	4 (2 – 6)	0.040*
Perform a caesarean section without using a second-line method	2 (1 – 3.5)	2 (1 – 4)	0.788
Attitudes inconsistent with the real outcome, median (IQR)			
Caesarean section when the real outcome was a vaginal delivery (6 medical records)	1 (0 – 2)	0 (0 – 2)	0.641
Continuing labour when the real outcome was a caesarean section (4 medical records)	0 (0 – 1)	1 (0 – 1)	0.032*
Cumulative inconsistent attitudes (10 medical records)	1 (0.5 – 2)	1 (1 – 3)	0.490
Attitudes consistent with the real outcome, median (IQR)			
Caesarean section when the real outcome was a caesarean section (4 medical records)	2 (0 – 2)	2 (1 – 2)	0.641
Continuing labour when the real outcome was a vaginal delivery (6 medical records)	2 (0.5 – 2)	2.5 (1 – 4)	0.042*
Cumulative consistent attitudes (10 medical records)	3 (2 – 4)	4 (2 – 6)	0.039*
Second-line method performed when the pH was $\geq 7.30$ (4 medical records), median, IQR	0 (0 – 1)	0 (0 – 1)	0.921

\*  $p < 0.050$ .

second-line method was not significantly different between groups (0 [0–2] caesarean sections on 6 records vs. 1 [0–2];  $p = 0.641$ ). amongst 4 records for which the result of foetal scalp blood sampling was superior to 7.30, the median number of decisions to perform second-line method was not significantly different for both groups (0 [0–1] vs. 0 [0–1];  $p = 0.921$ ).

#### 3.3. Examples of medical records

The description of the medical records with the answers from the participants can be found in Table 3. We also provide a detailed description of the two medical records for which the rates of inconsistent answers with regard to the real outcome were the greatest (Fig. 1):

Medical Record #7: A 24-year-old woman, gravida 1, para 0, presented at 38 weeks of gestation with oligohydramnios and decreased active foetal movements in the setting of gestational diabetes with foetal macrosomia (estimated foetal weight above the 99th percentile). Induction of labour was achieved with oxytocin under epidural anaesthesia. CTG abnormalities appeared at 9 cm of cervical dilatation and led to foetal scalp blood sampling (Fig. 1a). The result was 7.27, and the obstetrician decided to continue labour with iterative foetal scalp blood sampling. One hour after the first sampling, the patient vaginally delivered a 3800 gram newborn boy. The Apgar scores were 10, 10, and 10 at 1, 5 and 10 min, respectively, and the umbilical cord pH was 7.17.

Regarding this medical record, 42% of participants decided to perform a caesarean section without using second-line method (38% of the participants in the trained group and 53% of the participants in the control group). Only 3 participants (7%) from the trained group decided to continue labour without using second-line method, and no participant from the control group decided to continue labour.

Medical Record #9: A 38-year-old woman, gravida 1, para 0, presented in labour at 39 gestational weeks in the setting of gestational

**Table 1**  
Characteristics of the participants.

	Control group <i>n</i> = 17	Training group <i>n</i> = 40	P value
Level of experiences, n/N (%)			0.623
Residents	13/17 (76.5%)	26/40 (65.0%)	
Fellow	2/17 (11.8%)	5/40 (12.5%)	
Attending physician	2/17 (11.8%)	9/40 (22.5%)	
Place of work, n/N (%)			0.802
University hospital	14/17 (82.4%)	34/40 (85.0%)	
Public Hospital	3/17 (17.6%)	6/40 (15.0%)	
Frequent use of second-line methods in the maternity, n/N (%)	12/17 (70.6%)	30/40 (75.0%)	
Type of CTG-training, n/N (%)			
CTG Masterclass (2 days)	–	11/40 (27.5%)	
Other shorter training (less than a day)	–	29/40 (72.5%)	
Reading the book "CTG interpretation"	–	10/40 (25.0%)	
Date of the CTG-training, n/N (%)			–
More than 6 months	–	30/38 (78.9%)	
Less than 6 months	–	8/38 (21.1%)	
Use of the precepts taught in the CTG-training in current practice	–	38/40 (95.0%)	

**Table 3**

Description of the medical records and detailed answers from the participants.

#	Age, years	Parity, n	Gestational age, GW	Cervical dilatation, cm	scalp pH	Actual outcome	Answers from all participants, n/N (%)			Answers from the training group, n/N (%)			Answers from the control group, n/N (%)		
							2nd Line	continue	caesarean	2nd Line	continue	caesarean	2nd Line	continue	caesarean
1	38	0	39	8	7.35	V	35/57 (62%)	19/57 (33%)	3/57 (5%)	22/40 (55%)	16/40 (40%)	2/40 (5%)	13/17 (76%)	3/17 (18%)	1/17 (6%)
2	34	0	40	6	7.19	C	21/57 (37%)	5/57 (9%)	31/57 (54%)	13/40 (33%)	4/40 (10%)	23/40 (57%)	8/17 (47%)	1/17 (6%)	8/17 (47%)
3	38	0	41	9	7.29	V	23/57 (40%)	33/57 (58%)	1/57 (2%)	12/40 (30%)	27/40 (67%)	1/40 (3%)	11/17 (65%)	6/17 (35%)	0/17 (0%)
4	18	0	39	9	7.31	V	25/57 (44%)	21/57 (37%)	11/57 (19%)	17/40 (42%)	14/40 (35%)	9/40 (23%)	8/17 (47%)	7/17 (41%)	2/17 (12%)
5	32	0	40	9	7.35	V	19/57 (33%)	27/57 (48%)	11/57 (19%)	12/40 (30%)	22/40 (55%)	6/40 (15%)	7/17 (42%)	5/17 (29%)	5/17 (29%)
6	30	0	38	4	7.17	C	25/57 (44%)	5/57 (9%)	27/57 (47%)	16/40 (40%)	4/40 (10%)	20/40 (50%)	9/17 (53%)	1/17 (6%)	7/17 (41%)
7	24	0	38	9	7.27	V	30/57 (53%)	3/57 (5%)	24/57 (42%)	22/40 (55%)	3/40 (7%)	15/40 (38%)	8/17 (47%)	0/17 (0%)	9/17 (53%)
8	25	0	38	8	7.16	C	27/57 (47%)	2/57 (4%)	28/57 (49%)	17/40 (42%)	2/40 (5%)	21/40 (52%)	10/17 (59%)	0/17 (0%)	7/17 (41%)
9	38	0	39	6	7.16	C	27/57 (47%)	27/57 (47%)	3/57 (5%)	16/40 (40%)	22/40 (55%)	2/40 (5%)	11/17 (65%)	5/17 (29%)	1/17 (6%)
10	35	3	40	7	7.33	V	29/57 (51%)	27/57 (47%)	1/57 (2%)	19/40 (47%)	20/40 (%)	1/40 (3%)	10/17 (59%)	7/17 (41%)	0/17 (0%)

Abbreviations: # = number of the medical record; GW= Gestational weeks V = Vaginal delivery; C = cesarean section; 2nd Line = Second line method; Continue = Continuing labor without a second line method; cesarean = cesarean section without a second line method.

diabetes without foetal macrosomia. CTG abnormalities appeared at 6 cm of cervical dilatation and led to foetal scalp blood sampling (Fig. 1b). The result was 7.16, and the obstetrician decided to perform a caesarean section. The newborn boy weighed 2605 gs and had Apgar scores of 8, 9, and 9 at 1, 5 and 10 min, respectively, with an umbilical cord pH of 7.14. He was admitted to the neonatal intensive care unit for respiratory distress and required continuous positive airway pressure for 24 h.

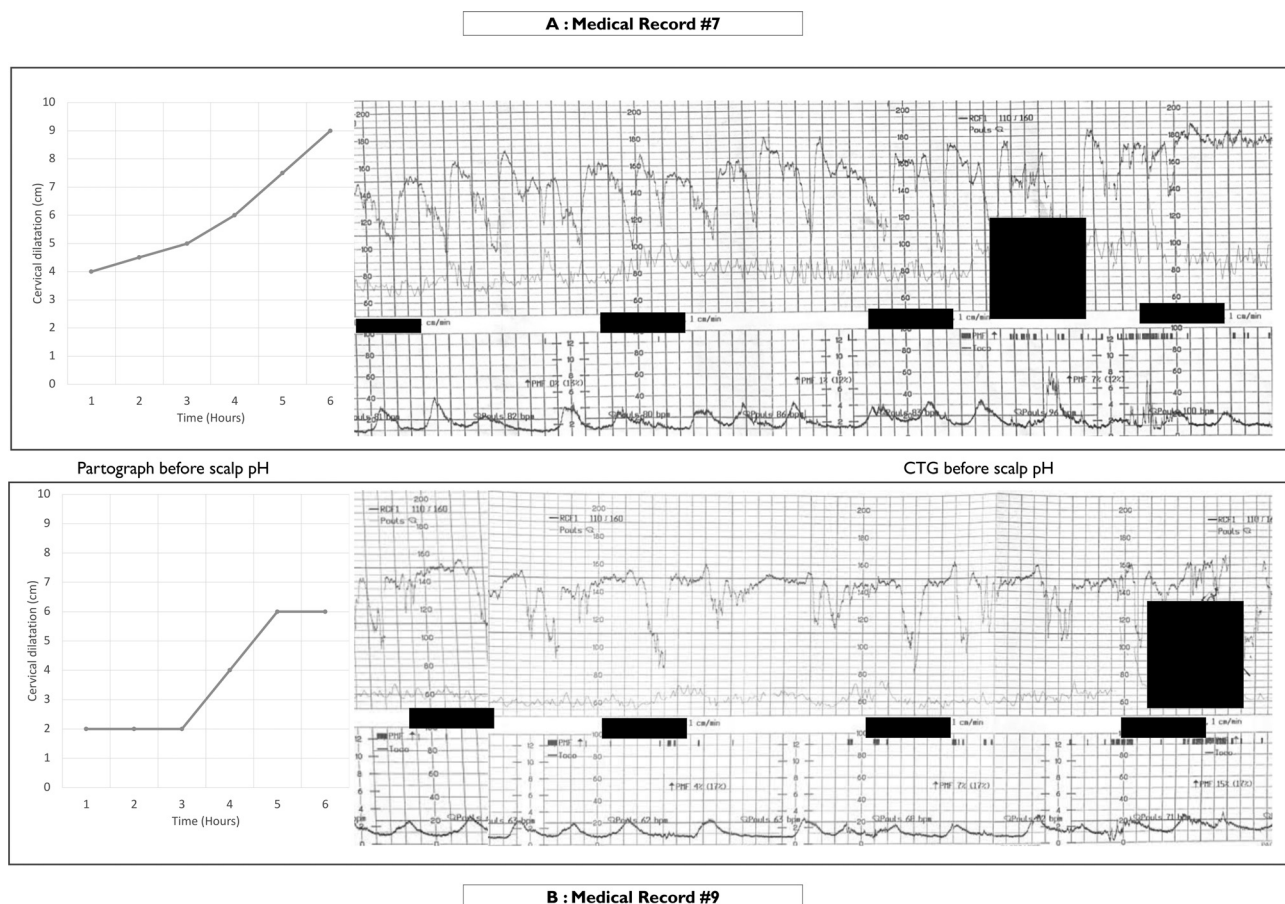
Regarding this medical record, 47% of participants would have decided to continue labour without using second-line method (55% of the participants in the trained group and 29% of participants in the

control group). Only two participants (5%) from the trained group would have chosen to perform a caesarean section without using a second-line method, and one from the control group (6%) would have chosen to perform a caesarean section.

## 4. Discussion

### 4.1. Interpretation of main findings

To date and to our knowledge, this is the first study to evaluate the influence of specific training in physiology-based CTG



**Fig. 1.** Examples of medical records. Left side: Partograph; Right side: Cardiocograph. 1A: Medical Record #7 before foetal scalp blood sampling. The result was 7.27, and the obstetrician decided to continue labour with iterative foetal scalp blood sampling. The patient delivered vaginally. 1B: Medical Record #9 before the foetal scalp blood sampling. The result was 7.16, and the obstetrician decided to perform a caesarean section. The newborn was admitted to the neonatal intensive care unit for respiratory distress and required continuous positive airway pressure for 24 h.



interpretation on professional attitudes towards recourse to second-line method. Our results suggest that obstetricians who underwent this type of training would less often decide to use second-line method when confronted with CTG abnormalities. This advantage would come at the cost of more often deciding to continue labour in situations that would have required a caesarean section to preserve neonatal well-being. Conversely, the obstetricians who did not undergo this training did not seem to opt more often for a caesarean section when the patient actually delivered vaginally.

#### 4.2. Strengths and limitations

The main strength of this study was the careful selection of medical records. Ten medical records were selected amongst forty others by four reviewers, including one expert in court. Clear instructions were given beforehand to the reviewers to only retain records whose outcome was unequivocal. In other words, the four reviewers had to agree that the actual mode of delivery (either a caesarean section or a vaginal delivery) was the best possible outcome in the clinical context with knowledge of the entire medical record, including the results of the foetal scalp blood sampling and the neonatal status. This rigorous selection process legitimises the claim that choosing an alternative mode of delivery without using second-line method and pH estimation would at least result in a nonoptimal outcome for the patient or her newborn. The exhaustive and careful presentation of all the information necessary for the participants to make a decision should also be emphasized. Real CTGs were presented either entirely since the beginning of labour or partially since before the beginning of CTG abnormalities (when the tracings exceeded three hours). Hence, this online questionnaire allowed an original simulation of real clinical situations, and we believe that it is a reliable evaluation of the participants' professional attitudes.

However, several considerations mitigate the conclusions that can be drawn from the results of this study. Despite the aforementioned precautions, it is impossible to assert with absolute certainty the outcome of an alternative scenario. Although we consider it unlikely, it is not formally impossible that amongst the 4 records that resulted in a caesarean section, one or more records could have ended differently. Several participants also pointed out that reducing the choice to three options was too restrictive and did not give a fair representation of reality. In particular, it is possible that some participants would have opted to continue labour only for some time before ultimately performing a caesarean section or a second-line method. Similarly, some participants suggested that other options were available, such as positioning the patient differently or stopping oxytocic administration. As stated before, although four reviewers deemed that the actual outcome was the best possible option, alternative scenarios cannot formally be excluded.

In addition, there is no way of verifying that the participants would have actually made the stated decision in a real-life situation. It is possible that the context of the anonymous questionnaire, devoid of any stress related to the consequences and presented as a test, encouraged participants to take more risks in their decision-making. It is also worth mentioning that the majority of the participants of this online survey were residents. Although we only included residents in their fourth year or higher who are ordinarily already self-reliant in obstetrical decision-making, we can hardly extrapolate the results to more experienced physicians.

Furthermore, all modes of training for the CTG physiology-based interpretation were placed on an equal footing in the trained group. The number of participants was insufficient to provide subgroup analysis for each type of training. Although the vast majority of the participants from the trained group declared that they used the precepts of CTG physiology-based interpretation in their daily practice, it is possible that our results are biased by the insufficient training of some participants.

#### 4.3. Validity of results

The underlying goal of physiology-based CTG interpretation is to dispense with second-line methods<sup>14,15</sup>. In a 2014 review, Edwin Chandrachar pointed out the absence of evidence supporting second-line method during labour<sup>13</sup>. This critique was enriched with a detailed list of pathophysiological inconsistencies associated with the use of this test; in particular, a sample of blood from nonessential peripheral tissue (foetal scalp) is being used to assess the acid–base status of essential central organs. His conclusion was that foetal scalp blood sampling was an outdated practice and that it should no longer be recommended. This review provoked a debate amongst various authors whose responses were just as interesting as the original article, essentially discussing the pathophysiological basis of foetal scalp blood sampling [17–19]. These expert debates are enlightening, but no pathophysiological analysis can ever replace the evidence provided by a well-conducted clinical study. Since 2014, despite this article, which should have encouraged research on this matter, little has been done to demonstrate the usefulness of second-line methods, which are still widely used despite this lack of evidence [20,21].

The same reasoning could easily be applied to physiology-based CTG interpretation training. There is no doubt that pathophysiological teaching leads to a deeper understanding of medical phenomena and should be encouraged. Recent studies showed that training programmes based on foetal physiology led to a long-term improvement in CTG interpretation and to homogenization of obstetrical decisions in simulated situations [22,23]. However, there is a strong need for clinical evidence regarding the teaching of this method before totally discouraging second-line methods. As suggested by our results, overconfidence in the interpretation of CTG could lead to wrong decisions and it should therefore be taught with humility and by stressing the importance of being cautious when in doubt. The present article is up to date and, to our knowledge, is the only attempt to analyse the effect of physiology-based CTG interpretation training on obstetrical practice. Although our work is clearly insufficient on its own to substantiate the benefits or shortcomings of this teaching, it does have the merits of raising the issue of the lack of evidence and should encourage further research.

#### 5. Conclusions

Our results suggest that participation in a training course in physiology-based interpretation of CTG could be associated with a less frequent use of second-line method at the cost of more frequently continuing labour with the risk compromising foetal and maternal well-being. Neither this study nor the current state of the literature allows us to recommend abandoning second-line methods in favour of an enhanced CTG interpretation. The same methodology could be used on a larger scale to confirm or refute these results.

#### Declaration of Competing Interest

The authors declare no conflict of interest related to this study.

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Ms. Marquet wrote the questionnaire and took care of its distribution, and Mr. Netter and Ms. Blanc carried out the statistical analyses.

Ms. Marquet and Mr. Netter wrote the final paper and all the co-authors helped to edit the final paper.

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