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Hippolyte Dupuis, Louise Ghesquière, Adeline Pierache, Damien Subtil, Veronique Debarge, Charles Garabedian

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## **Title page**

Evaluation and impact of fetal physiology training on fetal heart rate analysis.

H. Dupuis<sup>1,2</sup>, L. Ghesquière<sup>1,2</sup>, A. Pierache<sup>1,3</sup>, D. Subtil<sup>1,2</sup>, V. Houfflin-Debarge<sup>1,2</sup>, C. Garabedian<sup>1,2</sup>

<sup>1</sup> Univ. Lille, EA 4489 – Perinatal Environment and Health, F-59000 Lille, France

<sup>2</sup> CHU Lille, Department of Obstetrics, F-59000 Lille, France

<sup>3</sup> CHU Lille, EA 2694 – Public Health: epidemiology and quality of care, F-59000 Lille, France

*Corresponding Author :*

Dr Harmonie DUPUIS

Obstetrics Center, Jeanne de Flandre Hospital, CHRU Lille

Avenue Eugène Avinée, 59037 Lille Cedex, France

Tel: 0033 (0)3.20.44.67.99 Fax: 0033 (0)3.20.44.63.11

Harmonie.dupuis@chru-lille.fr

1 **Abstract**

2 **Introduction** - Evaluation of fetal well-being during labor is based on fetal heart rate (FHR) analysis,  
3 which requires physiology expertise. The aim of the present study was to assess medical residents'  
4 fetal physiology training in terms of theoretical knowledge, FHR interpretation, and use of second-line  
5 examinations.

6 **Methods** - This single-center, prospective study of obstetrics and gynecology residents (N=34) at  
7 CHU de Lille Hospital (Lille, France) was conducted from November 2017 to November 2018.  
8 Evaluation and training were conducted in three stages. First, residents' pre-training knowledge of  
9 FHR interpretation and use of fetal scalp blood sampling (FBS) was assessed using clinical cases.  
10 Second, a didactic training session on fetal physiology was delivered. Finally, post-training knowledge  
11 was evaluated using the same cases presented during pre-training.

12 **Results** - Pre-training, 3%, 11.8%, and 14.7% of residents considered their training on fetal  
13 physiology, FHR analysis, and second-line examinations, respectively, to be sufficient. Training  
14 significantly improved their theoretical knowledge, which was assessed using multiple-choice  
15 questions (median [interquartile range]: 1.5 [1.0–2.0] vs. 4.0 [3.0–4.5],  $p < 0.001$ ), and reduced the  
16 number of FBS requested (36.3% vs. 29.5%,  $p = 0.002$ ). Krippendorff's alpha coefficient for the  
17 reproducibility of residents' responses improved significantly, reflecting greater homogenization of  
18 clinical practice decisions (alpha [95% confidence interval]: 0.60 [0.55–0.65] vs. 0.72 [0.67–0.76]).

19 **Conclusion** - Improved fetal physiology knowledge promotes more accurate FHR interpretation,  
20 better indications for second-line examinations, and greater homogenization of clinical practice  
21 decisions. Future studies should evaluate the impact of fetal physiology training on clinical practice.

22 **Keywords:** training, fetal physiology, fetal heart rate, resident, fetal scalp blood sampling

23

24 **Manuscript**

25 **Introduction**

26 Fetal surveillance during labor is primarily based on fetal heart rate (FHR) analysis. The  
27 purpose of the interpretation of the FHR is to detect signs of poor fetal tolerance and therefore  
28 situations at risk of fetal acidosis. Indeed, this acidosis can be responsible for morbidity and perinatal  
29 mortality including motor disability of cerebral origin (1). In these intermediate-risk situations of fetal  
30 acidosis, second-line methods exist such as fetal scalp sampling (pH or lactate measurement) or ST  
31 segment analysis (2–4).

32 Interpretation of abnormalities observed on the FHR or second-line exams requires knowledge of fetal  
33 physiology during labor (5,6). The recent FIGO recommendations modified in 2015 classify the FHR  
34 as normal, suspicious or pathological, leading to a more physiological analysis of the FHR. (7). On the  
35 other hand, the place of second-line exams is controversial. In fact, a US randomized study concluded  
36 that ST segment analysis was not helpful in preventing fetal acidosis and nor in reducing intervention  
37 (cesarean or instrumental extraction) (8). Moreover, the physiopathology and the interest of fetal blood  
38 scalp sampling are discussed (9). Therefore, it is proposed to improve the quality of the interpretation  
39 of the FHR thanks to a better knowledge of the fetal physiology and of the adaptation of the fetus to  
40 the hypoxemia during labor. Thus, the aim of the present study was to assess fetal physiology training  
41 in terms of theoretical knowledge, interpretation of FHR and use of second-line examination.

42 **Methods**

43 A single-center prospective study (CHU Lille, France) was conducted among obstetrics and  
44 gynecology residents from November 2017 to November 2018 whatever their degree of competence  
45 (residency lasts 5 years in France).

46 The evaluation of the residents was conducted in 3 stages and each resident could only  
47 participate once. The first evaluation session was organized before our teaching session called "pre-  
48 training period". After this first evaluation session, the residents received one hour and half of teaching  
49 on fetal physiology and FHR analysis. The second evaluation session, called "post-training period",

50 was organized after this teaching and these three sessions were realized at 3 different times during  
51 their internship.

52 Each assessment session (pre- and post-training period) was organized into 2 parts: a  
53 theoretical part of multiple-choice questions (MCQs), and a practical part on clinical cases. During the  
54 theoretical evaluation, the residents had to answer a series of 7 multiple-choice questions. For each  
55 question, five answers were proposed and several answers were possible. They got one point to the  
56 question if all the answers were correct, 0.5 point if they made a mistake and no point beyond an error.  
57 These questions focused on the fetal response to hypoxemia and thus to fetal physiology during labor  
58 (figure 1).

59 The practical part was based on 6 clinical cases resulting from real clinical situations chosen  
60 by 2 investigators of the study. These were cases of singleton pregnancy in labor (spontaneous or  
61 induced) at term and with presence of abnormalities of the FHR for which the medical team had been  
62 solicited. Among the 6 files selected, 5 had been the subject of one or more FBS for a total of 10 fetal  
63 pH measurements actually achieved. For each of these clinical cases, 3 to 5 periods (27 in total) were  
64 chosen during the labor and at each period the residents had to analyze the FHR according to the  
65 CNGOF classification (10) divided into 5 categories: normal, low risk of acidosis, intermediate risk of  
66 acidosis, significant risk of acidosis, major risk. They were then asked if they achieved FBS or not,  
67 and the estimate of the result of this pH measurement if achieved: below 7.20, between 7.20 and 7.25  
68 or above 7.25 (3). The obstetrical context and the progress of labour were explained but the  
69 participants were blinded to the FBS result. The second evaluation session (after teaching) was based  
70 on the same clinical cases, the neonatal outcome was not given at the end of the first session so as not  
71 to influence the answers (11).

72 The teaching session consisted of a 1.5 hour course and performed both times by the same  
73 teacher. During this session the basics of fetal physiology and FHR analysis were recalled. This class  
74 was based on the literature on this topic (12,13) and carried out in a team working in experimental  
75 development of a new fetal monitoring tool based on the analysis of the autonomic nervous system  
76 (14,15). The first evaluation was carried out at the beginning of the semester followed by the course.

77 shortly after and the second evaluation took place at the end of the semester (similar time between  
78 sessions).

### 79 *Statistical analyzes*

80 Qualitative variables were described in terms of frequency and percentage. The note of theoretical  
81 radiographic knowledge of the residents has been described in terms of median and interquartile range.

82 The comparison of the radiographic theoretical knowledge scores of the residents between the two  
83 sessions was evaluated using a rank test signed of Wilcoxon.

84 The distribution of FHR evaluation grades was compared between the 2 sessions using a mixed  
85 ordinal regression model including the session as a fixed effect and an internal random effect to take  
86 into account the correlation between the different assessments by resident (27 scenarios, 2 sessions).

87 To evaluate the impact of the training on the analyze of the FHR by the residents, the reproducibility  
88 of the responses between the 34 residents on the FHR graduation was evaluated using the  
89 Krippendorff's alpha coefficient with its confidence interval of 95% [95% CI].

90 The FBS requested rate and the rate of correct estimation of the pH (if requested) were compared  
91 between the 2 sessions using a mixed logistic model including the session as a fixed effect and an  
92 effect internal random.

93 The p-values were calculated with a significance level of 5%. Statistical analyzes

94 were performed using the SAS software (SAS Institute version 9.4).

### 95 **Results**

96 A total of 34 residents participated in the 3 sessions, with seniority ranging from the 1st to the  
97 5th year (Table 1). Only 11.8% of the residents surveyed felt that they had sufficient training on FHR  
98 analysis and 2.9% on fetal physiology during labor. Of these, 14.7% felt that they had sufficient  
99 training in the indication of second-line surveillance examinations. They were 81.8% have received  
100 specific training on FHR during their residency, mainly during a planned course in their university  
101 studies. Yet 90.9% believed that their training was insufficient on the use of the FIGO and CNGOF

102 classifications. As for FBS, 66.7% had already laid an indication and 48.4% had never achieved a  
103 FBS.

104 The median MCQ score before teaching was 1.5 [1.0 to 2.0] with scores ranging from 0.0 to  
105 4.5. After our training, the median was 4.0 [3.0 to 4.5] with scores ranging from 1.0 to 6.5 ( $p$   
106  $<0.0001$ ). Of all the FHR analyzed during the defined periods, 49.2% of the rhythms were considered  
107 normal or low risk before our training against 54.7% after (Table 2). The distribution of FHR grades  
108 found a less pejorative evaluation after training ( $p<0.001$ ). In fact, 17.4% of the FHR analyzed by the  
109 residents were considered to be at significant risk of acidosis and 2.7% at major risk in pre-training,  
110 compared with respectively 11.2% and 0.1%. The reproducibility of residents' responses to FHR  
111 evaluation was improved after training with Krippendorff's alpha index pre-training of 0.60 [IC95,  
112 0.55 to 0.65] and post training of 0.72 [IC 9, 0.67 to 0.76]. Before our formation, 327 FBS were  
113 requested on all clinical cases against 269 after our training, a decrease of 6.9% ( $p=0.002$ ). The  
114 evaluation of the pH estimate relative to the actual value (110 estimations concerned) was significantly  
115 different between the two sessions ( $p = 0.020$ ) with a higher good estimate rate after training (47.2%  
116 vs 40.0%) although not significant with  $p = 0.28$ , a lower underestimation rate after training (26.4%  
117 vs. 38.2%) and a higher overestimate rate after training (26.4% vs. 21.8%). The rate of  
118 underestimation and overestimation was identical after training  
119 The rate of underestimation and overestimation was identical after training.

## 120 **Discussion**

### 121 *Main Findings*

122 The cardiotocograph was developed in the 1960s to improve fetal surveillance. But its  
123 generalization has led to an increase in the rate of cesarean section and extractions for FHR  
124 abnormalities and without significant reduction in neonatal risk (16,17). A recent Cochrane review  
125 also found no differences in cerebral palsy, infant mortality, or other standard measures of neonatal  
126 well-being between intermittent or continuous FHR auscultation (17). The only difference found is the  
127 reduction of neonatal convulsion rates during continuous auscultation. These findings, including the

128 increase in caesarean section rate, are related to the high sensitivity of the FHR and its low specificity,  
129 but not only. Misinterpretations or erroneous decisions are involved with a failure to take into account  
130 a pathological pattern in 20% of cases in newborns with metabolic acidosis (18). It therefore appears  
131 essential to improve our analysis of FHR and we wanted to evaluate the interest of training on fetal  
132 physiology in obstetric gynecology residents regardless of their initial level. We find a better global  
133 knowledge in fetal physiology with a reduction of "extreme" classification during the analysis of FHR,  
134 resulting in a decrease in the number of FBS, a better estimation of these and a homogenization of  
135 practices in clinical cases performed. **Indeed, the increase in Krippendorff's alpha coefficient was**  
136 **significant with no overlapping of confidence interval.**

137         The FHR interpretation training starts at the residency but the training time is variable and  
138 generally limited. The training is not systematic in France and varies according to the enrollments in  
139 workshops during congresses and the courses planned in the university. Conversely, in other countries  
140 such as England, the regulation has imposed the need for continuing education on the interpretation of  
141 the FHR every 6 months for midwives (19). Residents can also be trained personally through scientific  
142 articles or by their senior in the delivery room or during everyday staff. But this training is extremely  
143 variable and involves personnel already sensitized to the more physiological analysis of FHR.  
144 Therefore, the formation of residents on the FHR and fetal physiology is insufficient in France and all  
145 of our residents interviewed were applicants for such training.

146         The FHR analysis makes it possible to detect situations at risk of fetal acidosis when its  
147 interpretation is correctly performed and thus to provide indications of second-line examinations or  
148 fetal extraction. Metabolic acidosis and associated neonatal morbidity could potentially be prevented  
149 in 40-50% of cases (18). Indeed, the most found errors are a misinterpretation of the RCF, an  
150 imprudent use of oxytocin and a failure to recognize at-risk pregnancies (20–22). Training  
151 development could reduce the consequences of inadequate monitoring. Indeed, Draycott and al  
152 conducted a retrospective study evaluating the value of training in obstetric emergencies. They were  
153 interested in the Apgar scores at 5 minutes of all the liveborn singletons with vaginal deliveries at  
154 term, between 1998 and 2003. They also identified hypoxic and ischemic encephalopathies. All the



155 medical staff (midwife, gynecologist, anesthesiologist ...) benefited from a training day during the year  
156 2000. Draycott and al did not analyze the year 2000 and compared two periods: a pre-training period  
157 (from 1998 to 1999) and a post-training period (from 2001 to 2003). They found a significant  
158 reduction in low Apgar scores (<6) and in the incidence of hypoxic and ischemic encephalopathy (23).  
159 Thellesen and al, for their part, found a 14% decrease in fetal extraction, without increased risk of fetal  
160 hypoxia, after a training program for midwives and gynecologists from a Danish maternity hospital  
161 (24). Their training consisted of e-learning sessions and a day of theoretical courses.

162         The interpretation of the FHR is subject to intra- and inter-observer variability well studied  
163 now (25–27). This variability persists despite the existence of classification and this is more important  
164 when it comes to FHR classified as intermediate or pathological according to the FIGO classification  
165 (28). Regular training on FHR could reduce this inter-observer variability. Pehrson and al interviewed  
166 the Medline database to study and evaluate FHR training programs (29). Of the 409 citations they  
167 found, 20 studies included and analyzed. They report a better inter-observer agreement after training  
168 on the physiology and interpretation of FHR. We had the same findings by studying the  
169 reproducibility of the responses and therefore the inter-observer variability via the Krippendorff's  
170 alpha index (0.60 before training vs. 0.72 after). Therefore, training in fetal physiology promotes the  
171 homogenization of answers. Thus, an education in the interpretation of the FHR would allow a  
172 reduction of its variability inter and intra observer and therefore standardize our practices.

173         Finally, we wanted to evaluate the impact on the use of a second-line examination. Indeed,  
174 when the FHR analysis is considered non-reassuring, there are different second-line exams to better  
175 characterize the fetal state such as the FBS with pH measurement to study the acidobasic state of the  
176 fetus (3,4,30). The interest of FBS is currently debated. It may not be representative of fetal acid-base  
177 status as it is derived from peripheral tissue or because of the compression of the fetal scalp during  
178 labor for example. This could lead to unnecessary interventions in fetuses that are not really hypoxic,  
179 which means that the debate on this subject persists (9,31). The purpose of this study was not to  
180 discuss the interest of FBS but to evaluate the decision to perform this second-line exam in our  
181 residents. We note a decrease in the number of FBS requested so second-line examination, currently

182 being discussed, through a better interpretation. However, the rate of underestimation and  
183 overestimation was identical after training with an increase in overestimation with consequently a risk  
184 of not indicating sampling or missing a hypoxemic situation.

#### 185 *Strengths and Limitations*

186 Our study was conducted directly with our residents and the clinical cases were derived from  
187 real situations in order to get as close as possible to a current clinical practice. However neonatal  
188 outcome was not communicated at the end of the first session so as not to influence the responses of  
189 the residents, the knowledge of an unfavorable neonatal outcome leading to a more pessimistic  
190 evaluation of the FHR (11,32).

191 This study has limitations, however. Only 6 cases were selected reflecting only part of FHR  
192 abnormalities and obstetric context. In addition, during the second session, the same clinical cases  
193 were evaluated. Finally, these positive results are based on theoretical cases and it will be interesting  
194 to evaluate their impact in current practice with study of obstetrical decisions. It would indeed be  
195 interesting to assess the impact on indications of birth and neonatal status.

#### 196 *Interpretation*

197 In this study, we showed that it is necessary to improve our knowledge of fetal physiology for  
198 a better interpretation of FHR with better indications of FBS and more generally, more similar  
199 practices between practitioners.

#### 200 **Conclusion**

201 Improved knowledge in fetal physiology allows for better interpretation of FHR with better  
202 second-line examination indications and homogenization of practices. It will be interesting to evaluate  
203 the impact of training of all professionals in current practice.

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- 295

<b>Characteristics of residents and their education</b>		<b>N = 34</b>
Women		26 (76.5)
Year of the residency		
1		12 (35.3)
2		5 (14.7)
3		8 (23.5)
4		6 (17.7)
5		3 (8.8)
Do you feel you have sufficient training on FHR analysis ?		Yes : 4 (11.8)
Do you feel that you have sufficient training in fetal physiology during labor ?		Yes : 1 (2.9)
Do you feel you have sufficient training on the indication of second-line exams ?		Yes : 5 (14.7)
Have you ever attended specific training on fetal heart rate ?		Yes : 27 (81.8)
If yes, this training took place within the framework:		
University		11 (33.3)
Congress		10 (30.0)
Hospital internship		7 (21.2)
Other		6 (18.2)
Will you be applying for such training during your residency ?		Yes : 34 (100)
When you are asked for the interpretation of FHR, what classification do you use ?		
FIGO		2 (6.3)
CNGOF		22 (68.8)
None		8 (25)
Do you consider your training sufficient on the use of classifications ?		Yes : 3 (9.1)
Have you ever asked the realization of a FBS ?		Yes: 22 (66.7)
How much FBS did you achieve ?		
None		15 (48.4)
1 to 5		12 (38.2)
6 to 10		3 (9.7)
> 10		1 (3.2)

296

297 *Table 1 : Characteristics of residents and their education. Results presented in number (percentage)*

298 *FIGO = International Federation of Gynecology and Obstetric; CNGOF = National College of*

299 *Gynecologists and Obstetricians ; FBS = Fetal Blood Sampling*

300

	Pre-training period	Post-training period	p
<b>Theoretical part (7 MCQs)</b>			
Score	1.5 [1.0 to 2.0]	4.0 [3.0 to 4.5]	<0.001
<b>Distribution of FHR evaluation grades according to the CNGOF classification</b>			
	<b>N= 905</b>	<b>N=912</b>	
Normal FHR	193 (21.3)	262 (28.7)	< 0.001
FHR at low risk of acidosis	252 (27.8)	237 (26.0)	
FHR at intermediate risk of acidosis	279 (30.8)	310 (34.0)	
FHR at high risk of acidosis	157 (17.4)	102 (11.2)	
FHR at major risk of acidosis	24 (2.7)	1 (0.1)	
<b>FBS requested</b>			
	<b>N= 900</b>	<b>N=913</b>	
Request of pH	327 (36.3)	269 (29.5)	0.002
<b>Evaluation of the estimated pH compared to the actual value realized pH. *</b>			
	<b>N= 110</b>	<b>N=110</b>	
Overestimation of pH	24 (21.8)	29 (26.4)	0.02
Good estimate of pH	44 (40)	52 (47.2)	
Underestimation of pH	42 (38.2)	29 (26.4)	
<b>Reproducibility of answers</b>			
Krippendorff's alpha index	0.60 [0.55 ; 0.65]	0.72 [0.68 ; 0.76]	NA

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303 *Table 2 : Results presented in number (percentage) and median [interquartile range]. FHR = fetal*  
 304 *heart rate.*

305 *\* Among all the clinical situations, 110 pH estimated by the interns were actually achieved and therefore their*  
 306 *results could be compared.*

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