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Title: Fetal physiology cardiotocography training, a regional evaluation.

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1 **Introduction:**

2 Cardiotocography (CTG) has its limits in detecting fetal acidosis and intrapartum asphyxia.
3 Our aim was to evaluate a CTG training programme based on fetal physiology in the
4 Mediterranean perinatal network.

5
6 **Methods:**

7 Professionals from 41 maternity units of the Mediterranean network were invited to
8 participate in a CTG masterclass based on fetal physiology in March 2019 and October 2019.
9 They were asked to react to three practical cases by a physiological approach before the
10 training course (T0), one month after (T1) and six to seven months after (T2). The mean
11 scores were compared by using a mixed model including lapse of time to evaluation,
12 profession of participants and level of the maternity unit as fixed effects.

13
14 **Results:**

15 A total of 248 professionals from 32 maternity units finally participated in the organizational
16 audit. By using a mixed model, we found a significant improvement of the mean score at
17 T1=6.44/10 compared to T0=4.97/10 ($p<0.0001$), and a significant improvement of the mean
18 score obtained at T2=6.17/10 compared to T0 ($p<0.0001$). T2 scores were not significantly
19 different from T1 scores ($p=0.143$).

20
21 **Discussion:**

22 A CTG training programme based on fetal physiology showed a significant improvement in
23 the professionals' interpretation of CTG at short term and stable results at long term.
24 Continuing medical education could help maintain and improve knowledge to ensure neonatal
25 safety.

26
27 **Key words :** Cardiotocography, fetal physiology, training

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1. Introduction:

40 Continuous monitoring of the fetal heart rate (FHR) by cardiotocography (CTG) is the
41 established reference method for fetal monitoring during labour. This tool has limits regarding
42 screening for fetal acidosis and intrapartum asphyxia [1]. The main differences in
43 performance were found in the interpretation of decelerations [2], the evaluation of variability
44 [3] and in the classification of intermediate tracings [4]. The subjectivity of this analysis was
45 also observed when the observer was aware or not of adverse neonatal outcome [5–7].
46 According to the 2017 Cochrane review [8], in comparison with intermittent auscultation
47 (IA), CTG was associated with a 63% increase in the rate of cesarean deliveries and with 15%
48 more instrumental extraction but was not associated with a reduced incidence of cerebral
49 palsy [9].

50

51 In France, use of the Collège National des Gynécologues Obstétriciens Français (CNGOF)
52 classification simplified by Carbonne et al in 2013 or the Fédération Internationale de
53 Gynécologie et Obstétrique (FIGO) classification revised in 2015 are recommended for CTG
54 analysis. These “3 or 5 tier” classifications are not used by all healthcare professionals and
55 their interpretation can vary. A CTG tracing that accounts for fetal physiology may reduce
56 this variability and respect fetal health conditions while reducing indications for emergency
57 fetal extraction [10,11].

58 Several physiologists defend the view that intrapartum foetal surveillance should be
59 approached from a physiological standpoint which also consists of accurately identifying
60 fetuses at risk of intrapartum compromise, rather than just focusing on the morphological
61 appearances of the FHR tracings [12–16]. These considerations however, have yet to be
62 validated to replace or at least be complementary to the CNGOF classification.

63 It is necessary to consider CTG interpretation as an essential skill in intrapartum health care
64 [17]. A literary review has already shown the importance of training in CTG analysis and its
65 positive impact in clinical practice [18], however there is no initial standardized and
66 generalized training on a regional, nor even an international level. On-site training has been
67 proposed since 2015 in the Auvergne-Rhône-Alpes perinatal network and its evaluation has
68 shown an improvement in healthcare professionals’ knowledge of CTG [19]. Likewise, in the
69 Aquitaine area there are FHR monitoring workshops with a “training network” accreditation

70 that enables to expand them to the majority of public or private maternity units in that area
71 [20].

72 With the aim of harmonizing this practice, we decided to evaluate a CTG teaching
73 programme within the Provence-Alpes-Côte d'Azur, Corsica and Monaco perinatal network.
74 Based on literature and the examples above, we hypothesized that knowledge would be
75 improved after a CTG teaching course including fetal physiology, even some time later. The
76 primary objective of our study was to evaluate this training by comparing the knowledge of
77 healthcare professionals before (T0) and a short (T1) or long (T2) term after the course.
78 Secondary objectives were to review the current practices concerning fetal monitoring in the
79 41 maternity units belonging to the Mediterranean Network (Réseau Méditerranée). We also
80 wanted to assess the participants' satisfaction with regards to the course.

81 **2. Material and Methods:**

82

83 **2.1 Teaching course on CTG analysis and evaluation of knowledge prior to the course** 84 **(T0):**

85

86 The Mediterranean Network proposed a teaching course on CTG interpretation including fetal
87 physiology. It took place in Marseille and Nice with two sessions in March 2019 and two
88 others in October 2019. The course was in the form of a masterclass led by a midwife
89 specialized in CTG and trained in fetal physiology [21,22].

90 A satisfaction questionnaire was handed out to all of the participants in order to evaluate
91 Kirkpatrick Level 1 [23].

92

93 The following subjects were treated:

94

95 - Physiology of FHR regulation during labour

96 - Singularity of the mother-fetus duo

97 - Sleep/wake cycles and variability

98 - Interpretation of decelerations

99 - Presentation of types of hypoxia (acute, sub-acute, chronic, evolving)

100

101 For the primary objective, participants were asked to fill in a computerized organizational
102 questionnaire on CTG before the course and respond to clinical cases on a computerized
103 multi-choice questionnaire:

104 - prior to the course (T0)

105 - short term (T1: in the month following the course)

106 - long term (T2: 6-7 months after the course)

107 **2.2 Computerized Collected data:**

108

109 *2.2.1 Organizational CTG audit:*

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111 The organizational audit provided us with the healthcare professional's profile (age, gender,
112 profession: trainee or registered midwife, junior doctor, public or private practitioner), amount
113 of time spent in the delivery room, classification used in practice to interpret CTG, training in
114 the subject, under what form and how regularly, and if they knew anything about fetal
115 physiology. The questionnaire gave the type of institution, whether public or private, shifts on
116 site or on call, access to which second-line tests, whether there was obstetric staff and at what
117 frequency.

118

119 *2.2.2 Clinical cases:*

120 Actual clinical cases were transformed into progressive files with about ten questions per file.
121 The first case illustrated chronic hypoxia on a vascular background; the second, sub-acute
122 hypoxia due to inappropriate use of oxytocin, the same as in the third case illustrating
123 evolving hypoxia finally leading to bradycardia in a low-risk patient. They were reviewed and
124 validated by the course instructor. Participants had access to information concerning the
125 patient's medical history, parity, gestational age, pregnancy, data from the last ultrasound
126 scan and the onset of labour. All of the CTG data, from the entrance exam to the expulsion
127 tracing, were available as well as information concerning the progress of labour, amniotic
128 fluid characteristics and monitor readings.

129 The participants had to give their answers in a computerized multi-choice questionnaire
130 during labour progress where they were asked to propose or criticize an intervention (no
131 intervention, corrective action, second-line tests, imminent birth) and to answer questions on
132 fetal physiology.

133 Neonatal outcome was hidden from the participants so as not to influence their answers.

134 The last questions on the cases asked for a prediction of pH at birth and in some cases the
135 APGAR score.

136 Participants were given a detailed correction with the neonatal outcome after T2.

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142 **2.3 Data collection:**

143 In order to study the participants' knowledge in a reproducible way, the same clinical cases
144 were studied at T0, T1 and T2. To preserve anonymity while respecting the study times,
145 participants gave the first three letters of their first and last names. To reduce the numbers of
146 people lost to follow-up, reminder emails were sent every week, after one month for the short-
147 term evaluation, and after 6-7 months for the long-term evaluation. Clinical cases were sent
148 at 7 months for the October training course due to the COVID-19 pandemic. Each participant
149 was given a score out of 42 (/12 for the first case, /15 for the second and last cases). Some
150 questions were weighted (x2) when treating an essential point of the course and others gave
151 negative points (-1) when the action or the non-action undertaken by the professional was
152 particularly at risk for the fetus. Scores were then given out of 10 for legibility.

153 **2.4 Statistical analysis:**

154

155 Statistical analysis was performed using SPSS v20 software and SAS software for the mixed
156 model.

157 Concerning the organizational part, descriptive analysis was performed on all of the collected
158 variables in order to describe the profile of the participants, the maternity units and
159 professional practices. Quantitative variables were expressed as average and standard
160 deviation, median, minimum and maximum. Categorical variables were expressed as numbers
161 or percentages. Correlation between different variables was tested with Chi-square tests.
162 Results were compared according to the level of maternity unit. Threshold for significance
163 was set at 5% for all tests.

164 Concerning the clinical case part, an average score out of 10 was given for each of the 3
165 clinical cases, as well as an average total score (out of 10). The 95% Confidence Interval was
166 calculated for each of these scores.

167 Mixed effects models were performed to analyze repeated measures and to manage
168 unbalanced design or incomplete data.

169 Fixed effects were as follows: time of evaluation (T0, T1, T2), type of profession (midwife,
170 obstetrician-gynaecologist), type of institute (level I, II, III), time of evaluation-by-type of
171 profession interaction, time of evaluation-by-type of institute interaction, and the random

172 effect was the subject. Mixed models were used with the restricted maximum likelihood
173 estimate method and Satterthwaite degrees of freedom approximation. Least square means
174 were compared between levels using Tukey-Kramer method. The level of significance was set
175 at a P value of 0.05. Statistical analysis was performed using SAS Version 9.4 (SAS Institute,
176 Cary, NC).

177
178 **3. Results:**

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180 **3.1 Organizational audit:**

181
182 Among the 260 healthcare professionals originally signed up for the training course, the audit
183 finally concerned 248 professionals including 198 midwives and 50 obstetrician-
184 gynaecologists. These professionals came from 32 maternity units (13 level I, 16 level II and
185 3 level III maternity units). There were 22 public facilities and 10 private clinics. Nine
186 maternity units were not represented, giving a response rate of 78%. All of the centres
187 combined, 85 professionals attended the March course and 163 professionals attended the
188 October course.

189 Items are detailed in Table 1. The majority of participants was confronted with CTG analysis
190 one or several times per week on shift. The classification the most often used was that of the
191 CNGOF modified by Carbonne in 2013 [24] followed by the FIGO classification[22].
192 Approximately one third of participants used an approach including fetal physiology. Among
193 the 133 professionals out of 248 who declared to have had training, this was mainly
194 occasional and took place less than once a year in 58% of cases. Among the 115 professionals
195 who declared to have had no training, 98% considered the course useful. Intermittent
196 auscultation was reported in slightly over half of the centres, all levels combined.

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Table 1 – Overview of the organizational audit results

	Total (n=242)	Level I (n=66)	Level II (n=123)	Level III (n=53)	p
Professionals with shifts systematically on site					
Obstetrician-Gynaecologist	187 (78%)	36 (54%)	99 (81%)	53 (100%)	<0.05
Junior Doctor	81 (34%)	1 (1%)	28 (23%)	53 (100%)	<0.05
Intermittent auscultation	125 (52%)	42 (64%)	58 (47%)	25 (48%)	NS
Classification for CTG interpretation	219 (90%)	56 (85%)	113 (92%)	50 (94%)	NS
FIGO 2015 [4]	86 (39%)	29 (52%)	33 (29%)	24 (48%)	<0.05
ACOG 2009 [25]	20 (9%)	3 (5%)	14 (12%)	3 (6%)	NS
CNGOF 2007	26 (12%)	8 (14%)	12 (11%)	6 (12%)	NS
CNGOF Carbonne 2013 [24]	129 (59%)	25 (45%)	74 (65%)	30 (56%)	<0.05
Murphy Criteria [26]	26 (12%)	8 (14%)	14 (12%)	4 (8%)	NS
Rosen 2004 (STAN) [27]	23 (10%)	4 (7%)	16 (14%)	3 (6%)	NS
Thoulon [28]	9 (4%)	1 (2%)	6 (5%)	2 (4%)	NS
FHR Coletta 2012 [29]	1	0	1	0	NS
2nd line tests	180 (75%)	32 (48%)	96 (78%)	53 (100%)	P<0.05
Fetal scalp pH	88 (36%)	11 (17%)	28 (23%)	49 (92%)	
Fetal scalp lactates	127 (52%)	23 (35%)	72 (59%)	32 (60%)	
STAN	20 (8%)	2 (3%)	15 (11%)	3 (6%)	
Digital fetal scalp stimulation	19 (8%)	3 (4%)	7 (6%)	9 (17%)	
Doppler ultrasound	26 (11%)	5 (8%)	10 (8%)	11 (21%)	
Pathophysiological approach	62 (26%)	17 (26%)	28 (23%)	17 (32%)	NS
CTG training	133 (55%)	28 (42%)	70 (57%)	35 (66%)	P<0.05
Service meeting	62 (26%)	8 (12%)	33 (27%)	21 (40%)	
Continuous personal development	41 (17%)	9 (14%)	23 (19%)	41 (77%)	
Masterclass	18 (7%)	5 (8%)	8 (6%)	5 (9%)	
Other	24 (10%)	7 (11%)	14 (12%)	3 (6%)	
Obstetric staff presence	192 (80%)	40 (61%)	100 (82%)	53 (100%)	P<0.05
Weekly	72 (37%)	24 (60%)	45 (45%)	3 (6%)	
Daily	81 (42%)	5 (12%)	27 (27%)	49 (92%)	
Several times per week	9 (5%)	1 (2%)	8 (8%)	0	
Monthly	15 (8%)	4 (6%)	11 (11%)	0	
Mortality and morbidity reviews	5 (3%)	2 (5%)	3 (3%)	0	

Other 11 (4%) 4 (6%) 7 (6%) 0

213 Data are presented as n(%)

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219 3.2 Clinical case results:

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221 236 professionals participated at T0, 107 participated at T1 and 73 participated at T2. (Table
222 2)

223 There was a significant increase in the average score obtained at T1 compared to that of T0
224 for the different cases and for the total scores, with an average T1 score of 6.44/10 versus an
225 average T0 score of 4.97/10 (p<0.001).

226 There was also a significant increase in T2 scores compared to T0 scores, with an average T2
227 score of 6.17/10 (p<0.001).

228 T2 scores were not significantly different from T1 scores (p=0.143). (Figure 1)

229

230 Type of maternity unit effect and type of profession effect were not significant for all scores,
231 except a tendency for case 3 where obstetrician-gynaecologists scores were higher than those
232 of midwives 7.2/10 [6.9 ; 7.5] vs 6.8/10 [6.7 ; 7.0] respectively (p=0.064).

233

234 Table 2 - Mean scores by time of evaluation – Mixed model

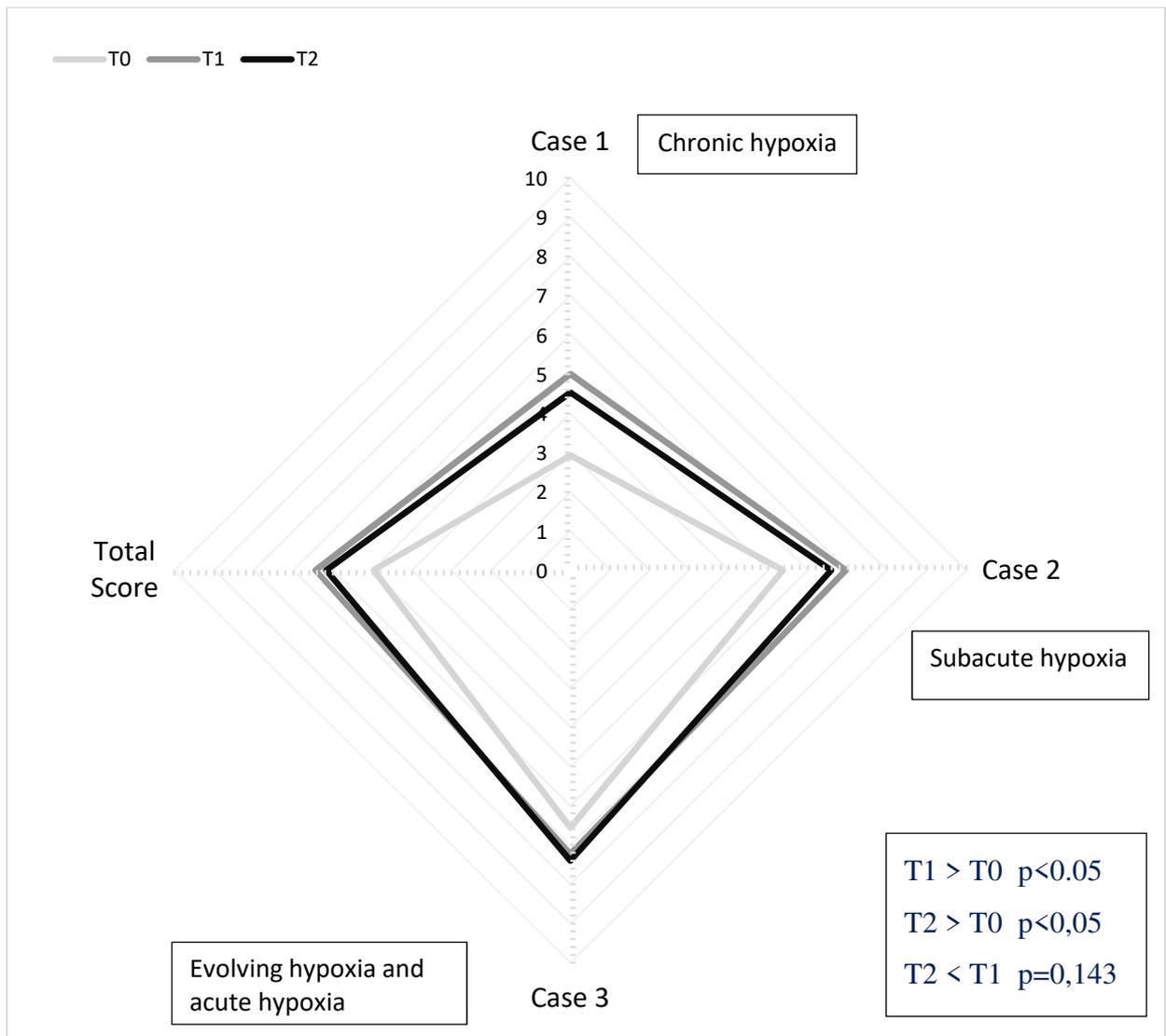
235

	T0 (n=236)	T1 (n=107)	T2 (n=73)	p-values Time of evaluation effect
Case 1	2.93	5.00	4.53	T0 < T1 (p<0.001)
Chronic hypoxia	[2.67 ; 3.18]	[4.57 ; 5.43]	[3.96 ; 5.11]	T0 < T2 (p<0.001) T1 > T2 (p=0.284)
Case 2	5.37	6.96	6.59	T0 < T1 (p<0.0001)
Subacute hypoxia	[5.20 ; 5.55]	[6.71 ; 7.21]	[6.26 ; 6.91]	T0 < T2 (p<0.0001) T1 > T2 (p=0.038)
Case 3	6.56	7.23	7.40	T0 < T1 (p=0.001)
Evolving and acute hypoxia	[6.39 ; 6.73]	[6.97 ; 7.49]	[7.07 ; 7.74]	T0 < T2 (p<0.001) T1 > T2 (p=0.660)
Total Score	4.97	6.44	6.17	T0 < T1 (p<0.001) T0 < T2 (p<0.001) T1 > T2 (p=0.143)

236 Data are mean scores and 95% confidence interval. P-value adjusted from mixed model included fixed effects:
237 “time of evaluation”, “type of institute”, “type of profession”, and their interactions with time of evaluation.

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241 Figure 1: Variation of mean scores for the clinical case results at different times T0, T1 and

242 T2 for each case and total score

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247 ***3.3 Satisfaction questionnaire:***

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249 The satisfaction questionnaire was handed out immediately after the teaching course to the

250 260 people signed up. In March the course was given a grade of 9.8/10 for usefulness, and in

251 October it got 9.8/10 for usefulness and 9.8/10 for the teaching method.

252

253

254 **4. Discussion:**

255

256 Our study found a significant increase in the average score obtained after the teaching course
257 compared to pre-teaching scores. This concerned short-term post-teaching scores and applied
258 to all of the different cases as well as to total scores. Long-term scores were not significantly
259 higher than short-term scores but the results were stable, indicating the necessity to
260 consolidate knowledge.

261

262 These results confirm those already published. One of the originalities of our study was that
263 we chose progressive clinical cases to evaluate performance, because real-life situations
264 seemed to be better than single choice questions about the teaching course. This evaluation
265 was inspired by the e.RCF website from Lille University, that was proved to be useful in the
266 study by Demailly et al [29]. Our study was also original because the training programme
267 used a physiological approach.

268 In a literary review, Pehrson et al [18] found that theoretical knowledge was retained 6 or 7
269 months after CTG training and that repetitive testing led to a marked improvement in
270 performance. After a 1997 survey on perinatal deaths in England, it was recommended that
271 CTG knowledge of healthcare professionals should be tested every 6 months.

272 Froc et al [19] also showed the interest of CTG analysis training in improving short-term and
273 long-term knowledge in the Auvergne-Rhône-Alpes perinatal network. Their evaluation used
274 a single choice questionnaire filled in before (T0) and immediately after (T1) theory training
275 in maternity units in the form of an “outreach visit”. Long-term evaluation took place over a
276 4-year period via “e-Learning”. Froc et al observed a significant decrease in T2 scores
277 compared to T1 showing once again the importance of repeated training.

278

279 **We first could discuss that the knowledge improvement observed might be the effect of any**
280 **CTG training programme. Our study could not confirm the superiority of this programme**
281 **based on fetal physiology versus another programme.**

282 Quite predictably, the highest rate of participation was at T0 and decreased over time (236
283 participants at T0, 107 at T1 and 73 at T2). This decrease may be explained by the fact that
284 the correction was not given immediately, the tracings were not easy to scroll through, and it
285 took time to fill in the clinical cases. There is, therefore, a selection bias, as the participants
286 who answered all three times were probably the most motivated. Nevertheless, our study

287 permitted us to collect exhaustive data representative of the network, even if the participants
288 were mostly midwives (80%) and healthcare professionals mainly from the public sector.
289 Even if the neonatal outcome remained hidden until T2, there may also be a memorization
290 bias **since there were only three practical cases.**

291 Our study provides an overview of the situation in the Mediterranean Network in order to
292 target its actions and respond better to practitioners' expectations. Despite the biases
293 mentioned above, we think that one of the important roles of the network is to continue to
294 harmonize professional practices. We observed inequalities in care organization and access to
295 education within the perinatal network. CTG training was significantly more important in
296 level II and level III maternity units compared to level I. Half of the participants declared that
297 this was their first teaching course on CTG, and the majority of the other half declared to have
298 only received very occasional training. This mainly took place during service meetings and
299 was mostly in level II and III maternity units, which also correlated with the number of
300 obstetrical staff members reported. They were reported to be present daily in less than half of
301 the maternity units, all units combined, and present weekly in just over a third of them. We
302 consider that this needs to be improved.

303
304 Care networks play an essential part in the definition of protocols and their dispersion [20] but
305 their impact is sometimes limited by the motivation of the healthcare workers, geographical
306 location (9 maternity units did not take part in the training programme, 4 of which were in the
307 Vaucluse area) or financial cost. On the contrary to the study by Froc et al. in which type II
308 maternity unit scores were better than type I scores, we found no significant differences
309 between the types of unit. We were not able to compare the private and public sectors due to
310 insufficient numbers.

311 Recent papers mainly state [18] that it is important to invest in a teaching policy that would
312 motivate healthcare workers to make improvements in their practice [30], some going as far
313 as suggesting compulsory knowledge tests [17]. Young et al. showed that the main causes for
314 intrapartum mortality were a delay in responding to recognized CTG anomalies or failure to
315 identify them [31]. These examples show that human factors are involved in adverse fetal
316 outcomes, they are the cause for variability in the interpretation of CTG and must be limited.
317 Education is one of the levers for reducing "improvisation" in healthcare. It demands
318 investment such as programmes for the prevention of serious adverse incidents, help in staff
319 communication and the development of medical technology.

320

321 In order to durably anchor knowledge into clinical practices, recommendations need to be
322 simple and reproducible, this is why the simplified 2013 version of the CNGOF classification
323 combined with a proposition of decision tree algorithms appeared to be a real solution.
324 However, in a study by Cheurfa et al [32] the diagnostic value of a coloured table simplified
325 by Carbonne remained limited in predicting acidosis (AUC <0.7) even though it made CTG
326 interpretation easier. One of the limitations of “3 or 5 tier” standard recommendations
327 possibly resides in the fact that they rely on the recognition of “patterns” for which our
328 analysis is mainly descriptive. The identification of the different types of hypoxia, via a better
329 comprehension of physiological processes at the origin of changes in CTG, is a method of
330 analysis which would probably allow an optimization in the use of this monitoring tool [33].
331 The diagnostic performance of this type of approach needs to be assessed, with objective
332 markers used in current practice to measure the clinical impact before and after a generalized
333 teaching programme including fetal physiology (Kirkpatrick levels 3 and 4). **Indeed, no study**
334 **has yet shown a significant impact on neonatal outcomes by using a more physiological**
335 **interpretation of CTG.** Here we studied Kirkpatrick level 1 which gave a positive feedback for
336 the training course.

337 A collaboration between perinatal networks could be the answer to help consolidate best
338 practices, thanks to sharing experiences and acting in compliance with mortality-morbidity
339 reviews. Then training on fetal physiology could be organized in each maternity unit by
340 professionals to relay knowledge and consolidate unity within the teams (Safety Attitude
341 Questionnaire). As in the United Kingdom and in other medical fields, trainee and
342 experienced professionals could be offered standardized education to maintain their CTG
343 knowledge, at a rhythm that remains to be defined. In any case, access to continuing medical
344 education should be made easier as it helps guarantee patient safety.

345

346 **5. Conclusion:**

347

348 A CTG training course based on fetal physiology was associated with a significant
349 improvement in knowledge at short-term and stable results at long-term. However, it is
350 probably necessary to repeat education courses to correctly maintain and improve long-term
351 acquisitions.

352 The objective of our study was not to assess the impact of CTG interpretation via an approach
353 involving fetal physiology on newborn and maternal health, and therefore it needs to be
354 evaluated in current practice using objective criteria. **It would be interesting to assess if it**

355 reduces the use of second line exams such as STAN or fetal scalp blood sample, operative
356 deliveries and the rate of umbilical cord artery pH < 7.

357 Our study backs our belief that continuing medical education and investment in a solid health
358 policy are the means of reinforcing the field of global skills connected with care and safety in
359 the delivery room.

360

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