Aus der Klinik

Für Frauenheilkunde Geburtshilfe und Reproduktionsmedizin

der

Medizinischen Hochschule Hannover.

Eine 2 ½-Jahres-Zwischenanalyse von seltenen geburtshilflichen Komplikationen nach der Einführung von dem Praktischen geburtshilflichen multiprofessionellen Training (PROMPT) an der Medizinischen Hochschule Hannover

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I. Introduction

Advances in medicine over the past decades have resulted in already low complication rates in pregnancy and childbirth. However, several rare conditions at birth lead to serious, long-lasting consequences for both the mother and her newborn. A substantial number of these conditions have been considered fateful until today because the dogma has been that they cannot be trained.

These include fetal acidosis and hypoxia, shoulder dystocia, spontaneous breech delivery and spontaneous twin birth, pre-eclampsia and eclampsia, maternal sepsis, maternal collapse and cardiac arrest, difficult airways, umbilical cord prolapse and acute uterine inversion. The outcome of both the mother and newborn will depend on the training, timely diagnosis and appropriate management of such cases.

The key to effective management of such conditions is a scientific effort derived from clinical studies, teamwork, communication and a standardized approach using algorithms for all specialisations involved, using patient actors and simple props (mannequins) including midwives and obstetricians, paediatricians and anaesthetists. This should include in holistic training concepts (authenticity). However, the most critical key is training together as a team ('those who work together should train together'), and training must be repeated at least annually in more than 90% of staff.

A team of obstetricians and midwives has introduced such a concept in Bristol, United Kingdom, at the Department of Women's Health, Southmead Hospital, Bristol BS10 5NB, the U.K. in 2000: **PR**ACTICAL **O**BSTETRIC **M**ULTI **P**ROFESSIONAL **T**RAINING (**PROMPT**).

Even well-designed training concepts have, in some cases, destabilized well-working teams and resulted in even higher complication rates. It is therefore mandatory for every training concept to be validated. This applies both to the idea itself and the maternity unit and labour ward where it is introduced.

The effectiveness of the PROMPT concept is published on the website of PROMPT New Zealand (https://www.promptnz.org/evidence-of-effectiveness), and there is now cumulative evidence of its efficacy in various hospitals, cities, countries and even continents (for details see also: http://www.promptmaternity.org, PROMPT overseas).

Previous studies have shown a reduction of permanent brachial plexus palsy, improved neonatal outcomes (reduced 5´ APGAR-score and hypoxic-ischaemic encephalopathy), the improved outcome of the management of umbilical cord prolapse, improved knowledge and skills, learning about the best suitable dummies and in particular reduced frequency and cost of litigation.

No studies or information are published on the spontaneous breech and twin birth, pre-eclampsia and eclampsia, maternal sepsis, maternal collapse and cardiac arrest, difficult airways, umbilical cord prolapse and acute uterine inversion.

The following paragraphs describe the evidence published already on the various complications in labour and childbirth.

A total of ten studies from the UK evaluated the differences in the neonatal outcome before and after the introduction of PROMPT training. PROMPT training has shown in a simulation setting an improved rate of **Shoulder Dystocia** delivery of the fetus from 50% to 85% (1) and from 42.9% to 83.3% (2), as well as an increased rate of performing the appropriate manoeuvres from 46,.3% to 99.8% (3). Furthermore, under clinical conditions, there was a reduction of **Brachial Plexus Injury** (**BPI**) from 9.3% to 2.3% (4,5) as well as a reduction of about 50% of **low APGAR-Scores** and **Hypoxic-Ischemic Encephalopathy** (**HIE**) (6) (Table 2). This resulted in a substantial overall improvement in shoulder dystocia management (1–4,6–9) (Tables 1 and 2). Also, the theoretical knowledge of midwives and obstetricians improved by 92.5% to a better score in an MCQ test after the training compared to before (9,10).

The studies by Draycott et al., 2008, Weiner et al., 2014 and Zhang et al., 2014 were tested the hypothesis that PROMPT-Training does not reduce BPI rate. The hypothesis was rejected at an α-level of $p<0.05$ (significant levels: *significant $p<0.05$, **highly significant $p<0.01$).

The hypothesis was disproven, and there was a reduction for both the percentage and the relative risk for brachial plexus injury in shoulder dystocia for each one of the studies and a combination of the three (Table 1) (3,4,11) In the study by Weiner et al., 2014 (11) the number of permanent brachial plexus injury went down to zero, whereas this was not the case for Draycott et al., 2008 (4) Bristol has, however, had no permanent brachial plexus injuries for the last ten years (12).

Table 1. Brachial plexus injury *in shoulder dystocia pre and post PROMPT Training:*

	Shoulder dystocia incidents	**Odds ratio (95% CI)**	**Brachial plexus injury (vaginal)**	**Odds ratio (95% CI)**	**Relative risk reduction (RRR) %**	**p-value**
1996-1999 (**pre**) (4)	324 (15,908) 2.04%		39 (324) 12.04%			
2001-2004 (**post**) (4)	262 (13,117) 2.00%	OR=0.98 (0.83, 1.16)	10 (262) 3.82%	OR=0.29 (0.14, 0.59)	68.1%	0.04*
2008-2010 (**pre**) (11)	113 (3285) 3.44%		10 (113) 8,5%			
2011-2012 (**post**) (11)	95 (2589) 3.67%	OR=1.07 (0.81, 1.41)	0 (95) 0%	OR= 0.05 (0, 0.95)	100%	<0.01**
2009-2012 (**post**) (3)	562 (17073) 3.29%		8 (562) 1,42%			
total (pre)[1]	437 (19193) 2.28%		49 (437) 11.21%			
total (post)[2]	919 (32779) 2.80%	OR=1.24 (1.1, 1.39)	18 (919) 1.96%	OR=0.16 (0.09, 0.28)	82.5%	0.009**

OR, relative risk reduction and statistical significance, CI, confidence interval.

(significant levels: *significant p<0.05, **highly significant p<0.01)

(5) Draycott et al., 2008
(20) Weiner et al., 2014
(4) **post** Zhang et al., 2014 **only**
[1]total **pre combined** (Draycott et al., 2008 and Weiner et al., 2014)
[2] total **post combined** (Draycott et al.; 2008; Weiner et al., 2014; Zhang et al., 2014)

Table 2. *Improvements in* ***neonatal outcome*** *pre and post PROMPT Training.*

Neonatal outcome	**1998-1999 (pre)**	**2001-2003 (post)**	**Relative risk reduction**	**p-value**
5´ APGAR-score <6	73 (8,430) 0.86%	49 (11,030) 0.44%	51%	<0.001**
Hypoxic ischemic encephalopathy (HIE)	23 (8,430) 0.27%	15 (11,030) 0.14%	50%	0.03*
Moderate / severe HIE	16 (8,430) 0.19%	11 (11,030) 0.10%	53%	0.09

(significant levels: *significant p<0.05, **highly significant p<0.01)

In the study by Draycott et al., 2006 (6), the following hypothesis was tested: PROMPT-Training does not improve the neonatal outcome. The hypothesis was rejected at an α-level of $p<0.05$.

A randomized control trial comparing the effectiveness of training for **eclampsia** in local hospitals and a regional simulation centre in the UK showed marked improvement in all aspects of care after training. There was a significant increase in completion of basic tasks (87% to 100%), such as the administration of Magnesium sulfate (61% to 92%) (13), which was almost 2.5' faster (14).

Deering et al. studied a simulation for **postpartum haemorrhage** (PPH) secondary to uterine atony (15,16). Unfortunately, less than one-half (45%) corrected the haemorrhage within 5 minutes, and 47.5% made a medication error. On the other hand, Maslovitz et al. and Siassakos et al. have shown that simulation training in PPH was associated with an improvement in competent management which was still seen six months after the training (17,18).

Siassakos et al. conducted a retrospective cohort study to assess the effect of PROMPT on the management of **cord prolapse** (19). After the training, a significant reduction in the diagnosis-delivery-interval from 25 min to 14 min, a decrease in low APGAR-scores from 6% to 0% and a reduction in the rate of admission to the neonatal intensive care unit (NICU) from 38.5% to 22.2% was observed (Table 3).

Table 3. *Improved* ***umbilical cord prolapse*** *management pre and post PROMPT.*

Umbilical cord prolaps	1993-1999 (**pre**)	2001-2007 (**post**)	p-value
Number of eligible cases (N,Y)	*N=34*	*Y=28*	
Diagnosis-delivery time	25'	14'	<0.001*
Actions to alleviate cord compression	34.78%	82.35%	0.003*
Low APGAR-score (5´<7)	6.45%	0%	0.302
Admission to NICU	38.46%	22.22%	0.210

(significant levels: *significant $p<0.05$, **highly significant $p<0.01$)

Also, the studies from Croft et al. (2,9,13,20,21) have shown a statistically significant increase in the participants' knowledge before and after the PROMPT-Training (Table 4).

Table 4. *The effect of PROMPT on the* ***knowledge and skills*** *of the trainees.*

Knowledge level of trainees	**Before** training	**After** training	Relative risk (difference in ability)	p-value
Participants score in multiple choice test (N=133) (9)	80.4 (185) 43.5%	101.0 (185) 54.6%	20.6%	0.03
Shoulder dystocia simulation trainees achieving delivery (2)	60 (140) 42.9%	110 (132) 83.3%	48.5%	<0.001
Teams of participants, completing basic tasks[1] (13)	20 (23) 87%	24 (24) 100%	13%	NP[2]
Teams preparing loading dose of Magnesium (LDM) (13)	17 (23) 74%	23(24) 96%	23%	0.06
Teams administering LDM (13)	14 (23) 61%	22 (24) 92%	33.7%	0.04
Teams preparing maintenance DM (13)	4 (23) 17%	9 (24) 38%	55.3%	0.06

(significant levels: *significant p<0.05, **highly significant p<0.01)

[1] Basic task: called for help, stated problem, called anaesthetist, lowered head rest, recovery position, oxygen administrated.
[2] NP: not possible to test because there were no disjoint pairs at all or only one.

These promising and impressive results led to the implementation of PROMPT in the U.S.A., Australia, New Zealand and South Africa.

A 5-year retrospective analysis from Kansas University (U.S.A.) showed a 6% reduction in C-section (CS) rates, improved recognition of shoulder dystokia and also a reduction of BPI from 10.7% to 0% (11). In addition, Samuel Smith's study in Baltimore (U.S.A.) showed a significant improvement in the management of shoulder dystocia, in particular, a delivery time reduction from 146 sec to 61 sec, a call for help and attendance of a paediatrician increase from 35% to 94% and from 8% to 75% respectively, and improved communication with patients increasing from 57% to 83% (22).

PROMPT was implemented in 8 maternity units of Australia in 2008. Initial studies have shown a positive impact on the perinatal outcome (23). Further confirmation came from a retrospective cohort study performed by Shoushtarian et al. (24), published in 2014. The percentage of staff participating in the training was 50%. The study population was 43,408 babies who were born between July 2008 and December 2011. Before implementing PROMPT, the 1´ APGAR-score < 7 was 9.1%, which could significantly be reduced to 8.3% during the training period (p=0.017). The training was upheld, leading to a further reduction to 7.7% (p=0.087). However,

the frequency of a 5´ APGAR-score <7 and major postpartum haemorrhage (>1500ml) remained unchanged. The percentage of umbilical cord lactate >5.27 mmol/l went down from 25% before to 24.7% during the training (p=0.044) and 23.4% following completion of the training (significant, p=0.028). Also, a significant reduction in the length of the hospital stay was observed during the training (mean [SD]= 2.79 [1.55] days) compared with pretraining (2.85 [1.55] days) (p=0.006).

PROMPT Training was implemented in New Zealand in 2016. There are many studies ongoing to evaluate the impact of PROMPT on the management and outcome of rare obstetrical emergencies.

A big challenge was the implementation of PROMPT in South Africa. According to the study of Neil F. Moran et al. (25), which was published in 2015, before the implementation of the multi-professional obstetric training, the maternal mortality rate caused by obstetric haemorrhage, hypertensive disorders of pregnancy and abortion was very high with 58.5% of the direct maternal deaths classified as clearly avoidable, had better care been supplied by the health care system (1998-2005). As a result, in 2005, professional development teaching courses were introduced to reduce the high mortality. However, these courses did not include practical training and were not structured and organized following evidence-based medicine. The result was an increase in maternal morbidity and mortality until 2007, with no effect on the neonatal outcome. Overall, 53% of maternal deaths were classified as possibly or potentially avoidable had better care been rendered by the health service.

In particular, deaths due to obstetric haemorrhage had increased by 40%, and 80% of the haemorrhage deaths were assessed as possibly or probably avoidable. In 2009 the first organized African continent-wide effort to implement ESMOE (**E**ssential **S**teps in the **M**anagement of **O**bstetric **E**mergencies) took place, a standardized, structured and regular theoretical as well as a practical training program for doctors and midwives, based on PROMPT's principles but adapted in the South African's health system and capabilities. The statistical analysis of the period 2011-2013 showed a decrease in maternal deaths by 11%. The effect of PROMPT is well recognized but is only a tiny step in increasing the safety of the health care system in South Africa. Many initiatives are underway to adapt and reconfigure the PROMPT concept locally to reduce further Africa's maternal and fetal morbidity and mortality.

One of the most important general aspects of PROMPT-Training is the positive influence on the teamwork and climate between the colleagues. Clinical skills, knowledge and the implementation of care practices (26) are considered the most prominent practical training goals. Still, its impact on social skills and the team climate are probably equally important. As expected (21,27), suboptimal teamwork (28), lack of leadership and inadequate communication will result in a poor outcome. The basic principle of PROMPT is that people who work together also train together. A retrospective analysis (29) has shown a statistically significant improvement in responses to questions relating to the safety culture on the wards (p=0.036). Teamwork climate and job satisfaction (30) also improved following training, but the

evidence was not strong (p=0.052). A significant post-training improvement was relevant for doctors and nurses 'working well together' (p<0.001).

A review analysis from Bristowe et al. (31) asked the trained teams about the factors that might influence teamwork during clinical emergencies and teamwork skills that were desirable but had been largely missing from their training or development as individuals or as a team. Clear **leadership**, **communication**, and **patient-centred care** were seen as necessary to most participants who described practical ways to 'be a leader', communicate critical information, delegate tasks or maintain a patient focus during the emergency. These assessments underline the importance of leadership. Cornthwaite et al. (32), in 2013, tried to summarize all the characteristics that 'make a good leader'. According to the study, leadership is best established by the person who has the most extensive experience in managing an emergency. It is also more effective when the leader knows all the members of the multi-professional team and their relevant roles before the emergency happens. Finally, the leader should keep in mind the three components of the emergency (team, situation, patient focus), establish the situation, allocate critical tasks with closed-loop communication (directed-acknowledged-confirmed), and, if necessary, pass leadership to team members that are more experienced for that specific emergency at hand.

According to these, we can conclude the virtues which each participant should get from the PROMPT-Training (33):

1. Find out the clinical situation (and maintain regular updates).
2. Know or find out what the team members can do for the emergency at hand.
3. Declare or allocate leadership verbally based on the relevant experience of the emergency at hand.
4. Use closed-loop communication to assign critical tasks to team members.
5. Keep patients and companions informed, paying attention to the content of the communication.
6. Team leaders should focus on leadership to ensure effective teamwork unless the task is simple or no one else can do it.

Another critical aspect of every training concept is the scientific basis, the props and the mannequins. As expected, the choice will affect the cost of the training and possibly the results achieved. PROMPT-Training has used both patient-actors and training with mannequins. Several studies were performed to compare the results of each concept and how they affected the outcome of training.

The results of using patients-actors or mannequins during the training were compared (34). There were two Groups of trainees. The first Group of 139 participants was trained in 46 scenarios with a patient-actor. The second Group consisted of 132 participants in 48 scenarios and was taught using mannequins. There was a significant improvement in all scores after the training (p=0.017-0.001). In addition, the perception of safety and communication during postpartum haemorrhage improved after patient-actor training compared to training with mannequins only (safety p=0.048, communication p=0.035). A further study was performed on students (35). Training consisted of a high-fidelity simulation teaching

session for 24 students and a refresher session for which the same students were randomly allocated to the two Groups. Half attended a small-Group tutorial (SGT), and the other half a simulation session with a patient-actor (hybrid simulation, HYB). During the scenario, they were asked to deliver a baby with simulated shoulder dystocia. Their practical communication skills between SGT and HYB were compared. The primary outcome measure was their communication score, using a validated scale. A secondary measure was the students' ability to deliver the baby appropriately. After the training, all students managed delivery properly. The Group trained with the patients-actor had significantly higher median total patient perception scores than SGT (11 simulation versus 9 tutorial, p=0.024). The results show clearly a superiority of the training with patients-actors compared with mannequins.

The use of well-trained patient-actors may be costly and may not always be possible. A possible solution for that is more extended use of mannequins in the training centres. The evolution of technology has led to more sophisticated training devices and has given mannequins new opportunities (36), making them more expensive. In a study by Crofts et al., (37) the question was addressed whether using high- or low-fidelity dummies to train shoulder dystocia yields better training results. The results are shown in the table below (Table 5).

Table 5. *Different results between using high- and low-fidelity mannequins.*

	High-fidelity mannequin (**post**-training) N^1 (64)	**Low**- fidelity mannequin (**post**-training) N^2 (68)	p-value
Successful delivery rate	94%	72%	0.002
Applied force	2,030 Newton seconds	2,916 Newton seconds	0.006
Call for pediatric support	22%	47%	0.003

(significant levels: *significant p<0.05, **highly significant p<0.01)

Each training was associated with improved performance pre-and post-training, respectively: use of **basic manoeuvres** 114 of 140 (81.4%) to 125 of 132 (94.7%) (p=0.002), **successful deliveries** 60 of 140 (42.9%) to 110 of 132 (83.3%) (p<0.001), **good communication with the patient** 79 of 139 (56.8%) to 109 of 132 (82.6%) (p<0.001). In addition, training on a high-fidelity mannequin offered some additional training benefits, such as increased delivery rates. Furthermore, it reduced the applied force, thus showing advantages in the process.

To conclude, the advantage of using patient-actors in these studies is evident and using high-fidelity dummies over low-fidelity ones. However, every training has improved the management and the control of incidents. Furthermore, training simulations should also be sustainable to provide the expected results (38,39).

Therefore, for every health centre that undergoes training, it is crucial to assess the consequences and the funds used for training to be cost-effective.

We will mention a critical issue, which is of interest for Health Organization Communities. It is the cost of implementing and maintaining a training program such as PROMPT. Many retrospective studies were performed to estimate the costs of PROMPT and how it affects the costs of adverse outcomes (40–44) (Table 6).

Table 6. *Reduction of* ***litigation Costs*** *after the implementation of PROMPT.*

USA	2003-2006 **(pre)**	2007-2009 **(post)**
Reduction of the litigation costs because of adverse perinatal outcomes (40,41)	28 million $	2.5 million $
Reduction of the litigation costs in the **United Kingdom** around **91%** (42)		
In **Australia,** the litigation costs' reduction is 20 times higher than the cost of the PROMPT-Training (42)		
This study made in the **Southend Hospital in Bristol** (about 6500 births annually) has shown that the estimated annual cost of PROMPT Training is 148.806€/year (22.000€/1000 births). Because of the training, the rate of **BPIs** and **HIE** is reduced, translating into a reduction of litigation costs to 7.5million €/year and 25million €/year, respectively. As a result, it is clear that at the expense of around 150.000 €/year, savings of 32.5million € were achieved. (43)		

The analysis of the results shows that local multi-professional obstetric emergency training is expensive. There is, however, evidence that it is cost-effective. In Australia an insurer funded the training and has also calculated the reduction in litigation claims: the reduction in litigation costs were over 20 times the cost of the training, the benefits to families and society notwithstanding (42).

PROMPT training was implemented at the Hannover Medical School (Germany) for the first time in 2017. The corresponding multidisciplinary training was based on scientific studies and teamwork while focusing intensely on communication skills. However, and most importantly, it was about enjoying the whole activity.

This study aimed at testing the hypothesis whether practical PROMPT-Training at the Hannover Medical School, Hannover, Germany, improved complication rates.

II. Materials and Methods

This retrospective and observational study compared the management, neonatal and maternal effects of births before and after introducing PROMPT (**PR**actical **O**bstetric **M**ulti-Professional **T**raining) at the Hannover Medical School.

The population included deliveries complicated by fetal acidosis and hypoxia, shoulder dystocia, spontaneous breech delivery and spontaneous twin birth, pre-eclampsia and eclampsia, maternal sepsis, maternal collapse and cardiac arrest, difficult airways, umbilical cord prolapse and acute uterine inversion.

The evidence suggested that PROMPT training was required as annual multi-professional obstetric team training at the Hannover Medical School. Furthermore, yearly attendance of at least 90% by all midwifery, obstetric, pediatric and anaesthetic staff is mandatory for PROMPT to be effective and was pursued (45).

Care for mothers and babies was delivered by three faculties. Each one consisted of several professions: **Obstetrics:** obstetricians & midwives, **Neonatology:** neonatologists & pediatric nurses and **Anaesthesiology:** anaesthesiologists & anaesthesia nurses and theater nurses. The attendants have Grouped accordingly into three Groups (numbers from 2019).

Most professionals were working full time, but a substantial number in each Group was working reduced part-time. However, the exact distribution was not accessible and was, therefore, not taken into account.

Obstetricians all participated in calls on the labour ward, but only about 1/3 worked exclusively in the labour ward full time. There were 46 gynaecologists in the department, 18 consultants/specialists and 28 residents. In obstetrics, there was one professor and 1.5 consultants. In Fetal Medicine, there was also one professor and two specialists working part-time and one resident.

The majority of *midwives* worked in the labour ward. There were 42 midwives in total, 33 working in the labour ward, five on high-risk pregnancy wards, two on the postpartum ward and two in the antenatal care outpatient clinic. A few of them followed a rota, but the majority did not rotate. On the wards, there were also nurses (23), pediatric nurses (23) and lactation consultants (7).

Neonatologists worked on the Neonatal Intensive Care Unit within the Department of Pediatrics. There were 20 neonatologists, 1.5 professors, the deputy, seven consultants and 11 residents. There were 62 nurses.

Some of the *anaesthesiologists* worked in the labour ward and the operating theatre. The Hannover Medical School is known as a transplantation centre. The total number of anaesthesiologists was 167, of which 102 were consultants and 67 were residents.

Thirty-two doctors participated in calls to the labour ward from this Group, including cesarean sections and epidurals (cesarean section Group on-call). This Group was the PROMPT training Group. In addition, 30 anaesthesia nurses and 15 theatre nurses participated in daily duties on the labour ward and were on calls. These professionals made up the team that cared for women and their babies.

Table 7. *Number and percentages of annual participants of each discipline in at least one whole training day consisting of a minimum of three to four modules (2018) and six modules (2019).*

PROMPT participation in the year 2017 (test run)			
	Cumulative	Participated	Not participated
Obstetricians			
Consultant doctors	14	5 (36%)	9 (64%)
Resident doctors	22	6 (27%)	16 (73%)
Midwives	38	11 (29%)	27 (71%)
Total participation	74	22 (30%)	52 (70%)

PROMPT participation in the year 2018			
	Cumulative	Participated	Not participated
Obstetricians			
Consultant doctors	17	10 (59%)	7 (41%)
Resident doctors	23	15 (65%)	8 (35%)
Midwives	38	35 (92%)	3 (8%)
Neonatologists			
Doctors	16	4 (25%)	12 (75%)
Nurses	64	0 (0%)	64 (100%)
Anaesthesiologists			
Doctors	28	7 (25%)	21 (75%)
Nurses	30	6 (20%)	24 (80%)
Theater nurses	14	5 (36%)	9 (64%)
Total participation	230	82 (35.7%)	148 (64.3%)

PROMPT participation in the year 2019			
	Cumulative	Participated	Not participated
Obstetricians			
Consultant doctors	18	10 (56%)	8 (44%)
Resident doctors	28	14 (50%)	14 (50%)
Midwives	42	42 (100%)	0 (0%)
Neonatologists			
Doctors	20	3 (15%)	17 (85%)
Nurses	62	4 (7%)	58 (93%)
Anaesthesiology			
Doctors	32	7 (22%)	25 (78%)
Nurses	30	4 (14%)	26 (86%)
Theater nurses	15	4 (27%)	11 (73%)
Overall participation	247	88 (35.6%)	159 (64.4%)

In 2017, there was a PROMPT test run.
In 2018, the 14 modules were split into four days. Each day comprised four modules, ensuring that the entire course incorporated all of the modules. Shoulder dystocia, spontaneous breech delivery and basic newborn resuscitaiton were repeated.
In 2019, the number of modules per day increased, allowing to run all modules (the whole course) twice a year.
Initially, this practice resulted in seven theoretical lectures and six practical simulations. However, rare complications such as cord prolapse and uterine inversion were infrequently run to slightly reduce the number of realistic simulations, as six modules were too challenging to follow for participants (Table 8).

Table 8. *Modules trained theoretically and practically during each training day in each year (2017,2018,2019).*

Training date	**Modules**
08.11.2017	– major obstetric haemorrhage – shoulder dystocia – spontaneous breech delivery
12.04.2018	– fetal monitoring – umbilical cord prolapse – shoulder dystocia – spontaneous breech delivery
15.05.2018	– shoulder dystocia – spontaneous breech delivery – spontaneous twin birth

	– basic newborn resuscitation
12.09.2018	– pre-eclampsia and eclampsia – maternal sepsis – major obstetric haemorrhage – acute uterine inversion
14.11.2018	– basic life support and maternal collapse – maternal cardiac arrest and advanced life support – maternal anaesthetic emergencies – basic newborn resuscitation and support of transition
27.02.2019	– fetal monitoring – umbilical cord prolapse – shoulder dystocia – spontaneous breech delivery – spontaneous twin birth – acute uterine inversion – basic newborn resuscitation and support of transition
13.03.2019	– basic life support and maternal collapse – maternal cardiac arrest and advanced life support – maternal anaesthetic emergencies – pre-eclampsia and eclampsia – maternal sepsis – major obstetric haemorrhage
18.09.2019	– fetal monitoring – umbilical cord prolapse – shoulder dystocia – spontaneous breech delivery – spontaneous twin birth – acute uterine inversion – basic newborn resuscitation and support of transition
13.11.2019	– basic life support and maternal collapse – maternal cardiac arrest and advanced life support – maternal anaesthetic emergencies – pre-eclampsia and eclampsia – maternal sepsis – major obstetric haemorrhage

The training days included a 4-hour theoretical presentation session about each complication's academic background and management algorithms. After a break, the course was continued by practical fire drills consisting of simulations using patient actors and high fidelity mannequins (PROMPT Flex, SimMom, Laerdal, Puchheim, Germany). Trainees were separated into Groups of 5-8 participants (1-3 midwives, 1-2 obstetricians, 1-2 anaesthesiologists, 1 paediatrician and nurses from each Group). Groups were split equally, with one-half practising and the other observing.

After 15 Minutes, they switched roles.
The training consisted of a briefing before the scenario, covering risk factors, recognition of the emergency, teamwork, communication, demonstration of resolution manoeuvres. Documentation and debriefing were done by the trainer, who also moderated a discussion with the trainees after each scenario. Participants were asked about their view and perception, things that went well were emphasized, subjects with the potential for improvement were also constructively mentioned. However, there was no pass or fail, and participants were not rated for their performance. Overall, there was an atmosphere without anxiety, allowing participants to practice and learn until they were satisfied with the techniques without fearing sanctions or being distressed.

The practical training started with a briefing by a midwife presenting the patient's clinical data to the obstetrician, who was supposed to determine the situation, call for help, and perform the necessary manoeuvres to solve the crisis. According to the module trained, the scenario ended after the delivery of the fetus, after the decision for an emergency caesarean section or after the mother's stabilisation.

The training aimed at improving the participants' knowledge about obstetrical emergencies, their capability to identify the problem, simplify the management of each crisis through fast algorithms, and achieve better communication and team working within the whole team.

The impact of training following its introduction was assessed by comparing complication rates before and after the implementation.

All infants born during 16 years, from January 1st 2004, until December 31st 2019, were identified using a computerized fetal database (Viewpoint V.5 and V.6).

A query was conducted to identify major complications described in the modules. Two identical questions, both for versions 5 and 6, were run. This step became necessary as Viewpoint went through a major update in July 2019.

In addition, all birth books from 2004 until 2019 were examined and checked by hand to identify further complications. Thus, all of the existing investigated complications were identified.

All cases of neonates with suspected plexus injury following shoulder dystocia were followed up at the age of one year, and the outcomes were recorded.

To visualise the PROMPT-Training effect, the cases were Grouped by module and compared between the Groups before and after the onset of training for the incidence of obstetrical complications.

Deliveries from January 1st 2004, and November 8th 2017, were from before the training.

The period from November 9th 2017 (test run) until 31st December 2019 were after the implementation of training.

The results were reported in absolute numbers as well as proportions (%), with p-value (<0.05 as considered to be significant), RRR and 5% to 95% CI, where appropriate.

Statistical Methods:

In the case of qualitative variables, absolute and per cent frequencies are shown.

The two study Groups (before and after PROMPT-Training) were contrasted using contingency tables and tested for significant differences using the chi-square test. If the expected frequencies proved too low, Fisher's exact test was applied. In case of significant differences, Odds Ratios with 95% CI were calculated. Relative risk reduction was also calculated for all qualitative parameters.

Quantitative variables were presented as the mean with standard deviation or median with range. The variables were tested against the hypothesis of normal distribution using the Kolmogorov–Smirnov test. In case of evidence for deviations from the normal distribution, both Groups were compared using the Mann–Whitney U test; otherwise, the independent samples t-test was used.

Statistical tests were performed two-sided at a significance level of 5%. Due to the descriptive nature of the present analysis, no alpha adjustment for multiple testing was applied, and the results were interpreted accordingly.

Statistical analyses were undertaken using IBM SPSS Statistics 26 (SPSS Inc. an IBM Company, Chicago, IL).

Ethical approval was obtained from the Hannover Medical School Ethical Committee (Nr.8268 BO K 2019, 16th January 2019).

Table 9. *Here, we present conditions searched for in the database using a variety of queries.*

<table>
<tr><th>Labour ward / Delivery</th><th>Newborn</th><th>Mother</th></tr>
<tr><td>Mode of delivery
Primary C-section
Secondary C-section</td><td>Newborn-biochemistry
NA-pH-Value
NV-pH-Value
BE artery and vein
Lactate</td><td>Puerperium bleeding
>1000ml
yes
Postpartum bleeding:
500-1000
1000-1500
1500-2000
2000-3000</td></tr>
<tr><td>C-section Details
Hysterectomy</td><td>Well-being
APGAR: 1-5-10 Minutes
Gender, Weight, KU, Length
Reanimation
Intubation
Transfer NICU</td><td>Puerperium eclampsia
Yes</td></tr>
<tr><td>Emergency C-section</td><td rowspan="5">Morbidity
Shoulder dystocia
Brachial plexus lesion
Brachial plexus injury
Subdural bleeding
Cerebral bleeding
Intraventricular bleeding
Subarachnoid bleeding
Intracranial non-traumatic bleeding
Severe asphyxia
Light asphyxia
Fetal death</td><td>Puerperium maternal death
Yes (42 days to 1 Year p.p.)</td></tr>
<tr><td>Bleeding >1000ml</td><td>Puerperium sepsis
Yes</td></tr>
<tr><td>Perineal tear
3rd Grade
4th Grade</td><td rowspan="2">Other diagnoses
Shock in labour
Cardiac arrest,
Hypoxia / ECMO
Pulmonary embolism
Premature placental abruption
Placenta Accreta
Placenta increta/percreta
postpartum bleeding,
Uterine atony
Subluxation of the symphysis
Cervical tear</td></tr>
<tr><td>Indications for operative Delivery
Uterine rupture before contractions
Uterine rupture in labour
Eclampsia:
- in pregnancy
- in labour</td></tr>
</table>

After obtaining the data of complications, results were organized according to the modules used for the training. Complication rates were then compared for the training periods before and after the introduction of training:

- Teamwork
- Basic life support and maternal collapse
- Maternal cardiac arrest and advanced life support
- Maternal anaesthetic emergencies
- Fetal monitoring in labour
- Pre-eclampsia and eclampsia

- Maternal sepsis
- Major obstetric haemorrhagia
- Shoulder dystocia
- Cord prolapse
- Vaginal breech birth
- Twin birth
- Acute uterine inversion
- Basic newborn resuscitation

The definitions for each one of the major obstetrical complications were as follows:

Pre-eclampsia (46): Any increased blood pressure ≥ 140/90 mmHg during pregnancy with at least one new organ manifestation that cannot be assigned to any other cause. In pre-eclampsia, the organ manifestation can typically be detected in the kidneys through proteinuria ≥ 300 mg/d or protein/creatinine-quotient ≥ 30 mg/mmol.

Eclampsia (46): Tonic-clonic seizures occurring during pregnancy (often associated with pre-eclampsia) that cannot be assigned to any other neurological cause (e.g. epilepsy).

Sepsis (47): The definition of sepsis was subjected to changes in 2016. In our cases, we used the definitions from 2003 to 2016 and from 2016 to 2020.

Sepsis I (2003-2016): a clinical syndrome with two or more SIRS criteria (Systemic inflammatory response syndrome), in addition to known or suspected infection.

SIRS Criteria:

- Fever (core temperature >38.3°C)
- Hypothermia (core temperature <36°C)
- Heart rate >90 bpm or >2 SD above the normal value for age
- Tachypnea: >30 bpm
- Altered mental status
- Significant oedema or positive fluid balance (>20 ml/kg over 24 h)
- Hyperglycemia (plasma glucose >110 mg/dl or 7.7 mmol/l) in the absence of diabetes
- Leukocytosis (white blood cell count >12,000/µl)
- Leukopenia (white blood cell count <4,000/µl)
- Normal white blood cell count with >10% immature forms Plasma C reactive protein >2 SD above the normal value Plasma procalcitonin >2 SD above the normal value
- Arterial hypotension (systolic blood pressure <90 mmHg, mean arterial pressure <70, or a systolic blood pressure decrease >40 mmHg in adults or <2 SD below normal for age)
- Mixed venous oxygen saturation >70%
- Cardiac index >3.5 l/min/m

- Arterial hypoxemia (PaO2/FiO2 <300)
- Acute oliguria (urine output <0.5 ml/kg/h for at least 2 h)
- Creatinine increase ≥0.5 mg/dl
- Coagulation abnormalities (international normalized ratio >1.5 or activated partial thromboplastin time >60 s)
- Ileus (absent bowel sounds)
- Thrombocytopenia (platelet count <100,000/µl)
- Hyperbilirubinemia (plasma total bilirubin >4 mg/dl or 70 mmol/l)
- Hyperlactatemia (>3 mmol/l)
- Decreased capillary refill or mottling

Sepsis II (2016-2020): a 'life-threatening organ dysfunction caused by a dysregulated host response to infection.' Septic shock is defined as lactate levels rising above two mmol/l without hypovolemia and initiation of vasopressor treatment to keep mean arterial pressure above 65 mmHg. Organ dysfunction is defined as an increase of two or more in the Sequential Organ Failure Assessment (SOFA) scoring system. It was determined that this caused a more than 10% increase in hospital-related mortality.

SOFA score	1	2	3	4
Respiration			----- with respiratory support -----	
PaO_2/FiO_2 (mm Hg)	<400	<300	<200	<100
Coagulation				
Platelets $\times 10^3/mm^3$	<150	<100	<50	<20
Liver				
Bilirubin (mg dL^{-1})	1.2-1.9	2.0-5.9	6.0-11.9	>12.0
Cardiovascular				
Hypotension	MAP <70	Dopamine ≤5 or dobutamine (any)	Dopamine >5 or norepinephrine ≤0.1	Dopamine >15 or norepinephrine >0.1
Central Nervous System				
Glasgow Coma Score	13-14	10-12	6-9	<6
Renal				
Creatinine (mg dL^{-1}) or urine output (mL)	1.2-1.9	2.0-3.4	3.5-4.9 or <500	>5.0 or <200

MAP: mean arterial pressure; vasoadministered for at least 1 hr (dopamine and norepinephrine µg kg^{-1} min^{-1}).

Major obstetric haemorrhage (48): the blood loss of more than 500 ml following a vaginal delivery or 1,000 ml following a C-section.

Shoulder dystocia (49): a vaginal cephalic delivery requiring additional obstetric manoeuvres to deliver the fetus after the head has shown and gentle traction has failed. Shoulder dystocia occurs when the anterior, or less commonly the posterior, fetal shoulder impacts the maternal symphysis or sacral promontory.

Umbilical cord prolapse (50): the descent of the umbilical cord through the cervix alongside (occult) or past (overt) the presenting part in the presence of ruptured membranes. Cord presentation is the presence of the umbilical cord between the fetal presenting position and the cervix, with or without intact membranes. The overall incidence of umbilical cord prolapse ranges from 0.1–0.6%.

Vaginal breech delivery (51): breech presentation refers to the fetus in the longitudinal lie with the buttocks or lower extremity entering the pelvis first. The three types of breech presentation include frank breech, complete breech, and incomplete breech. In a frank breech, the fetus has flexion of both hips, and the legs are straight with the feet near the fetal face, in a pike position.

Twin birth: the delivery of two offspring in a single birth event.

Basic newborn resuscitation (52): emergency medical intervention techniques employed immediately after childbirth to assist babies who cannot breathe independently after birth.

Birth acidosis (53): fetal pH ≤ 7.0 and base excess ≤ -12 mmol/l, determined from umbilical artery blood or blood samples taken immediately after birth.

Birth asphyxia (53): signs of ’fetal distress’ plus at least one of the following parameters:

1) umbilical cord artery pH < 7.0
2) Base excess < -16 mmol/l
3) 5´ APGAR-score < 7

Birth injury (54)**:** laceration of the skin and other soft tissue structures that separate the vagina from the anus in women. Perineal tears mainly occur in women as a result of vaginal childbirth, which strains the perineum. It is the most common form of obstetric injury.

1) First-degree tear: laceration is limited to the fourchette and superficial perineal skin or vaginal mucosa
2) Second-degree tear: laceration extends beyond fourchette, perineal skin and vaginal mucosa to perineal muscles and fascia, but not the anal sphincter
3) Third-degree tear: fourchette, perineal skin, vaginal mucosa, muscles, anal sphincter are torn
4) Fourth-degree tear: fourchette, perineal skin, vaginal mucosa, muscles, anal sphincter, and rectal mucosa are torn

III. Results

1. Pre-eclampsia and Eclampsia

The main findings following the introduction of the PROMPT-Training were an increase in the documented cases of pre-eclampsia and a highly significant increase in the administration of Magnesium sulfate ($MgS0_4$). In contrast, the number of pre-eclampsia cases that progressed to eclampsia remained the same.

In detail, the data before and after the training showed a statistically significant increase in **pre-eclampsia cases** from before 155/27,198 (0.6%) to after 60/6,564 (0.9%) by about 50%, (p=0.002), (Table 10).

Table 10. *Total pre-eclampsia cases.*

	Group		
Pre-eclampsia	1	2	Total
No	27,043 (99.4%)	6,504 (99.1%)	33,547 (99.4%)
Yes	155 (0.6%)	60 (0.9%)	215 (0.6%)
Total	27,198 (100%)	6,564 (100%)	33,762 (100%)

Furthermore, our analysis has shown that the total cases complicated with **severe pre-eclampsia** (Table 11) and **eclampsia** (Table 12) remained unchanged. In detail, the cases with severe pre-eclampsia were slightly reduced, with before 72/155 (46.5%) to after 24/60 (40%) (p=0.39). The cases with eclampsia were slightly increased, with before 7/155 (4.5%) to after 4/56 (6.7%) (p=0.52) respectively, but none of these changes was statistically significant.

Table 11. *Total severe pre-eclampsia cases.*

Severe pre-eclampsia	Group		
	1	2	Total
No	83 (53.5%)	36 (60%)	119 (73.04%)
Yes	72 (46.5%)	24 (40%)	96 (26.96%)
Total	155 (100%)	60 (100%)	215 (100%)

Table 12. *Total eclampsia cases.*

	Group		
Eclampsia	1	2	Total
No	148 (95.5%)	56 (93.3%)	204 (94.9%)
Yes	7 (4.5%)	4 (6.7%)	11 (5.1%)
Total	155 (100%)	60 (100%)	215 (100%)

There was a statistically highly significant increase in the *total* number of cases of pre-eclampsia with **$MgSO_4$** administered from before 19/155 (12.3%) to after 20/60 (33.3%), ($p<0.001$), (Table 13).

Table 13. *Total cases of pre-eclampsia depending on $MgSO_4$ administration.*

	Group		
$MgSO_4$	1	2	Total
No	136 (87.7%)	40 (66.7%)	204 (94.9%)
Yes	19 (12.3%)	20 (33.3%)	39 (5.1%)
Total	155 (100%)	60 (100%)	215 (100%)

In *severe* pre-eclampsia, we observed a higher proportion in before 19/71 (26.76%) to after 20/25 (80%) $MgSO_4$-administration compared to pre-eclampsia ($p<0.001$), (Table 14).

Table 14. *Total severe pre-eclampsia cases depending on $MgSO_4$-administration.*

	Group		
$MgSO_4$	1	2	Total
No	52 (73.24%)	5 (20%)	57 (94.9%)
Yes	19 (26.76%)	20 (80%)	39 (5.1%)
Total	71 (100%)	25 (100%)	96 (100%)

In *eclampsia* again, there was an increase in cases after $MgSO_4$-administration from before 4/7 (57.14 %) to after 4/4 (100%).

A comparison was also performed between the two populations before and after the initiation of PROMPT-Training, in terms of other parameters associated with pre-eclampsia. These parameters were fetal pathologies, including IUGR (intrauterine

growth restriction), SGA (small for gestational age) and pathological doppler parameters. The results of this analysis are depicted in the diagrams below.

They clearly show that the percentage of pre-eclampsia pregnancies without associated fetal pathologies went down from 58% to 49%. In contrast, simultaneous fetal complications of hypertensive pregnancy disorders, in particular Fetal Growth Restriction, increased from 29% to 35%.
In addition, the proportion of fetal pathologies increased as well as the incidence of pre-eclampsia (0.57% vs 0.92%).

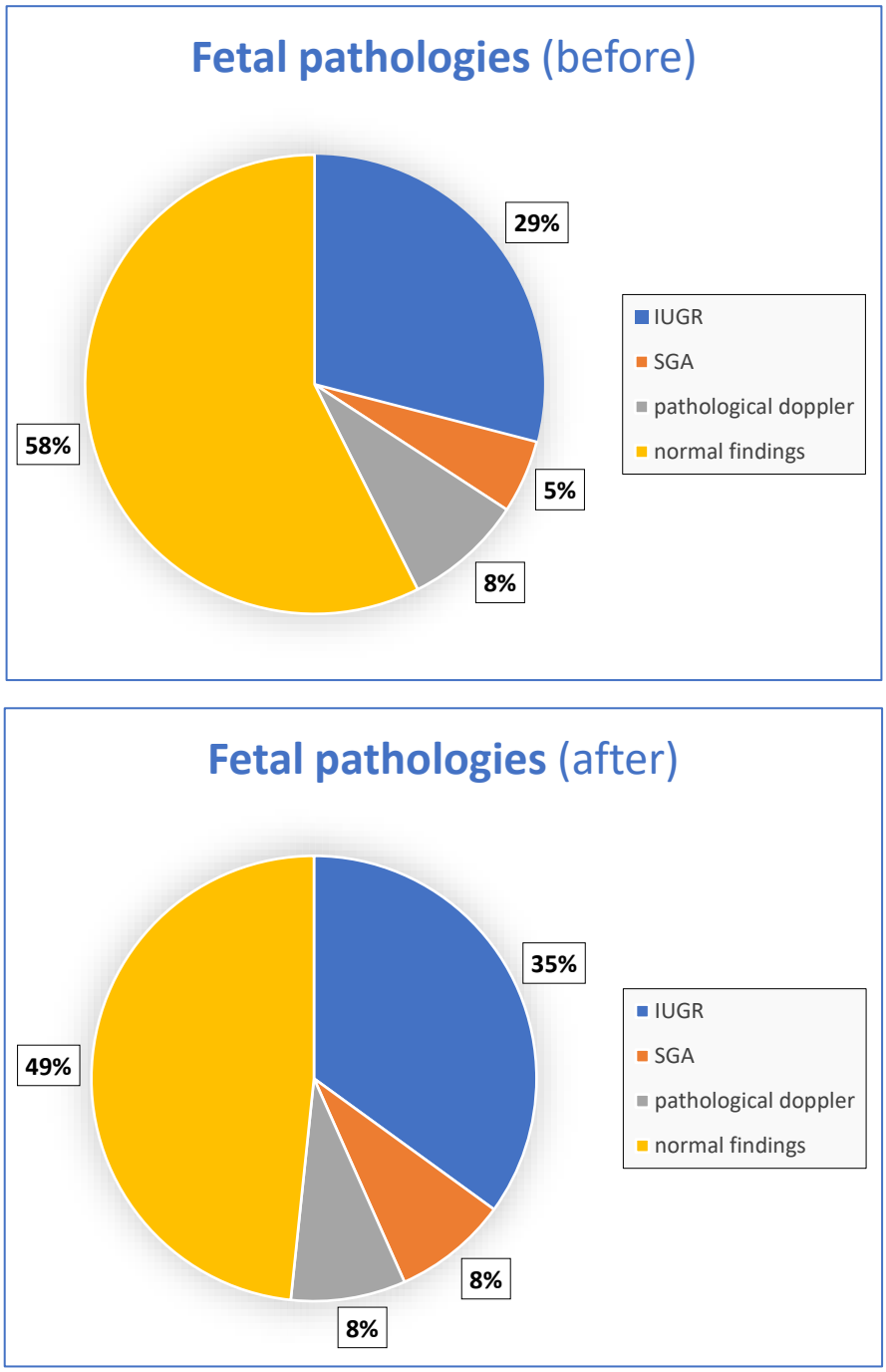


Figure 1. *The percentages of pregnancies with AGA, SGA and IUGR fetuses and those with pathological doppler findings before and after the training are shown.*

While the incidence of pre-eclampsia following the introduction of PROMPT-Training increased, the percentage of eclampsia did not.

2. Sepsis

The main findings after following the PROMPT-Training are a decrease in the number of pregnancies complicated by severe sepsis and a reduction in adverse outcomes following sepsis. However, a statistical analysis could not be performed as we only observed a single case with sepsis and zero adverse outcomes after the training.

In detail, the data before and after the training showed a decrease in **sepsis cases** from before: 17/27,198 (0.1%) to after: 1/6,564 (0.0001%), (Table 15).

Table 15. *Total sepsis cases.*

	Group		
Sepsis	1	2	Total
No	27,181 (99.9%)	6,563 (99.9%)	33,744 (99.9%)
Yes	17 (0.1%)	1 (0.0001%)	18 (0.1%)
Total	27,198 (100%)	6,564 (100%)	33,762 (100%)

Furthermore, our analysis has shown that the adverse outcomes, including **hysterectomy** and **maternal death**, were also drastically reduced from before 2/17 (11.8%) to after 0/1 (0%) and from before 3/17 (17.6%) to after 0/1 (0%) respectively, demonstrated in tables 16 and 17.

Table 16. *Hysterectomies for maternal sepsis.*

	Group		
Hysterectomy	1	2	Total
No	15 (88.2%)	1 (100%)	16 (88.9%)
Yes	2 (11.8%)	0 (0%)	2 (11.1%)
Total	17 (100%)	1 (100%)	18 (100%)

Table 17. *Maternal death cases.*

	Group		
Maternal death	1	2	Total
No	14 (82.4%)	1 (100%)	15 (83.3%)
Yes	3 (17.6%)	0 (0%)	3 (16.7%)
Total	17 (100%)	1 (100%)	18 (100%)

In addition, we performed a descriptive statistical analysis of other parameters associated with the clinical management of sepsis (Table 18).

Table 18. *Descriptive statistics of sepsis cases before and after training.*

Group		N	Mean	Min	Max	Centiles		
						25th	50th Median	75th
1	Days (ICU)	16	11.81	0	78	0	1	21.25
	Days (ward)	15	7.6	0	23	0	7	13.00
	Days (antibiotics)	16	33.13	1	282	7	9	25.75
	Sepsis onset before birth (days)	9	2.89	1	10	1	3	3.00
	Sepsis onset after birth (days)	8	4	1	8	1.25	5	5.00
2	Days (ICU)	1	0	0	0			
	Days (ward)	1	4	4	4			
	Days (antibiotics)	1	9	9	9			
	Sepsis onset before birth (days)	n.a.	n.a.	n.a.	n.a.			
	Sepsis onset after birth (days)	1	1	1	1			

The onset of sepsis before and after birth was identical (9/17 before and 8/17 cases after birth). Before introducing the PROMPT-Training, the following results were observed: the mean hospitalization duration in a ward was 11.8 days, a mean ICU treatment lasted 7.6 days, and an antibiotic treatment had a mean duration of 33.1 days.

After the PROMPT-Training, the single isolated case needed only in-house treatment for four days and antibiotics for nine days, without ICU treatment. Finally, comparing the timing of the diagnosis of sepsis after the delivery, we observed a fourfold time reduction from four days to only one.

These data showed a reduction in severe sepsis cases, presumably due to the earlier diagnosis and more effective management, following the implementation of the PROMPT-Training. However, the number of cases was small.

3. Major Obstetric Haemorrhage

The main findings following the PROMPT-Training showed an increase in diagnosed cases with major obstetric haemorrhage. In addition, there was a statistically significant decrease in the C-sections associated with haemorrhage and a reduction of re-laparotomies, hysterectomies, and in the number of blood products and clotting factors used around birth.
In detail, the data before and after the training show a statistically significant increase in the cases complicated with **major obstetric haemorrhage / peripartum haemorrhage** (PPH) from before: 65/27,198 (0.2%) to after: 34/6,564 (0.5%), (p< 0.001) (Table 19).

Table 19. *Major obstetric haemorrhage.*

	Group		
PPH	1	2	Total
No	27,133 (99.8%)	6,530 (99.5%)	33,663 (99.7%)
Yes	65 (0.2%)	34 (0.5%)	99 (0.3%)
Total	27,198 (100%)	6,564 (100%)	33,762 (100%)

The proportion of C-sections with PPH changed significantly from before 25/65 (38.5%) to after 3/34 (8.8%) (p=0.002), (Table 20). Simultaneously, there was a reduction of C-sections from before 9,167/27,198 (33.7%) to after 1,955/6,564 (27.8%). These findings indicate reduced blood loss at C-section in general and, possibly, improved management of either the operation technique or a more consequent application of contracting agents, improving the outcome.

Table 20. *Spontaneous deliveries / C-sections.*

	Group		
	1	2	Total
Vaginal delivery	40 (61.5%)	31 (91.2%)	71 (71.7%)
C-section	25 (38.5%)	3 (8.8%)	28 (28.3%)
Total	65 (100%)	34 (100%)	99 (100%)

In addition, the number of cases which required **re-laparotomy** and/or **hysterectomy** were significantly reduced from before 12/65 (18,5%) to after 1/34 (2.9%) (p=0.032) and from before 8/65 (12.3%) to after 0/34 (0%) (p=0.048), respectively (Tables 21 and 22). However, the number of **curettages** increased from before 34/65 (52.3%) to after 22/34 (64.7%). But this effect was not significant (p=0.24), (Table 23).

Table 21. *Re-laparotomies.*

	Group		
Re-laparotomies	1	2	Total
No	53 (81.5%)	33 (97.1%)	86 (86.9%)
Yes	12 (18.5%)	1 (2.9%)	13 (13.1%)
Total	65 (100%)	34 (100%)	99 (100%)

Table 22. *Hysterectomies*.

	Group		
Hysterectomies	1	2	Total
No	57 (87.7%)	34 (100%)	91 (83.3%)
Yes	8 (12.3%)	0 (0%)	8 (16.7%)
Total	65 (100%)	34 (100%)	99 (100%)

Table 23. *Curettages.*

	Group		
Curettages	1	2	Total
No	31 (47.7%)	12 (35.3%)	43 (43.4%)
Yes	34 (52.3%)	22 (64.7%)	56 (56.6%)
Total	65 (100%)	34 (100%)	99 (100%)

The descriptive analysis is shown below (Table 24). The populations before and after the implementation of PROMPT-Training are subcategorised according to the delivery mode (*C-section vs vaginal birth*).

In the *vaginal births,* we observed no differences in blood loss (lowest Hb and units of blood given). The number of platelets given was slightly reduced from a mean value of before=0.11 to after=0. The number of FFPs increased from before=0.11 to after=0.35, but none of these changes was statistically significant. Finally, we have seen a statistically significant fourfold increase in the mean amount of Tranexamic Acid given from 0.16 to 0.48 (p=0.033).

In the Group of the *C-sections,* we observed a reduction of the mean blood loss from before=1.852 ml to after=1.167 ml and an increase in the mean of the lowest Hb from before=6.9g/dl to after 7.6g/dl. The mean number of given blood units was reduced from before=5.29 to after=0.67. Additionally, the mean numbers of given platelets and FFPs were reduced from before=0.48 and 3.38 to after=0, respectively. The mean number of Tranexamic Acid given increased from before=0.33 to after=0.67, but this finding was not statistically significant.

Table 24. *Descriptive analysis of the quantitative data of major obstetric haemorrhage.*

							Centile	
			N	Mean	Min	Max	25th	50th Median	75th
Vaginal birth	1	Blood loss (ml)	40	1,448.75	1,000	5,000	1,000	1,400	1,500
		Lowest Hb (g/dl)	40	6.8	5	10.7	6	6.55	7.75
		Units of blood	37	1.59	0	10	0	2	2
		Platelets	38	0.11	0	2	0	0	0
		FFPs	37	0.11	0	4	0	0	0
		Tranexamic Acid	38	0.16	0	2	0	0	0
	2	Blood loss (ml)	31	1,420.97	1,000	2,300	1,050	1,400	1,600
		Lowest Hb (g/dl)	31	6.9	4.4	10.9	6.2	6.7	7.6
		Units of blood	31	1.52	0	8	0	2	2
		Platelets	31	0	0	0	0	0	0
		FFPs	31	0.35	0	9	0	0	0
		Tranexamic acid	31	0.48	0	2	0	0	1
C-section	1	Blood loss (ml)	25	1,852	1,000	4,000	1,200	1,500	2,000
		Lowest Hb (g/dl)	25	6.9	4.4	10.4	5.75	6.9	7.6
		Units of blood	21	5.29	0	20	1	4	8
		Platelets	21	0.48	0	2	0	0	1
		FFPs	21	3.38	0	32	0	0	3
		Tranexamic Acid	21	0.33	0	4	0	0	0
	2	Blood loss (ml)	3	1,167	1,000	1,500	1,000	1,000	1,500
		Lowest Hb (g/dl)	3	7.6	5.2	9.5	5.2	8.1	9.5
		Units of blood	3	0.67	0	2	0	0	2
		Platelets	3	0	0	0	0	0	0
		FFPs	3	0	0	0	0	0	0
		Tranexamic acid	3	0.67	0	2	0	0	2

The findings indicate an improvement in the perioperative management of PPH following the PROMPT-Training.

4. Shoulder Dystocia

The main findings of the training are an increase in the number of shoulder dystocia cases detected. In contrast, simultaneously, the numbers of permanent brachial plexus injury and instances of asphyxia went to zero.

In detail, the numbers before and after the training showed a highly significant increase of shoulder dystocia cases (before: 48/18,031 (0.27%), after: 23/4,609 (0.5%), p=0.017), (Table 25).

Table 25. *The total number of deliveries (spontaneous and vaginal operative) and cases complicated with shoulder dystocia.*

Shoulder dystocia total cases	Group		
	1	2	Total
No	17,983 (99.73%)	4,586 (99.50%)	22,569 (99.69%)
Yes	48 (0.27%)	23 (0.50%)	71 (0.31%)
Total	18,031 (100%)	4,609 (100%)	22,640 (100%)

Brachial Plexus injury was present in 7/48 (14.6%) cases before and in 1/23 (4.3%) after (p=0.261) the training began, in the peripartum period. The incidence of permanent brachial plexus injury after one year follow up was 1/7 (14.2%) before and 0/1 (0%) after (p=n.a.*) (Table 26).

This reduction from one case to zero had a high impact on the affected families. After only two years of training, the frequency decreased from 14.6% to 4.3%, with 0% permanent injuries.

Table 26. *Total brachial plexus Injury (BPI) at birth and after one year (permanent BPI).*

Total brachial plexus Injury (BPI)	Group		
	1	2	Total
No	41 (85.4%)	22 (95.7%)	63 (88.7%)
Yes	7 (14.6%)	1 (4.3%)	8 (11.3%)
Total	48 (100%)	23 (100%)	71 (100%)

	Group		
Permanent BPI	1	2	Total
No	6 (85.72%)	1 (100%)	7 (87.5%)
Yes	1 (14.2%)	0 (0%)	1 (12.5%)
Total	7 (100%)	1 (100%)	8 (100%)

n.a.: The statistical significance calculation is unavailable for these Groups (0 cases in Group 2).*

The second most crucial adverse outcome in shoulder dystocia besides BPI is asphyxia, which has a long-term negative impact on the newborn and the family.

Here, the results were unexpected as birth asphyxia increased substantially from 3/48 (6.3%) to 4/23 (17.4%) in shoulder dystocia (p=0.23). However, looking at the one-year outcome for adverse effects of asphyxia, before there were only 1/3 (33.3%) cases and after 0/4 (0%) (p= n.a.*). The single child affected suffered from recurrent pneumonitis (inflammation of lung tissues) (Table 27).

Table 27. *Perinatal asphyxia at birth and outcome after one year.*

Total cases complicated with	Group		
asphyxia	1	2	Total
no	45 (93.7%)	19 (82.6%)	64 (90%)
Yes	3 (6.3%)	4 (17.4%)	7 (10%)
Total	48 (100%)	23 (100%)	71 (100%)

Adverse outcome after	Group		
one year	1	2	Total
no	2 (66.7%)	4 (100%)	6 (85.7%)
yes	1 (33.3%)	0 (0%)	1 (14. 3%)
Total	3 (100%)	4 (100%)	7 (100%)

n.a.: The statistical significance calculation is unavailable for these Groups because of 0 cases in Group 2.*

The reduction in adverse outcomes is the result of improved clinical management for shoulder dystocia.

Subsequently, McRoberts manoeuvre, suprapubic pressure and internal rotation manoeuvres, including manual extraction of the arm in shoulder dystocia, are reported.

The most important finding is a statistically significant increase in performing McRoberts manoeuvre, before: 37/48 (77.1%) and after: 23/23 (100%) (p=0.013) and a clinical increase in suprapubic pressure, before: 13/48 (27.1%) and after: 7/23 (30.4%) (p=0.784). Also, internal rotational manoeuvres, including manual extraction of the arm, were more frequently applied, before: 6/48 (12.5%) and after: 5/23 (21.7%) (p=0.319), which was, however, not statistically significant (Table 28).

Table 28. *Manoeuvres performed.*

McRoberts' manoeuvre	Group		
	1	2	Total
No	11 (22.9%)	0 (0%)	11 (15.5%)
Yes	37 (77.1%)	23 (100%)	60 (84.5%)
Total	48 (100%)	23 (100%)	71 (100%)

Suprapubic pressure	Group		
	1	2	Total
No	35 (72.9%)	16 (69.6%)	51 (71.8%)
Yes	13 (27.1%)	7 (30.4%)	20 (28.2%)
Total	48 (100%)	23 (100%)	71 (100%)

Internal rotation & manual extraction of arm	Group		
	1	2	Total
No	42 (87.5%)	18 (78.3%)	60 (84,.5%)
Yes	6 (12.5%)	5 (21.7%)	11 (15.5%)
Total	48 (100%)	23 (100%)	71 (100%)

The descriptive analysis of both Groups is shown below (Table 29). There were no significant differences between both training Groups regarding the gestational age (both weeks and days), gravida, para and birthweight, indicating similarity between both populations.

The outcome parameters 5´ APGAR-score, umbilical artery pH, base excess and blood loss were similar and slightly worse in Group 2 (base excess and blood loss), indicating either higher blood loss in Group 2 or improved estimation and recordings of blood loss.
None of the above parameters was significantly different between the two Groups.

Table 29. *Descriptive analysis of the quantitative data of shoulder dystocia.*

						Centiles		
						25th	**50th**	**75th**
Group	**Categories**	**N**	**Mean**	**Min**	**Max**		**Median**	
1	5´ APGAR-score	48	8.75	2	10	8	9	10
	Umbilical artery pH	47	7.20	6.99	7.4	7.16	7.2	7.29
	Base excess	47	-7.74	-19.1	1,7	-10.5	**-6.7**	-5.3
	Gestational age (weeks)	48	39.6	37	41	39	40	40
	Gestational age at delivery (days)	48	279.48	261	290	276	280	285.75
	Gravida	48	2.56	1	7	1	2	3
	Para	48	2.02	1	6	1	2	2
	Birthweight	48	3,945.21	2,785	4,885	3,652.5	4,062.5	4,303.75
	Blood loss	48	**297.92**	150	2000	200	**225**	300
2	5´ APGAR-score	23	8.17	4	10	8	9	9
	Umbilical artery pH	23	7.21	7.03	7.47	7.15	7.2	7.29
	Base excess	23	-7.78	-26	-0.7	-10.3	**-7.4**	-3.9
	Gestational age (weeks)	23	39.57	33	41	39	40	41
	Gestational age at delivery (days)	23	279.39	231	291	277	281	289
	Gravida	23	2.13	1	8	1	2	2
	Para	23	1.78	1	6	1	1	2
	Birthweight	23	3,941.74	2,230	4,830	3,605	3,910	4,350
	Blood loss	23	**375.22**	150	1300	200	**300**	350

The further analysis of the categories before and after the implementation of the PROMPT-Training (Groups 1 and 2) has shown an increase in the cases with **5´ APGAR-score <7** from 4/48 (8.3%) to 4/23 (17.4%). An increase of **umbilical artery pH ≤ 7.10** from 7/47 (14.9%) to 4/23 (17.4%), an increase of the **base excess ≤-12** from 6/47 (12.8%) to 4/23 (17.4%), as well as an increase in blood loss ≥ 500ml from 2/48 (4.2%) to 3/23 (13%), was observed.

The percentage of **nulliparous** women with shoulder dystocia was increased from before 19/48 (39,.6%) to after 12/23 (52.2%). Also, the share of women in **post-term** pregnancies (**≥40^{+0} wks of gestation**) increased from before 21/48 (43.8%) to after 12/23 (52.2%). However, the **mean birthweight** was slightly reduced from before 4,062.5g to after 3,910g (3.8% RRR). In addition, there was a reduction in the number of **vaginal operative deliveries** from before 10/48 (20.8%) to after 3/23 (13%) (59.7% RRR), a reduction in **episiotomy** from before 14/48 (29.2%) to after 4/23 (17.4%) (RRR 67.71%) and a slight increase in the numbers of **perineal tears > II°** from before 1/48 (2.1%) to after 1/23 (4.3%).

5. Umbilical Cord Prolapse

The main findings following the PROMPT-Training are an increase in the cases of umbilical cord prolapse, a faster response time, and an increase in the adverse outcomes after one year follow up of the newborns.

In detail, the data before and after the training show a significant increase in **cases with umbilical cord prolapse** from before: 15/27,198 (0.06%) to after: 9/6,564 (0.14%), (p=0.025), (Table 30).

Table 30. *Total cases with umbilical cord prolapse.*

Umbilical cord prolapse	Group		
	1	2	Total
No	27,183 (99.4%)	6,555 (99.86%)	33,738 (99.93%)
Yes	15 (0.06%)	9 (0.14%)	24 (0.07%)
Total	27,198 (100%)	6,564 (100%)	33,762 (100%)

Furthermore, our analysis has shown that the number of cases with **asphyxia** has increased from before 3/15 (20%) to after 5/9 (55.6%), (p=0.099), (Table 31).

Table 31. *Total cases with asphyxia.*

Asphyxia	Group		
	1	2	Total
No	12 (80%)	4 (44.4%)	16 (66.7%)
Yes	3 (20%)	5 (55.6%)	8 (33.3%)
Total	15 (100%)	9 (100%)	24 (100%)

In addition, the data show a significant increase in cases with **adverse outcomes**. In all cases, this was neonatal death, rising from from before 0/15 (0%) to after 3/9 (33.3%) (p=0.042), (Table 32).

Table 32. *Neonatal death.*

	Group		
Neonatal death	1	2	Total
No	15 (100%)	6 (66.7%)	21 (87.5%)
Yes	0 (0%)	3 (33.3%)	3 (12.5%)
Total	15 (100%)	9 (100%)	24 (100%)

We received significant results from the descriptive analysis, explaining the increased adverse outcomes following the PROMPT-Training (Table 33).

Table 33. *Descriptive analysis of the quantitative data for umbilical cord prolapse.*

						Centile	
						50th	
Group		**N**	**Mean**	**Min**	**Max**	**25th**	**(Median)**	**75th**
1	**Response Time**	14	**7.64**	4	11	6.75	8	9
	5´ APGAR-score	15	8.67	6	10	8	9	10
	Umbilical Artery pH	15	7.27	6.99	7.39	7.24	7.29	7.33
	Base excess	14	-4.6	-12.9	-0.6	-6.3	-3.25	-1.725
	Length of pregnancy [d]	15	**242.4**	167	290	205	250	281
	Gravida	15	2.67	1	5	2	3	4
	Parity	15	2.13	1	4	1	2	3
2	**Response Time**	8	**5.5**	3	9	4,25	5	6.75
	5´ APGAR-score	8	7.38	5	10	6.25	7.5	8
	Umbilical Artery pH	9	7.24	6.98	7.43	7.14	7.24	7.35
	Base excess	9	-8.7	-20.9	-1	-12.15	-8.6	-3.5
	Length of pregnancy [d]	9	**214.89**	176	286	184.5	192	259
	Gravida	9	2.67	1	10	1	2	3
	Parity	9	2.33	1	8	1	1	3

Both populations showed similar results for the 5´ APGAR-score, umbilical artery pH, base excess, gravida and parity. There were no significant differences before and after the PROMPT-Training.

There were differences between the populations, particularly in the **length of the pregnancy** at delivery: Group 1: 242.4 days (34^{+4} weeks) vs Group 2: 241.89 days (30^{+5} weeks). Also, all newborns who died after delivery were highly premature and were delivered between 25^{+3} and 28^{+3} weeks of gestation. The causes of death were hypoxic-ischemic encephalopathy (HIE) following RDS, failed resuscitation in the

fetus following prolonged anhydramnios, and necrotic enterocolitis (NEC). All of these complications are highly associated with prematurity and low fetal birthweight. Also, the risk of these was significantly lower after 34 weeks of gestation. Thus, the mean difference of **four weeks of gestation** at birth between Groups 1 and 2 is the most important contributing factor in the increased adverse outcomes in Group 2.

Finally, we have also observed a significant reduction in the **response time** (time between the diagnosis of cord prolapse and the delivery of the fetus). Here, the mean time from before 7.64 min was reduced to after 5.5 min, corresponding to an absolute reduction of 2.1 min. This reduction indicated an even faster response to the emergency following the implementation of PROMPT-Training, already beginning at a very high level.

6. Vaginal Breech Delivery

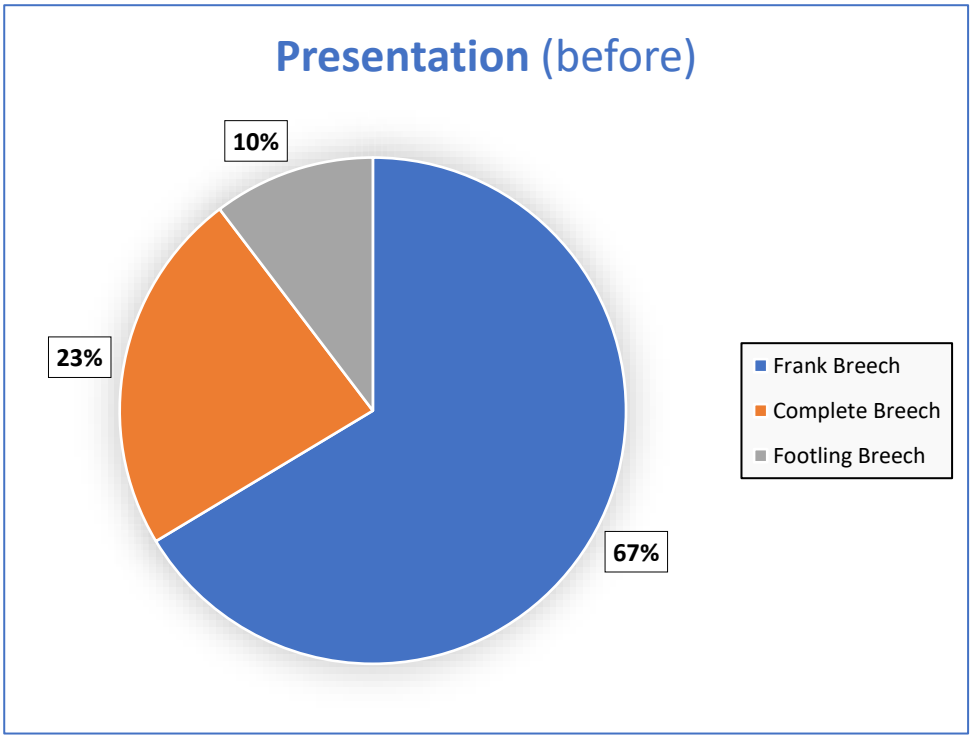
The main findings following the introduction of the PROMPT-Training were an increase in the number of vaginal breech deliveries. At the same time, the cases of asphyxia and adverse outcomes after one year of follow-up were reduced.

In detail, the numbers before and after the training showed a statistically significant increase in **vaginal breech deliveries** (before: 116/27,198 (0.43%), after: 42/6,564 (0.64%), p=0.023), (Table 34).

Table 34. *The total number of spontaneous vaginal breech deliveries.*

Vaginal breech deliveries	Group		
	1	2	Total
no	27,082 (99.57%)	6,522 (99.36%)	33,604 (99.53%)
yes	116 (0.43%)	42 (0.64%)	158 (0.47%)
Total	27,198 (100%)	6,564 (100%)	33,762 (100%)

Our analysis also showed an increase in twin pregnancies where the second fetus was delivered spontaneously with a breech delivery. Here, the cases increased from before 36/116 (31%) to 16/42 (38.1%) after.



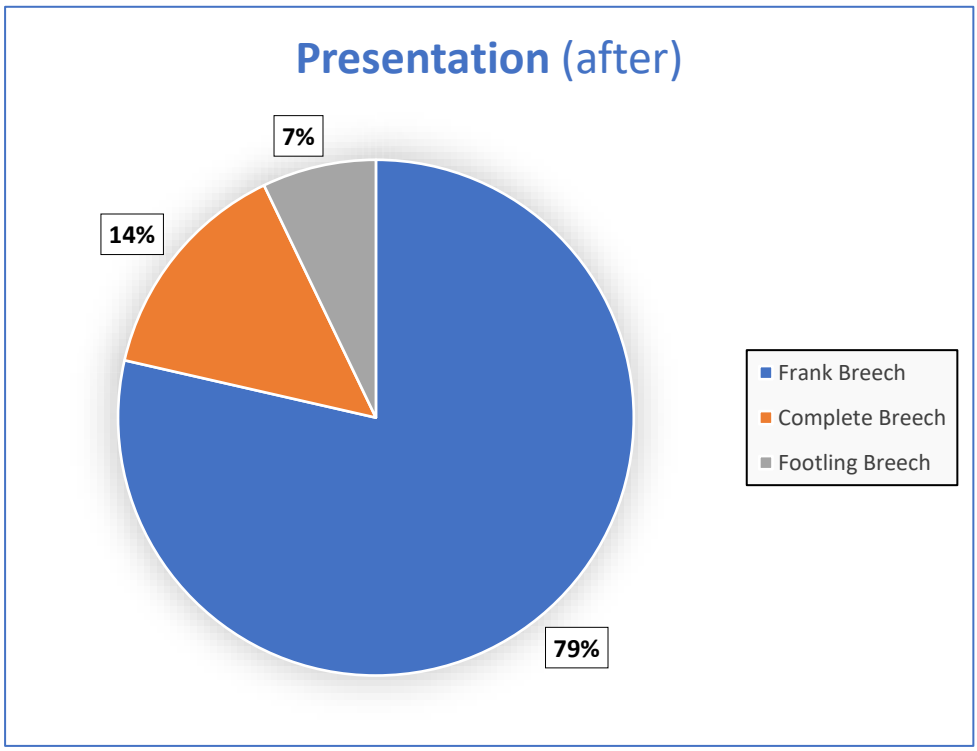


Figure 2. *The percentages of pregnancies with Frank Breech, Complete Breech and Footling Breech presentation before and after the training are shown.*

As shown in the diagrams above, we have observed a relative increase in the deliveries from Frank Breech presentation from before 77/116 (67%) to after 33/42 (79%).
Our analysis has not shown a difference in the delivery manoeuvres initiated, including Bracht, Bickenbach, Veit-Smillie and classical delivery of the posterior arm.

Furthermore, we have observed a decrease in birth asphyxia from 9/116 (7.8%) to 2/42 (4.8%). However, looking at the one-year outcome for adverse effects of asphyxia, before there was 2/9 (22.2%) and after 0/2 (0%) (p=n.a.*). One of the two affected children suffered from hypoxic-ischemic encephalopathy resulting in spastic paresis, and the other died (Table 35).

Table 35. *Perinatal asphyxia and adverse outcome after one year.*

Total cases complicated with **asphyxia**	Group		
	1	2	Total
No	107 (92.2%)	40 (95.2%)	147 (93%)
Yes	9 (7.8%)	2 (4.8%)	11 (7%)
Total	116 (100%)	42 (100%)	158 (100%)

Adverse outcomes after one **year**	Group		
	1	2	Total
No	7 (77.8%)	2 (100%)	9 (81.8%)
Yes	2 (22.2%)	0 (0%)	2 (18,2%)
Total	9 (100%)	2 (100%)	11 (100%)

n.a.: The statistical significance calculation is unavailable for these Groups (0 cases in Group 2).*

The reduction in adverse outcomes was the result of improved clinical management for vaginal breech delivery.

The descriptive analysis of the quantitative data of both Groups is shown below (Table 36). The clinical differences showed a slight improvement for Group 2.

The Group comparisons demonstrated a highly significant increase in the **number of nulliparous women** after the implementation of the PROMPT-Training, from before 46/116 (39.7%) to after 31/42 (73.8%) ($p<0.001$, OR=4.29). In addition, the **mean birthweight** increased from before 2,683.9 g to after 2,813.3 g. This increase indicated confidence in the management abilities of vaginal breech delivery following the PROMPT-Training.

The percentage of women in **post-term** pregnancies (**≥ 40^{+0} weeks of gestation**) decreased from before 12/116 (10.3%) to after 1/42 (2.4%) as more inductions were done.

An important finding is that the mean time between the first and second fetus decreased from 12.8 min to 9.69 min. This effect was not significant ($p=0.093$) but indicated an absolute decrease of 24.3%.

Table 36. *Descriptive analysis of the quantitative data of vaginal breech deliveries.*

Group		N	Mean	Min	Max	Centiles		
						25th	50th (Median)	75th
1	**Time between first and second fetus**	36	**12,8**	2	48	6. 25	11.00	15.75
	5´ APGAR-score	116	8.99	0	10	9.00	9.00	10.00
	Umbilical artery pH	116	7.25	6.78	7.44	7.185	7.26	7.32
	Base excess	114	-5.92	-28.7	1.90	-8.10	-5.30	-3.275
	GA at delivery (days)	116	258.98	159	290	253.25	263	272.75
	Gravida	116	2.73	1	13	1.00	2.00	3,00
	Parity	116	**2.24**	1	10	1.00	**2.00**	3.00
	Birthweight	116	2683.9	495	4095	2332.5	2735	3070
	Blood loss	116	224.57	100	700	200	200	250
2	**Time between first and second fetus**	16	**9.69**	3	35	5,00	7.00	10.5
	5´ APGAR-score	42	9.33	6	10	9.00	10.00	10.00
	Umbilical artery pH	42	7.25	7.04	7.38	7.217	7.235	7,325
	Base excess	42	-5.85	-15.7	-0.70	-8.20	-5.40	-2.45
	GA at delivery (days)	42	262.2	183	281	257	267	275
	Gravida	42	2.26	1	9	1.00	2.00	3.00
	Parity	42	**1.50**	1	7	1.00	**1.00**	2.00
	Birthweight	42	2813.3	1060	4060	2355	3010	3206.2
	Blood loss	42	234.52	150	800	200	200	250

GA=Gestational Age

Further analyses showed (Group 1 and 2) a decrease in cases with **5´ APGAR-scores < 7** (from 8/116 (6.9%) to 1/42 (2.4%), a reduction in **umbilical artery pH ≤ 7.10** (from 8/116 (6.9%) to 1/42 (2.4%)) and an increase of **base excess ≤ -12** from (8/114 (7%) to 5/42 (11.9%)). There was no change in blood loss in both Groups.

Finally, we observed a significant reduction in the initiation of **episiotomy** from before 61/116 (52.6%) to after 5/42 (11.9%) ($p<0.001$, OR=8.21) and a slight decrease in the numbers of **perineal tears > II°** from before 2/116 (1.7%) to after 0/42 (0%), (Table 37).

Table 37. *Episiotomy and perineal tear > II°.*

Total cases with **episiotomy**	Group		
	1	2	Total
No	55 (47.4%)	37 (88.1%)	92 (58.2%)
Yes	61 (52.6%)	5 (11.9%)	66 (41.8%)
Total	116 (100%)	42 (100%)	158 (100%)

Total cases with **perineal tear > II°**	Group		
	1	2	Total
No	114 (98.3%)	42 (100%)	156 (81.8%)
Yes	2 (1.7%)	0 (0%)	2 (18.2%)
Total	116 (100%)	42 (100%)	158 (100%)

7. Twin Birth

The main findings were an increase in spontaneously delivered twin pregnancies following the PROMPT-Training. Further, a significant increase in the number of monochorionic/diamniotic twin deliveries, a reduction in the adverse outcomes after a one-year follow-up, and a reduction in the number of pregnancies that ended in a C-section for the second twin was observed.

In detail, the data before and after the training showed that the number of the **twin pregnancy cases that delivered spontaneously** increased from before 206/1172 (17.58%) to after 51/226 (22.57%) (p=0.076), (Table 38).

Table 38. *Spontaneous Twin Deliveries.*

Spontaneous twin deliveries	Group		
	1	2	Total
No	966 (82.42%)	175 (87.43%)	1,141 (81.62%)
Yes	206 (17.58%)	51 (22.57%)	257 (18.38%)
Total	1172 (100%)	226 (100%)	1,398 (100%)

Furthermore, our analysis showed a significant increase in the number of spontaneous **monochorionic/diamniotic (MC/DA)** twin deliveries from before 21/206 (10.19%) to after 11/51 (21.57%) (p=0. 025), (Table 39).

Table 39. *Spontaneous MC/DA twin Deliveries.*

MC/DA	Group		
	1	2	Total
No	185 (89.81%)	40 (78.43%)	225 (87.55%)
Yes	21 (10.19%)	11 (21.57%)	32 (12.45%)
Total	206 (100%)	51 (100%)	257 (100%)

We have also subcategorised the twin pregnancies according to the **presentation of the second twin**, in cephalic presentation and breech presentation. The analysis showed a significant increase in the number of spontaneous twin deliveries with breech presentation of the second twin from before 37/206 (17.96%) to after 16/51 (31.37%), (p=0.034), (Table 40).

Table 40. *Presentation of the second twin.*

	Group		
	1	2	Total
Cephalic	169 (82.04%)	35 (68.63%)	204 (79.38%)
Breech	37 (17.96%)	16 (31.37%)	53 (20.62%)
Total	206 (100%)	51 (100%)	257 (100%)

In addition, the number of spontaneous twin deliveries with **episiotomy** was reduced significantly from before 90/206 (43.69%) to after 11/51 (21.57%), (p=0.003), (Table 41).

Table 41. *Episiotomies.*

	Group		
Episiotomies	1	2	Total
No	116 (56.31%)	40 (78.43%)	156 (60.7%)
Yes	90 (43.69%)	11 (21.57%)	101 (39.3%)
Total	206 (100%)	51 (100%)	257 (100%)

The number of twin pregnancies with **C-sections** for the **second twin** was reduced from before 20/206 (9.71%) to after 2/51 (3.92%), as demonstrated in Table 42. Although this difference was not significant (p=0.86), it indicated potentially better management following the PROMPT-Training.

Table 42. *C-section of the second twin.*

C-section of the second twin	Group		
	1	2	Total
No	186 (90.29%)	49 (96.08%)	235 (91.44%)
Yes	20 (9.71%)	2 (3.92%)	22 (8.56%)
Total	206 (100%)	51 (100%)	257 (100%)

Additionally, we analysed the cases complicated with **asphyxia** for each twin separately and, also, we documented the **adverse outcomes after a one-year follow-up** of the newborns.

In the Group **Twin I,** we observed a reduction in cases of asphyxia from before 6/206 (2.91%) to after 0/51 (0%) (Table 43). Adverse outcomes were observed only in Group 1. In Group 2, there were no asphyxia cases.

Table 43. *Asphyxia in the twin I Group.*

	Group		
Asphyxia twin I	1	2	Total
No	200 (97.09%)	51 (100%)	251 (97.67%)
Yes	6 (2. 91%)	0 (0%)	6 (2.33%)
Total	206 (100%)	51 (100%)	257 (100%)

In the Group **twin II**, we observed a slight reduction in cases of asphyxia from before 15/206 (2.91%) to after 3/51 (0%) (p=0.72) (Table 44). In addition, adverse outcomes were also reduced from before 3/15 (20%) to after 0/3 (0%), (Table 45).

Table 44. *Asphyxia in the twin II Group.*

	Group		
Asphyxia twin II	1	2	Total
No	191 (92.72%)	48 (94.12%)	239 (93%)
Yes	15 (7.28%)	3 (5.88%)	18 (7%)
Total	206 (100%)	51 (100%)	257 (100%)

Table 45. *Adverse outcomes in the twin II Group.*

Adverse	Group		
outcomes Twin II	1	2	Total
No	12 (80%)	3 (100%)	15 (83.33%)
Yes	3 (20%)	0 (0%)	3 (16. 67%)
Total	15 (100%)	3 (100%)	18 (100%)

After combining the cases of asphyxia of both twin Groups (I and II), we observed a reduction in before 21/412 (5.1%) to after training 3/102 (2.9%) (p=0.355). In addition, there was also a reduction in adverse outcomes to zero. Although this effect was not significant, it showed a possible improvement in the management of spontaneous twin deliveries following the PROMPT-Training.

The descriptive analysis of the quantitative data of both Groups is shown below (Table 46). We observed an absence of statistically significant differences in both Groups, in terms of gestational age at delivery, parity and birthweights.

The parameters associated with the delivery management, including pH, APGAR score, base excess and blood loss, also did not differ between both Groups. However, the analysis showed a notable reduction in the (mean) **time between the delivery of the first and second twin** from before 14.51 min to after 10.21 min.

Table 46. *Descriptive analysis of the quantitative data of vaginal twin births.*

						Centile	
Group	**N**	**Mean**	**Min**	**Max**	**25th**	**50th (Median)**	**75th**
1	**Time between Fetus I and II**	204	**14.51**	1	173	5	8	15
	Gestation at delivery (days)	206	254.47	167	279	247.5	259	262
	Gravida	206	2.1	1	11	1	2	2
	Parity	206	1.82	0	9	1	1	2
	Blood loss	205	435.12	200	5,000	250	300	437.5
	Umbilical cord pH (I°)	202	7.28	7.01	7.47	7.235	7.29	7.35
	Base excess (I°)	200	-5.49	-19.8	2.7	-7.1	-5,.1	-2.8
	Birthweight (I°)	206	2,474.8	360	3,955	2,195	2,540	2,792.5
	Umbilical cord pH (II°)	203	7.24	6.94	7.41	7.19	7.25	7.3
	Base excess (II°)	201	-5.76	-18	0.9	-8.2	-5.4	-2.9
	Birthweight (II°)	205	2,446.4	550	3,720	2,162.5	2,485	2,700
2	**Time between Fetus I and II**	50	**10.21**	2	45	5	8	13
	Gestation at delivery (days)	51	257.31	231	267	256	260	262
	Gravida	51	2.11	1	9	1	2	2
	Parity	51	1.51	1	4	1	1	2
	Blood loss	51	421.43	200	2,000	300	300	400
	Umbilical cord pH (I)	51	7.29	7,.15	7.4	7.25	7.3	7.33
	Base excess (I)	51	-4.85	-12.9	1.2	-5.9	-4.2	-3
	Birthweight (I)	51	2,587.9	1,665	3,320	2,430	2,555	2,820
	Umbilical cord pH (II)	51	7.25	6.91	7.37	7.19	7.29	7.32
	Base excess (II)	51	-5.58	-19.3	-0.9	-6.8	-3.9	-3
	Birthweight (II)	51	2,585.9	1,960	3,150	2,405	2,610	2,840

8. Newborn Outcomes

We collected and analysed all newborns with pathological umbilical artery pH < 7.0 and/or a 5´ APGAR-score < 6 at birth and the one-year follow-up to compare the short and long-term adverse outcomes in the present data.

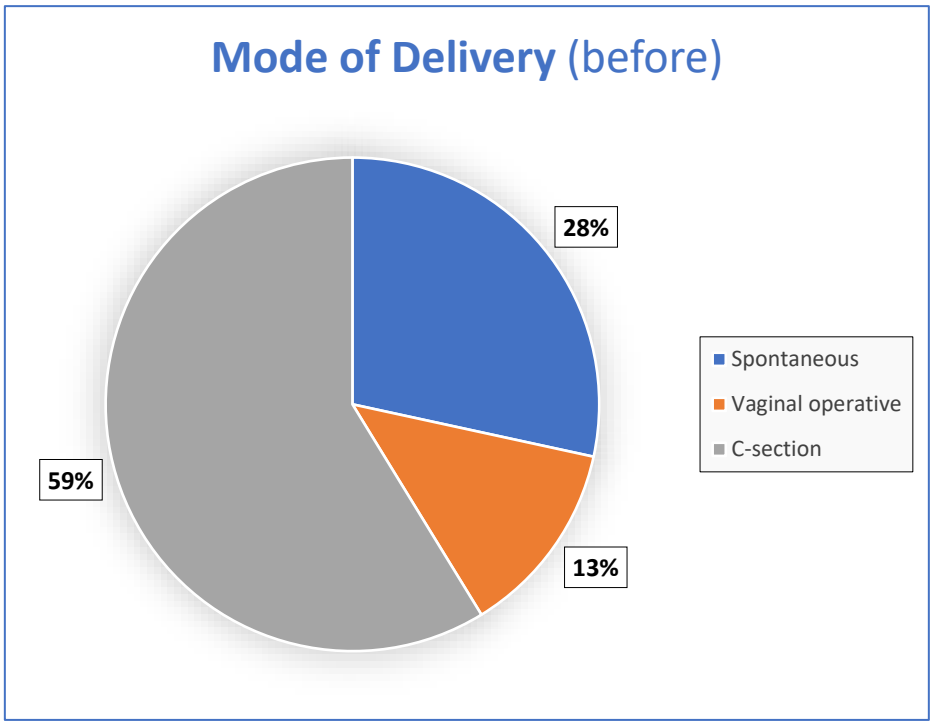
This analysis excluded gestation < 24 weeks, lethal chromosomal defects or genetic syndromes, and hydrops fetalis. Included were all cases with the intention to treat and where a maximum of therapy was applied.

The main findings following the PROMPT-Training were similar newborns with pathological pH and APGAR-score values at birth. In contrast, the number of adverse outcomes after one year, including handicap and death, was reduced. In addition, we observed an improvement in the management of the newborns, especially in terms of resuscitation and extended treatment, including cooling.
In detail, the number of **newborns with pathological values** at birth was slightly reduced from before 257/27,198 (0.9%) to after 51/6,564 (0.8%), (p=0.199), (Table 47).

Table 47. *Newborns with pathological pH and/or 5´APGAR-scores.*

Newborns with pathological values	Group		
	1	2	Total
No	26,941 (99.1%)	6,513 (99.2%)	33,454 (99.1%)
Yes	257 (0.9%)	51 (0.8%)	308 (0.9%)
Total	27,198 (100%)	6,564 (100%)	33,762 (100%)

The proportion of each mode of delivery was about the same before and after the training.



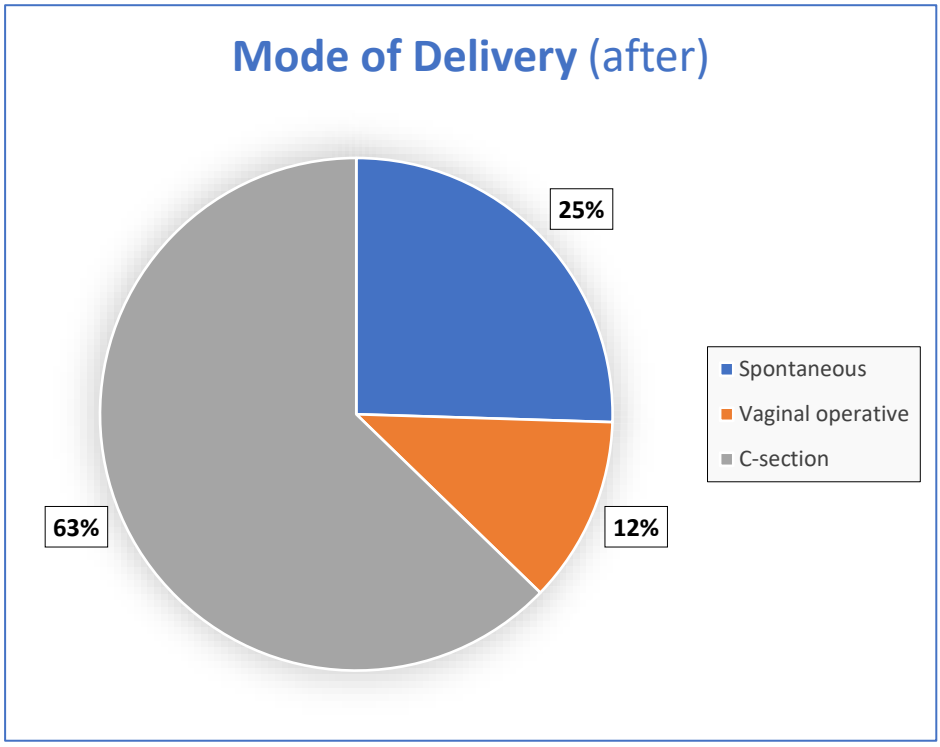


Figure 3. *The proportion of pregnancies with spontaneous vaginal birth, vaginal operative delivery and C-sections before and after the training are shown.*

Furthermore, the percentage of newborns with **anomalies or syndromes** was slightly increased in the second Group (Table 48).

Table 48. *Newborns with anomalies/syndromes.*

Newborns with anomalies/syndromes	Group 1	Group 2	Total
No	198 (77.3%)	38 (74.5%)	236 (76.9%)
Yes	58 (22.7%)	13 (25.5%)	71 (23.1%)
Total	256 (100%)	51 (100%)	307 (100%)

We observed a reduction in the number of children who fulfilled the criteria of **acidosis** from before 159/253 (62.8%) to after 30/51 (58.8%), as well as the newborns who fulfilled the criteria of **asphyxia** from before 99/253 (39.1%) to after 16/51 (31.4%), shown in tables 49 and 50, respectively.

Even though these changes were not statistically significant, they showed a potential improvement in the treatment of the newborns at risk following the PROMPT-Training.

Table 49. *Acidosis in the investigated periods.*

Acidosis	Group 1	Group 2	Total
No	94 (37.2%)	21 (41.2%)	115 (37.8%)
Yes	159 (62.8%)	30 (58.8%)	189 (62.2%)
Total	253 (100%)	51 (100%)	304 (100%)

Table 50. *Asphyxia in the investigated periods.*

Asphyxia	Group 1	Group 2	Total
No	154 (60.9%)	35 (68.6%)	189 (62.2%)
Yes	99 (39.1%)	16 (31.4%)	115 (37.8%)
Total	253 (100%)	51 (100%)	304 (100%)

The number of newborns at risk who received **resuscitation** immediately after birth increased significantly, from before 233/257 (90.7%) to after 51/51 (100%) (p=0.019), (Table 51), showing a faster response of the team to the emergency following the PROMPT-Training.

Table 51. *Newborns with resuscitation.*

	Group		
Reanimation	1	2	Total
No	24 (9.3%)	0 (0%)	24 (7.8%)
Yes	233 (90.7%)	51 (100%)	284 (92.2%)
Total	257 (100%)	51 (100%)	308 (100%)

Further, an increase in the number of newborns with hypoxic-ischemic **encephalopathy** (HIE) was observed (before 25/257 (9.8%) to after 9/51 (17.6%) (p=0.101), Table 52). At the same time, the number of newborns that were treated with cooling therapy increased significantly from before 17/239 (6.6%) to after 8/43 (15.7%), (p=0.046), (Table 53).

Considering that the cooling therapy needs to be administrated within 6 hours of birth to be effective, we can saw a faster response of the team and a quicker diagnosis and risk assessment of the situation as a result of the PROMPT-Training.

Table 52. *Newborns with hypoxic ischemic encephalopathy (HIE).*

Hypoxic ischemic	Group		
encephalopathy	1	2	Total
No	231 (90.2%)	42 (82.4%)	273 (88.9%)
Yes	25 (9.8%)	9 (17.6%)	34 (11.1%)
Total	256 (100%)	51 (100%)	307 (100%)

Table 53. *Newborns cooling therapy.*

	Group		
Cooling therapy	1	2	Total
No	239 (93.4%)	43 (84.3%)	282 (91.9%)
Yes	17 (6.6%)	8 (15.7%)	25 (8.1%)
Total	256 (100%)	51 (100%)	307 (100%)

In the long-term, we observed a decrease in adverse outcomes after one-year follow-up (from before 74/257 (28.8%) to after 12/51 (23.5%) (p=0.444)).

In terms of **neonatal death,** we saw a decrease from before 61/74 (82.4%) to after 7/12 (58.3%), (p=0.056). The findings are shown in tables 54 and 55, respectively.

Table 54. *Adverse outcome at one year.*

Adverse outcomes	Group 1	Group 2	Total
No	183 (71.2%)	39 (76.5%)	222 (72.1%)
Yes	74 (28.8%)	12 (23.5%)	86 (27.9%)
Total	257 (100%)	51 (100%)	308 (100%)

Table 55. *Neonatal death (in the first year of life).*

Neonatal death	Group 1	Group 2	Total
No	13 (17.6%)	5 (41.7%)	18 (21%)
Yes	61 (82.4%)	7 (58.3%)	68 (79%)
Total	74 (100%)	12 (100%)	86 (100%)

Finally, the descriptive analysis of the **quantitative data** of both Groups is shown below (Table 56).

We found no significant clinical effects between Groups for the following variables: 5'APGAR score, umbilical artery pH, base excess and gestational age at birth. However, the mean reanimation time was reduced from 20.39 min to 17.12 min.

Table 56. *Descriptive analysis of the quantitative data of the newborn outcomes.*

					Centiles		
Group	**N**	**Mean**	**Min**	**Max**	**25th**	**50th Median**	**75th**
1 5´ APGAR-score	247	5.43	0	10	4	5	7
Umbilical artery pH	248	7.08	6.5	7.49	6,94	7.06	7.28
Base excess	243	-11.07	-28.4	4.9	-17,1	-11.8	-4.9
Gestation at delivery (days)	257	248.2	162	293	222	261	278
Reanimation time (min)	208	20.39	0	170	10	12	27.25
2 5´ APGAR-score	51	5.02	1	9	4	5	6
Umbilical artery pH	50	7.11	6.88	7.43	6,97	7.07	7.29
Base excess	50	-11.2	-23.2	0.8	-17.47	-12.65	-4.6
Gestation at delivery (days)	51	256.78	166	293	254	272	283
Reanimation time (min)	49	17.12	3	75	7	11	21

9. Perineal Tears grades III & IV

The main findings following the training are a substantial decrease in episiotomies, whereas the number of perineal tears of grades III & IV increased. The number of vaginal operative deliveries remained the same.

In detail, the data before and after the training showed a significant increase **of perineal tears grades III & IV** from before: 92/18,031 (0.51%) to after: 39/4,609 (0.85%), (p=0.007), (Table 57).

Table 57. *The total number of perineal tears grades III & IV.*

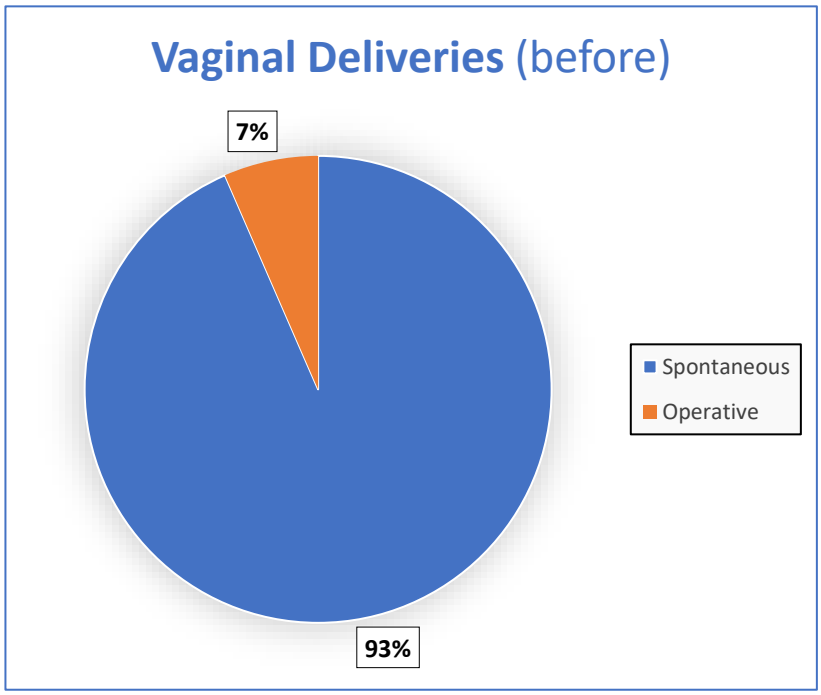
Perineal tears grades III & IV	Group		Total
	1	2	
No	17,939 (99.5%)	4,570 (99.15%)	22,509 (99.4%)
Yes	92 (0.5%)	39 (0.85%)	131 (0.6%)
Total	18,031 (100%)	4,609 (100%)	22,640 (100%)

Our analysis also showed a significant decrease in the use of **episiotomy** from before 5,267/18,031 (29.21%) to after 836/4,609 (18.14%), (p<0.001), (Table 58).

Table 58. *Total episiotomies performed.*

Episiotomies	Group		Total
	1	2	
No	12,764 (70.8%)	3,773 (81.9%)	22,509 (73%)
Yes	5,267 (29.2%)	836 (18.1%)	131 (27%)
Total	18,031 (100%)	4,609 (100%)	22,640 (100%)

On the other hand, the percentage of vaginal operative deliveries remained the same, as demonstrated in the diagrams below.



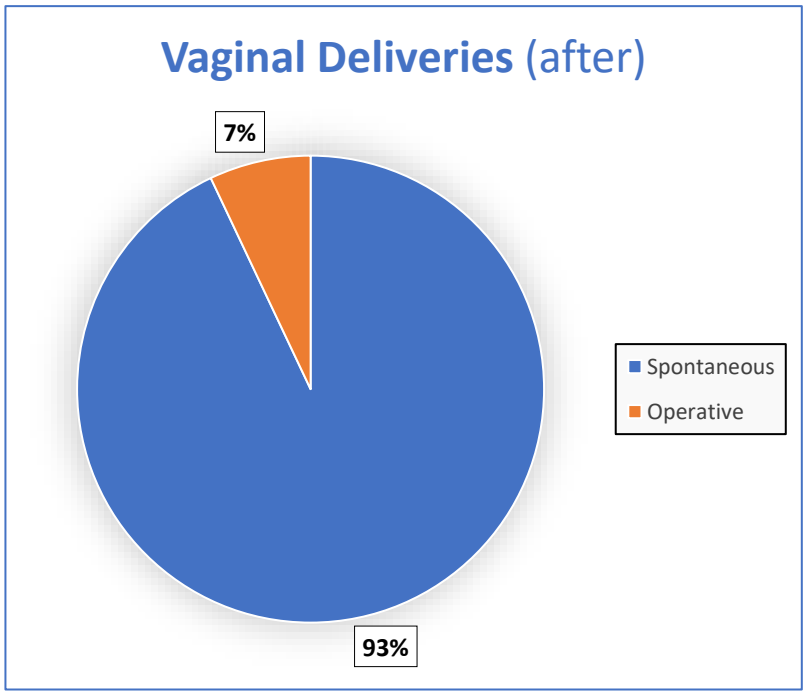


Figure 4. *The percentages of pregnancies with vaginal births and vaginal operative deliveries before and after the training are shown.*

The data collected were analysed further. As a result, the number of perineal tears grades III & IV following a spontaneous delivery, excluding vaginal operative deliveries, was increased from before 71/16,853 (0.42%) to after 26/4,285 (0.60%). However, this was statistically not significant (p=0.1).
From the total **vaginal operative deliveries** alone, we observed a significant increase in the frequency of perineal tears grades III & IV from before 21/1,178 (1.78%) to after 13/324 (4.01%), (p=0.017), as demonstrated in Table 59.

Table 59. *The total number of vaginal operative deliveries, complicated by perineal tears grades III & IV.*

Perineal tears grades III & IV	Group		Total
	1	2	
No	1,157 (98.2%)	311 (96%)	1,468 (97.7%)
Yes	21 (1.8%)	13 (4%)	34 (2.3%)
Total	1,178 (100%)	324 (100%)	1,502 (100%)

Finally, looking at the frequency of **episiotomies** done in perineal tears grades III & IV, we observed a decrease from before 52/92 (56.5%) to after 15/39 (38.5%), which was statistically not significant (p=0.059).

The descriptive analysis of both Groups is shown below (Table 60).

Table 60. *Descriptive analysis of the quantitative data of perineal tears grades III & IV.*

						Centiles	
						50th	
Group	**N**	**Mean**	**Min**	**Max**	**25th**	**Median**	**75th**
1	Length of pregnancy [d]	92	277.8	236	293	273	280	284
	Gravida	92	1.52	1	5	1	1	2
	Para	92	1.18	1	3	1	1	1
	Birthweight	92	3,517.7	2,105	4,530	3,252.5	3,540	3,841.2
	Head circumference	92	35.06	30	38	34	35	36
2	Length of pregnancy [d]	39	279.1	249	293	273	281	287
	Gravida	39	1.28	1	3	1	1	1
	Para	39	1.13	1	2	1	1	1
	Birthweight	39	3,604.1	2,950	4,405	3,310	3,660	3,810
	Head circimferance	39	35.19	33	37.5	34	35	36

We applied the national policy and did not apply routine episiotomy in every case of operative vaginal delivery. As a result, while the number of vaginal operative deliveries remained constant, episiotomies decreased substantially, and perinatal tears grades III & IV increased.

IV. Discussion

We present the first study of the effectiveness of PROMPT-Training in Germany and the most extensive study in terms of the population, including almost 30.000 patients from 2004 to 2020. After only two years of training, we observed a reduction in morbidity and mortality for women and newborns in high-risk pregnancies and births complicated with severe obstetrical complications.

Briefly, we observed an increase in the documented cases of **pre-eclampsia** and an increase in the administration of Magnesium sulfate (MgS04). In contrast, the number of pre-eclampsia cases that progressed to **eclampsia** remained the same. In addition, the number of pregnancies complicated by severe **sepsis** and the cases with severe adverse outcomes such as hysterectomy and maternal death decreased significantly.

The evaluation of blood loss and, as a result, the identification of **major obstetric haemorrhage** improved. This included the number of re-laparotomies, obstetrical hysterectomies, and the number of blood products and clotting factors needed around births.

The number of **shoulder dystocia** cases detected increased, while simultaneously, the numbers of permanent brachial plexus injury and cases of asphyxia went to zero.
The response time in cases of **umbilical cord prolapse** was significantly reduced. However, the adverse outcomes of the newborns increased.

Furthermore, the number of **vaginal breech deliveries** increased, while the cases of asphyxia were reduced and adverse outcomes went to zero.
The number of **twin pregnancies** delivered spontaneously increased, and the time between the first and the second twin was significantly reduced. In addition, the number of pregnancies that ended in a C-section for the second twin was reduced, and the adverse outcomes, particularly for the 2nd twin, were reduced.
The total **adverse outcomes in newborns,** including handicap and death, were reduced. In parallel, the management of the newborns at risk, resuscitation, and extended treatment, including cooling, did improve.
Finally, we observed a significant decrease in **episiotomies**, while the number of **perineal tears** grades III & IV slightly increased.

Pre-eclampsia and eclampsia (PET) are two of the most common causes of maternal and perinatal mortality. The overall incidence of pre-eclampsia and eclampsia worldwide, estimated in the systematic review of Edgardo Abalos et al. (55), was 4.6% and 1.4% of all deliveries, respectively, with a wide variation across regions.
Our study shows that the documented cases with pre-eclampsia before the PROMPT-Training were at 0.6% and at 0.9% after (looking at whole births). Thus, the numbers observed are significantly lower than the expected incidence, which can be explained by underdocumentation. However, the increase of the documented cases following the implementation of the PROMPT-Training, in our maternity unit shows a clear improvement in the quality of documentation.

There is primary prevention of PET using screening at 11-13^{+6} weeks of gestation (algorithm of the Fetal Medicine Foundation) and ASS 150mg from 12-36 weeks in cases with a risk >1:100. Using this approach, the risk for PET < 37 weeks can be reduced to 20% and the chance for fetal growth restriction (FGR) to 50% (56).
The primary complications of PET are iatrogenic prematurity, renal and cardiac problems, and placental insufficiency. The main long-term consequences are an increased risk for hypertensive disorders, acute myocardial infarction, stroke, and venous thromboembolism (57).

Approaches for secondary prevention of PET's complications and prolonging the pregnancies to reduce the effects of prematurity for the fetuses include maternal extracorporeal soluble fms-like tyrosine kinase-1 (SFLT-1) removal like shown in the studies of Stepan et al. (58,59). The current results are promising, showing a prolongation by 13. 5 days on average, but further studies with larger sample sizes are needed to come to more solid conclusions.

The most important and scientifically proved means of treatment, as a result of the training, is to reduce maternal death and eclampsia by giving Magnesium sulfate and lowering blood pressure. This approach is one of the most critical conclusions from the confidential enquiry into the death of mothers (CEMD-MBRRACE UK), which found that the mothers dying from PET by stroke and cerebral bleeding, the blood pressure was only moderately increased just above 160 mmHg. Furthermore, studies, such as Gadappa et al. (60), confirmed the essential role of Magnesium Mg Sulfatein administration in cases of severe pre-eclampsia, which improved the maternal outcome by reducing the incidence of eclampsia and the progression of the disease.

As mentioned before, the evaluation of the older training concepts (13,14) have shown improvements in the administration of Magnesium from 61% to 92% but only in an academic environment and not with actual patients. Considering, we observed an auspicious outcome after only two years of PROMPT-Training, which was the threefold increase of the administration of Magnesium Sulfate in severe pre-eclampsia cases from 26.7% to 80%. The outcome gave rise to the expectation that the PROMPT-Training will lead to further management improvements in the future.

Sepsis, in general, is a condition that arises when the body's response to an infection injures its tissues and organs. In obstetrics, in particular, it is the underlying cause of 11% of all maternal deaths, as shown in the study of Bonet et al. (61). As a result, the effective prevention, early identification and adequate management of this condition become a priority for every maternity unit. The improvement of these factors is the main aim of the PROMPT-Training. As demonstrated in our study, after only two years of training, the incidence of maternal sepsis could be substantially reduced from 0.1% to 0.0001%.

There is primary prevention of sepsis in pregnancy using antibiotics for asymptomatic bacteriuria (62) and screening for vaginal infection. However,

especially for Group B, a streptococcal infection can be devastating for newborns and mothers if not treated promptly and adequately (63).
Prevention also includes antibiotic prophylaxis in premature prelabour rupture of the membranes (PPROM) (64), C-section (65) and vaginal operative delivery (66). However, treatment of established sepsis is still a challenge. The efficacy and development depend on both the diagnostic timing and the antibiotic and volume replacement therapy (67).

The earlier the diagnosis, the better the outcome (68). Our study showed that PROMPT-Training had the effect of an earlier diagnosis (day one after delivery) compared to the time before training (four days after delivery).
A delayed diagnosis and/or suboptimal therapy of sepsis can cause severe ongoing damage. Potential complications include hysterectomy, a permanent organ failure, including brain injury and maternal death (69).

The appropriate management after diagnosis includes the transfer to an intensive care unit (ICU), intubation, the administration of catecholamines, volume, antibiotics, and sometimes more advanced treatments like dialysis and extracorporeal membrane oxygenation (ECMO).

An optimal therapy substantially reduces an adverse outcome, but even in that case, mortality may be up to 41.9% (70). We observed a reduction in hysterectomies from 11.8% to 0% and maternal death from 17.6% to 0% in our unit following the PROMPT-Training. Also, none of the survivors suffered from long term complications such as organ dysfunction or brain damage. These promising results may indicate improvement of the teams' knowledge, a faster diagnosis and rapid initiation of treatment following only two years of training. Ongoing practical training may be crucial for these effects to persist and make obstetrical sepsis management even more successful.

Major obstetric haemorrhage and postpartum haemorrhage (PPH) are the most frequent causes of maternal death, accounting for 35% of all cases worldwide.

The incidence was reported at 2-4% after a vaginal delivery and 6% after a C-section (71). The most common aetiology of PPH is uterine atony, occurring in about 80% of the affected cases. Coagulopathies aside, many risk factors can lead to atony, such as multiple gestation, polyhydramnios, high parity, and prolonged labour. However, the majority of women who develop PPH have no identifiable risk factors (72). Thus prevention is not always possible. Therefore, the patient's survival depends on a prompt diagnosis and a timely and aggressive treatment. It is widely known that postpartum blood loss is underestimated in almost 65.4% of the cases (73), which leads to a situation where too little is done too late. In terms of estimated blood loss, we observed a 2.5-fold increase in the documented cases with PPH from 0.2% to 0.5% following the PROMPT-Training in our unit, showing a better capability of the team to estimate the patients' blood loss.

The primary prevention of a PPH includes the identification of high-risk patients as mentioned above but also the prophylactical use of uterotonics (such as oxytocin and misoprostol) for low-risk patients, both in vaginal deliveries and C-sections, which leads to a reduction of blood loss and prevention of atony (74).

The treatment of PPH is a combination of two types of therapy: a surgical one, which includes the execution of re-laparotomies, hysterectomies and curettages, and a medical one, using blood units, platelets, fresh frozen plasma (FFP), tranexamic acid and a variety of clotting factors.

Analysing the PPH cases in our unit, we observed a four-fold reduction of the C-sections complicated by PPH from 38.5% to 8.8% following the PROMPT-Training. This outcome is a clear indicator for a more aggressive approach. Also, a six-fold reduction was shown in the number of initiated re-laparotomies and the number of obstetrical hysterectomies reduced from 12.3% to 0%. In terms of medical therapy, we observed a reduction in the number of blood units, platelets and FFPs administrated and, simultaneously, increased use of tranexamic acid. These differences were translated into a better knowledge of the team, faster and more precise identification of the blood loss, and, thus, better management following only two years of training.

Shoulder dystocia is a rare but severe obstetrical emergency, leading to severe complications for the newborn, such as brachial plexus injury (BPI), brain damage due to hypoxia, and fetal death. It may also seriously harm the mother. The actual incidence of shoulder dystocia is thought to be between 2-3% worldwide (75). The incidence documented in our maternity unit was calculated before and after the PROMPT-Training. We observed an increase from 0.27% to 0.5%, showing a possible improvement of the identification and documentation skills of the team following the training.

The prevention of shoulder dystocia has been a focus of attention for many years. Risk factors have been identified, such as fetal macrosomia, preexisting or gestational diabetes, shoulder dystocia in a previous pregnancy, induction of labour, epidural anaesthesia, vaginal operative delivery and very short and prolonged second stage of labour (76). However, these risk factors are of low predictive value for shoulder dystocia in labour, and many cases of shoulder dystocia are not associated with any of these parameters. While C-section is a mode of delivery excluding shoulder dystocia, it can not be performed in every delivery. It can be a successful preventive measure in pregnancies with a high risk for shoulder dystocia. However, it is associated with short term complications such as infection, excessive bleeding, thrombosis, bowel, bladder and fallopian tube damage, and long-term complications such as rupture and placenta accreta spectrum in future pregnancies (77).

If an obstetrical complication cannot be entirely prevented, standardized, evidence-based approaches are beneficial. Specific manoeuvres such as Mc Roberts', suprapubic pressure, internal rotation, delivery of the posterior arm, Zavanelli and

symphysiotomy are well-established to resolve the emergencies, and positive effects are demonstrated (78). Following the PROMPT-Training, we observed an increase in the initiation of these manoeuvres by 10% and, in particular, the use of McRoberts' manoeuvre increased from 77.1% to 100%.

Brachial plexus injury is the most common complication of shoulder dystocia, with an incidence of 0.5 to 4.0 per 1000 cases (79). Therefore, its prevention has a high priority. It has been shown in many studies that the implementation of training can reduce the incidence of in BPIs (80). A retrospective analysis of Draycott found that practical training leads to a significant reduction of BPIs from 7.4% to 1.3%. After suitable training, they could even reduce permanent BPIs to 0% (12). Also, the size of the maternity unit with more than 6000 deliveries per year underscores the value of these results.

After two years of training, embracing the training concept led to a reduction of BPIs from 14.6% to 4.3% in our unit. Permanent BPIs even dropped from 14.28% to 0%. These results show, albeit somehow preliminary, a very promising impact of the training and are the study's most important findings. Ongoing repetitive practical training is, however, required to make these results sustainable.

Umbilical cord prolapse (UCP) is a rare but potentially life-threatening obstetrical emergency. It is associated with high neonatal mortality rates, approximately 32-47%, mainly due to asphyxia (81). The overall incidence of cord prolapse ranges from 0.1% to 0.6% (82). However, following PROMPT-Training, we observed an increase in the incidence of UCP from 0.06% to 0.14%. The reason for this increase may be an improvement of documentation, but also in demographical parameters such as the increased prevalence of gestational diabetes from 6.2% (83) to 16.8% (84), resulting in an increase of polyhydramnios, which is the most critical risk factor for UCP.

Prevention of this emergency is impossible (85), as it occurs spontaneously after the rupture of the membranes, which is highly unpredictable. Therefore, the outcome depends on the early recognition and intervention, which is an emergency C-section. This is the reason why a vaginal examination should be performed immediately after the rupture of the membranes. The analysis of the cases in our unit has shown an increase in neonatal asphyxia from 20% to 55.6% and an increase of neonatal deaths from 0% to 33.3%, which came as a surprise because our response time between diagnosis and delivery was simultaneously reduced from 7.64 min to 5.5 min. However, a deeper analysis of the cases has shown that the mean pregnancy week at delivery was before 34^{+4} weeks and after 30^{+4} weeks. In addition, all the demised newborns were born between 25^{+3} and 28^{+3} weeks. The death causes were exclusively associated with prematurity (RDS, NEC) or other extreme predisposing factors like prolonged life anhydramnios resulting in lung hypoplasia.

PROMPT-Training has contributed to a faster response time of the team to the emergency. Still, it was accompanied by a worse neonatal outcome, highly dependent on the parameters mentioned above and not directly associated with

UCP. Subsequent analysis may determine the long-term effects of the training in the management of umbilical cord prolapse.

The fetal breech presentation frequency is about 3% to 4% in terms of pregnancies (51). However, over the past two decades, many studies have shown a decline in the number of women choosing a **vaginal breech delivery (VBD)** mode over a C-section. For example, as demonstrated in the study of Hehir et al. (86), in 16 years, the rate of vaginal breech delivery in nulliparous women decreased from 15.3 to 7.2%, and in multiparous women from 32.6 to 14.8%, respectively. The authors can explain this result because many observational studies have shown a two- to five-fold higher perinatal mortality and morbidity of a VBD than an elective C-section, which has been reported in the meta-analysis from Berhan et al. (87). Also, the Term Breech Trial (88,89) has shown that an elective C-section significantly reduces perinatal mortality and morbidity. However, the 2-year follow-up of the children did not show significant differences in the neurological development between the two Groups. Therefore, it remains unknown if the children's long-term benefits outweigh the maternal risks associated with a C-section.

We observed an increase of the VBD cases from 0.43% to 0.64% in our maternity unit following the introduction of the PROMPT-Training. The numbers are small, 158 in total, which can be explained through a careful selection of the women who meet the safety criteria for a VBD (frank or complete breech presentation, no fetal anomalies on ultrasound examination, adequate maternal pelvis, estimated fetal weight between 2,500g and 3,800g, no increased abnormal head to abdomen circumference ratio (90)). They are also small because a high proportion of the women with breech presentation also opt for an external cephalic version, which, successful in about 50-60%, leads to vaginal cephalic delivery. There is now a tendency in favour of spontaneous vaginal breech delivery compared to an elective C-Section. In addition, the percentage of nulliparous women opting for spontaneous vaginal breech birth increased almost twofold from 39.7% to 73.8%. This can be explained through improved training and skills and enhanced team self-confidence following the training.

An essential evaluation factor for the success of VBD is the complication rates (asphyxia and neonatal death). In other studies (87,91,92), asphyxia rates vary between the world regions from 3.3 to 47.2% and neonatal death rates from 2% to 15.7% in asphyctic children. The high complication rates have stimulated the implementation of training concepts to improve outcomes. However, the recent literature (93,94) is poor, showing no difference in the neonatal outcomes or no analysis was made at all for the effectiveness of the training. Our study observed a reduction in neonatal asphyxia from 7.8% to 4.8%, and a drastic decrease in neonatal death from 22.2% to zero. These results depict a positive impact of the PROMPT-Training after only two years, showing an increase in the VBD and an increase in the VBD and safety. Therefore, continuing the training would make the results more sustainable and presumably increase the number of vaginal breech births.

Twin pregnancy has an incidence from 1.9% to 3.4% (95,96) between the world regions, including dichorionic diamniotic twins (DCDA), monochorionic diamniotic twins (MCDA) and monochorionic monoamniotic twins (MCMA). We excluded the MCMA from our analysis because they are always delivered by elective C-section (97). Twin pregnancies were delivered by **vaginal twin birth** in almost 25% (96). In our clinic, the incidence of twin pregnancies dropped from 4.3% to 3.4% following the PROMPT-Training. However, we observed an increase of successful vaginal twin birth from 17.58% to 22.57% and an increase of MCDA vaginal births from 10.19% to 21.57%. This reflects an improvement of the team's skills, knowledge, and confidence following the PROMPT-Training.

Another evaluating factor for the effectiveness of the vaginal twin birth management is the prevalence of emergency C-section for the second twin, which varies in the literature from 3.4% to 17% (98,99). Analysing the data of our unit, we observed a reduction of emergency C-sections in the second twin from 9.71% to 3.92%, following the training, indicating an improvement in labour management. This is another major improvement following the PROMPT-Training.

We were comparing the perinatal outcomes between twin births and singleton births in the literature and observed, as expected, significantly higher morbidity and mortality rates in twin pregnancies. Also, we observed a relative risk increase for asphyxia between the first and second twin, between 7.8% and 10.1% and neonatal death from 3.5% and 5.2%, respectively (100). Furthermore, an emergency C-section of the second twin is associated with an increased risk of asphyxia, a need for ventilation and seizures of 8.27%, 13.39% and 0.31%, respectively, compared with vaginal delivery, where the same risk is 3.07%, 7.51% and 0.08%, respectively (101). These data highlight the clinical significance of the 2.5-fold reduction of the emergency C-section rates for the second twin, following the PROMPT-Training. In addition, we observed a reduction from 2.91% to 0% for the first twin and 7.28% to 5.88% for the second twin, respectively, analysing the whole numbers of neonatal asphyxia before and after the training. In terms of long-term adverse outcomes, including neonatal death, we observed a reduction from 1.2% to 0% for the first twin and 20% to 0% for the second twin, respectively. Comparing these findings with the world prevalence of complications, the positive impact of the PROMPT-Training becomes apparent.

Finally, an increased time interval between the delivery of the first and the second twin seems to be associated with an adverse perinatal outcome for the second twin (102,103). Therefore, a maximum of 30 min time interval between the twins is recommended (104). In our unit, we prefer and practise active management after the delivery of the first twin to keep the time interval as low as possible. Starting at a mean interval of 14.51 min (min: 1 min, max: 173 min), we observed a reduction to a mean interval of 10.21 min (min: 2 min, max: 45 min) following the PROMPT-Training.

In conclusion, the implementation of PROMPT-Training resulted in an improvement of the vaginal twin birth management and, at the same time, contributed to a

reduction of the adverse perinatal outcomes. Thus, repeated annual PROMPT training of all team members, including vaginal twin birth, will possibly increase the confidence and safety of vaginal twin deliveries.

A maternity unit's most important evaluation factor in safety and obstetrical management is the short- and long-term **Neonatal outcomes**. Reference criteria of the fetal wellbeing after birth and a distinguishing factor between newborns at risk, which demand immediate and intensive care, and the healthy ones, are the umbilical artery pH (105) and the 5´ APGAR-score (106). A combination of umbilical artery pH < 7.0 and a 5´ APGAR-score ≤ 5 had an 80% positive predictive value for the development of seizures, as shown by Perlman and Risser (107). Using the identical selection system, we collected the data from all newborns in our unit with umbilical artery pH < 7.0 and/or a 5´ APGAR-score ≤ 5 (newborns at risk). We excluded gestation < 24 weeks, lethal chromosomal defects or genetic syndromes and hydrops fetalis from the study. Included were all cases with the intention to treat and where a maximum of therapy was applied.

Analysing the neonatal data in our unit, we observed a slight reduction of the newborns at risk from 0.9% to 0.8% following the PROMPT-Training. As far as the demographical factors are concerned, we observed that the proportion of each mode of delivery (vaginal, vaginal operative and C-section) remained unchanged after the training. On the other hand, the number of newborns with anomalies/syndromes slightly increased from 22.7% to 25.5%. Considering the improved documentation provided by the training, we observed an improvement in our peri- and postpartum management.

Asphyxia is a potentially hazardous condition that can result in severe short- and long-term handicaps for the newborn if not diagnosed promptly and treated appropriately. Globally, the incidence of asphyxia is 0.2% to 1%, depending on the country and region (108). In our unit, we observed an incidence of documented asphyxia of 0.36%, decreasing to 0.24% (a reduction of 30%) following the PROMPT-Training. Furthermore, we observed a reduction in newborn-related asphyxia from 39.1% to 31.4% among the newborns at risk.

Newborn resuscitation, especially the timing and documentation of critical events, is a determining factor for reducing adverse outcomes of neonates (109). Following the PROMPT-Training, we observed a drastic increase in the number of newborns at risk who received immediate resuscitation from 90.7% to 100%. However, the number of newborns at risk o suffered from hypoxic ischemic encephalopathy (HIE) increased from 9.8% to 17.6% following the training. One of the potential reasons is a simultaneous increase of FGR cases which in about 20% suffer from intrauterine hypoxia or an increase in the proportion of low birthweight and deficient birthweight infants, both risk factors for HIE. It can also be attributed to better identification and documentation. A further explanation is a decrease in management skills. However, adverse outcomes at one year and neonatal death in the first year were both substantially decreased.

Simultaneously the cooling therapy increased 2.5-fold from 6.6% to 15.7%, which is clinically important considering that the cooling treatment must be administrated within 6 hours of birth to be effective (110). These findings can indicate a quicker diagnosis, risk assessment, and speedier team response to the emergency following the PROMPT.

Finally, the whole purpose of better clinical management of the newborns at risk is the reduction of adverse outcomes, including bodily and mental handicaps and the reduction of neonatal deaths. That is, of course, the purpose of implementing multi-professional obstetrical team training such as the PROMPT. The results from other training concepts vary. In the study of Nielsen et al. (111) and Weiss et al. (112), no differences could be observed for the adverse outcomes before and after the training. This also applies to the THISTLE study (113). PROMPT training in Scotland – the way it was implemented - did not affect the 5´ APGAR-score. Large-scale implementation was found to be more difficult than anticipated. Therefore, both the training concept and the performance must be monitored and validated. The authors conclude that further research is required to understand why the positive effects observed in other single-unit studies have not been replicated in Scottish maternity units and how they can best support implementing the intervention authentically and effectively locally. Other training concepts included the analysis of Daelemans et al. (114), which has shown a positive outcome of the training and reduced neonatal adverse outcomes.

From the data analysis, before and after PROMPT-Training, we observed an 18.4% reduction of the newborns at risk, which suffered from adverse outcomes and a 30% reduction in neonatal deaths.

In conclusion, after only two years of implementing the PROMPT-Training, we observed positive results reducing neonatal complications and adverse outcomes. In addition, in our opinion, the training has improved the obstetrical management in our unit, contributing to increased safety for the newborns. As a result, continuing the training may lead to even better results in the years to come.

Third and fourth-degree Perineal Tears have a prevalence rate from 0.6% to 8% (115). These birth complications can cause serious short- and long-term harm for the mothers, including faecal incontinence (116) and sexual dysfunction (117). Therefore, their prevention is an essential study objective for the obstetrical community. A very controversial theme is the use of episiotomy. Some observational studies have shown that the use of episiotomy for vaginal births (118) and vaginal operative deliveries (vacuum and forceps) (119) is associated with a risk reduction. However, other evidence has shown no impact of the episiotomy (120) or that episiotomy increases the risk of third- and fourth-degree tears (121). The analysis of the data in our maternity unit showed an increase of third and fourth-degree tears from 0.51% to 0.85% following the PROMPT-Training with a simultaneous decrease of the use of episiotomy from 29.2% to 18.1%, showing a possible positive impact of its usage in the reduction of the risk of third and fourth-degree tears.

It is widely proven that one of the most critical risk factors for third- and fourth-degree perineal tears are maternal obesity and fetal macrosomia, and vaginal operative delivery with a 2.6-fold risk increase (120). A finding from the data analysis is that the percentage of vaginal operative births remained unchanged before and after the training at around 7% and the mean fetal weight increased slightly from 3,517g to 3,604g (n.s.). In addition, we observed an increase in the incidence of vaginal operative deliveries resulting in third and fourth-degree tears from 1.8% to 4% after the training. It is essential to mention that the national policy not to apply routine episiotomy in every case of operative vaginal delivery was applied. These data can be translated into an increase of the risk for third- and fourth-degree tears due to the reduced use of episiotomy, but this can also be explained with an improvement in documentation following the PROMPT-Training.

In our opinion, the reduced use of episiotomy may have led to an increased incidence of third- and fourth-degree perineal tears. However, other factors such as the increased incidence of diabetes, the increased obesity, the increased mean maternal age, the underdocumentation and the subsequent increase in the labour induction should be considered, and additional long-term analysis should be performed.

The use of the scientifically written authentical training concept, the adaptation of the training materials into the German language taking into account German guidelines and drugs, the use of high fidelity simulators and the implementation of the PROMPT-Training concept involving teams of midwives, obstetricians, paediatricians and anesthesiologists on a labour ward with more than 3,000 deliveries per annum and with a wide variety of high-risk pregnancies, such as the Hannover Medical School, has resulted in significant improvements after only two and a half years. The main findings were improved communication, better team interactions, and the feeling of being part of one unit looking after women and their babies together. However, when the practical training was paused because of SARS-Cov 2, the detrimental effects became visible after a few weeks, with teams disintegrating and staff leaving. The feeling of loss of being a member of a team was mentioned as the underlying cause. On the other hand, improved communication, team interaction, knowledge and skills, better management of the rare but potentially hazardous obstetrical emergencies resulted in better outcomes.

In conclusion, these data indicate that a short period of practical training enhances communication, teamwork, and the fetal-maternal outcome of birth complications.

V. References

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VI. Summary

With the advancement of medicine, complications during childbirth have already been reduced to lower levels. However, this does not apply to rare complications, which can have ongoing severe consequences for the woman and newborn. Many such difficulties have been considered inevitable in the past. Therefore, they were thought to be untrainable. This study was conducted to challenge that dogma.

Rare but potentially devastating complications include shoulder dystocia, fetal hypoxia and acidosis, pre-eclampsia and eclampsia, umbilical cord prolapse, maternal collapse and cardiac arrest, difficult airways, sepsis and acute uterine inversion. They must be recognized immediately and treated adequately.

Training is expensive and should therefore be effective. Practical training improves the outcome. The critical elements of training are based on clinical studies (authenticity), theoretical tuition, practical training (simulation), teamwork, communication and annual re-training with at least 95% of the staff. This requires midwives, obstetricians, neonatologists and anesthesiologists in mutual training. Also, the concept must be evaluated in general and in terms of its practical implementation in hospitals.

The effectiveness of the PROMPT training has been demonstrated in various studies in different countries and continents (https://www.promptnz.org/evidence-of-effectiveness). However, some hospitals have initially seen an increase in complications upon the introduction of training. The introduction of training has therefore to be monitored, and feedback on the outcomes must be given. However, training became effective when it ensured that critical elements were implemented, i.e. > 95% staff training.

The objective of this study was to determine if the implementation of PROMPT training using the original PROMPT concept would affect outcomes after 2½ years of training. This included translations of trainer materials, slides and proceedings into the German language.

PROMPT training was introduced at the Department of Obstetrics and Gynecology at the Hannover Medical School on November 8th 2017. All professional Groups participating in labour and childbirth, such as obstetricians, midwives, neonatologists, pediatric nurses, anaesthetists, anaesthesia nurses, and theatre nurses, participated in the training. The training was aimed at improving the knowledge and skills for obstetrical emergencies. This included the capability to assess the situation, simplify and standardize the management of each crisis using algorithms, and achieve better communication and teamwork.

The impact of training was assessed by comparing neonatal complication rates before and after the implementation. All infants born during the 16 years from January 1st 2004 (when the labour ward was established at the Hannover Medical

School) until December 31st 2019, were identified using a computerized fetal database. Deliveries from January 1st 2004, and November 8th 2017, were from before the training. The period from November 9th 2017 (test run) until 31st December 2019 was after the implementation of training.

Before and after the training, the complication rates included pre-eclampsia and eclampsia, maternal sepsis, major obstetric haemorrhage, shoulder dystocia, umbilical cord prolapse, vaginal breech delivery, twin birth, and newborn outcomes perineal tears grades III & IV.

The case numbers with pre-eclampsia increased and Magnesium sulfate ($MgSO_4$) was more frequently administered, whereas progress to eclampsia remained the same. The number of pregnancies complicated by severe sepsis decreased significantly, including cases involving severe adverse outcomes such as hysterectomy and maternal death. The evaluation of blood loss and, as a result, the identification of major obstetric haemorrhage improved. Also, the number of re-laparotomies, obstetrical hysterectomies, blood products, and clotting factors used around birth for haemorrhage was reduced. The number of shoulder dystocia cases detected increased, while simultaneously, the numbers of permanent brachial plexus injury and cases of asphyxia went to zero. The response time in cases of umbilical cord prolapse was shortened. However, the adverse outcomes of these newborns increased. The number of vaginal breech deliveries increased, while the cases of asphyxia were reduced and adverse outcomes went to zero. The number of twin pregnancies delivered spontaneously increased, and the time between the first and the second twin was significantly reduced. In addition, the number of pregnancies that ended in a C-section for the second twin was reduced, and there were fewer adverse outcomes for the neonates. The total neonatal adverse outcomes, including handicap and death, was reduced, while simultaneously the management of the newborns at risk, in terms of resuscitation and extended treatment, including cooling, improved. Finally, we observed a significant decrease in episiotomies, while the number of perineal tears grades III & IV slightly increased. Hierarchie became less critical, and people felt belonging to a Group and a member of a Group of professionals looking after pregnancy and childbirth. There was a feeling of satisfaction and happiness working in that context. The team members also felt more appreciated, and their progress in skills – regardless of their specialisation – was highly acknowledged.

In conclusion, the implementation of the PROMPT concept at the Department of Obstetrics and Gynecology (Hannover Medical School, Germany) has demonstrated that after 2½ years, significant improvement in the management of rare obstetrical emergencies can be achieved by training.

VII. List of Fonts

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VIII. Curriculum Vitae

Spyridon Papageorgiou
Medical Doctor

Gynecological and Obstetric Specialist

PERSONAL DATA

Date and Place of Birth:	15.10.1991, Amarousion Athens, Greece
Family-Status:	Single
Residence:	Nussriede 16, 30627, Hannover, Germany
Nationality:	greek
Mobile phone number:	+49 176-29079501

STUDIES

School

1997 - 2003	Private School Erasmeios Ellinogermaniki (greek & german) in Athens
2003 - 2009	Private School Arsakeion in Psychico in Athens
2009	Graduation (Note: 19.9/20)

University

2009 - 2015	Studies in Human Medicine, National and Kapodestrian University of Athens
2013 - 2014	Erasmus Student Exchange Programme (Ludwig-Maximilians-Universität Munich)
2015	University Degree (Grade: 8.43/10)
2015	Approbation as a Doctor in Greece
18.1.2016	Approbation as a Doctor in Germany
8.9.2021	Gynecological and Obstetric Specialist in Germany

LANGUAGES

English	C2 (Cambridge Proficiency)
German	C1 (Goethe Institut Athen)
Greek	Native Speaker

PROFESSIONAL EXPERIENCE

15.9.2015 - 14.10.2015	Private Hospital HYGEIA in Athens, Trainee in the Department for Plastik Surgery.
15.10.2015 - 14.11.2015	Private Hospital HYGEIA in Athens, Trainee in the Department for Abdominal Surgery.
15.11.2015 - 15.1.2016	Private Hospital HYGEIA in Athens, Trainee in the ICU.
18.5.2016 - 31.5.2017	Johannes Wesling Klinikum Minden, Department of Obstetrics and Gynecology, University Hospital, Resident.
1.6.2017 – 8.9.2021	Hannover Medical School, Departmant of Obstetrics and Gynecology, Resident.
1.2.2020 – 8.9.2021	Hannover Medical School, Outpatient Clinic (Fetal Medicine), Resident.
8.9.2021 – today	Hannover Medical School, Departmant of Obstetrics and Gynecology, Fellow.
8.9.2021 – today	Hannover Medical School, Outpatient Clinic (Fetal Medicine), Fellow.

QUALIFICATIONS

6.1.2020	DEGUM Level I for Obstetrics and Gynecology
25.1.2020	DEGUM certificate feto-maternal Doppler Sonography
7.4.2020	Certificate of Competence of the ‘11-13 weeks Scan’ Fetal Medicine Foundation London (including Nasal Bone, Tricuspid Valve, Ductus venosus and Pre-eclampsia screening)
6.4.2021	Certificate of Competence ‘Fetal abnormalities’ of the Fetal Medicine Foundation London

PUBLICATIONS

10.2018	Ultraschalldiagnostik in der Schwangerschaft, Medizinische Monatsschrift für Pharmazeuten, 41. Jahrgang, Heft 10

Hannover, den 23. Oktober 2021

Spyridon Papageorgiou

IX. Erklärung nach §2 Abs. 2 Nr. 7 und 8 PromO

Ich erkläre, dass ich die der Medizinischen Hochschule Hannover zur Promotion eingereichte Dissertation mit dem Titel:

Eine 2 ½-Jahres-Zwischenanalyse von seltenen geburtshilflichen Komplikationen nach der Einführung von dem Praktischen geburtshilflichen multiprofessionellen Training (PROMPT) an der Medizinischen Hochschule Hannover

in der Klinik für Frauenheilkunde, Geburtshilfe und Reproduktionsmedizin unter Betreuung von Prof. Dr. Constantin von Kaisenberg mit der Unterstützung durch Ulrike von Hehn (Statistik) ohne sonstige Hilfe durchgeführt und bei der Abfassung der Dissertation keine anderen als die dort aufgeführten Hilfsmittel benutzt habe. Das Englisch wurden durch einen muttersprachlichen Briten, Dr. rer. nat. Steven R. Talbot (MHH) überprüft. Die Gelegenheit zum vorliegenden Promotionsverfahren ist mir nicht kommerziell vermittelt worden. Insbesondere habe ich keine Organisation eingeschaltet, die gegen Entgelt Betreuerinnen und Betreuer für die Anfertigung von Dissertationen sucht oder die mir obliegenden Pflichten hinsichtlich der Prüfungsleistungen für mich ganz oder teilweise erledigt. Ich habe diese Dissertation bisher an keiner in- oder ausländischen Hochschule zur Promotion eingereicht. Weiterhin versichere ich, dass ich den beantragten Titel bisher noch nicht erworben habe. Ergebnisse der Dissertation sind zur Publikation vorgesehen, jedoch noch nicht eingereicht.

Hannover, den 23. Oktober 2021

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(Unterschrift)