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MRI-based pelvimetric measurements as predictors for a successful vaginal breech delivery in the Frankfurt Breech at term cohort (FRABAT)

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ABSTRACT

Objectives: The purpose of this study was to investigate the role of the maternal pelvis, assessed by MRI pelvimetry in nulliparous women expecting a term fetus in breech presentation, to predict a successful and safe vaginal birth.

Study design: In this monocentric and anonymized cohort study, we enrolled 367 nulliparous women with breech presentation at 39^{+0} to 41^{+0} weeks of gestation during a period of 8 years at the University Women's Hospital in Frankfurt/Main. Pelvic measurements were obtained by standard MRI imaging. We correlated the obstetric conjugate, the pubic angle and the distance between the ischial tuberosities (intertuberous distance) with the maternal and fetal outcomes of vaginally intended breech births. The data was evaluated using logistic regression analysis.

Results: 241 of 367 participants (65.7%) experienced a successful vaginal delivery whereas 126 patients (34.3%) were subjected to secondary cesarean section. An increasing obstetric conjugate was significantly associated with an increasing rate of successful vaginal deliveries. No significant correlation of the intertuberous distance and the pubic angle with the mode of delivery could be shown. Although statistically not significant, we were able to define cut-off values of 10.9 cm in the intertuberous distance and 70° in the pubic angle; below these values, no successful vaginal delivery was recorded. No significant differences in the short-term outcomes were seen between the neonates of the vaginal delivery and the cesarean section groups. Inter- and intraobserver variability showed excellent reproducibility for all MRI parameters.

Conclusion: The obstetric conjugate correlates with the rate of vaginal deliveries in nulliparous women at term and can be used as a useful criterion for pre-selection and counseling of women with breech presentation and the desire for a vaginal delivery.

Introduction

A singleton fetus in breech presentation is seen in 3–4% of term pregnancies [1]. International societies regard the vaginal breech delivery (VBD) as safe; it should be offered to a selected group of women [2–7]. In the Western world, many providers fear adverse outcomes and medicolegal consequences, which translates into a growing number of elective cesarean sections (CS) associated with unfavorable maternal outcomes [8–11]. Also, the expertise of providers to conduct and teach vaginal breech deliveries is declining. Many pro- and retrospective studies with strict management protocols and a selected patient clientele documented excellent neonatal outcomes after vaginal delivery [2,12]. In this regard, evidence of the PREMODA trial shows no difference in neonatal morbidity or mortality after VBD when compared with elective CS [2].

Society guidelines and committee opinions recommend an “adequate maternal pelvis” as a selection criterion for vaginal breech births. The concept of pelvimetry dates back to 1675, when Deventer associated pelvic dimensions with a successful vaginal delivery [13]. The method was refined by utilizing X-Ray and later Magnet Resonance Imaging (MRI) for pelvic assessments [14,15]. Authors hypothesized that decisions for VBD guided by pelvimetry may be followed by fewer adverse neonatal outcomes than those based on clinical criteria alone [15,17,18]. Although MRI pelvimetry is a promising tool to identify nulliparous women as candidates for a VBD [15,19], we still need more evidence on how to use pelvic metrics as predictors for a successful and safe trial of labor.

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Hence, it is the overall purpose of this study to investigate MRI-based pelvimetry to predict a successful and safe vaginal breech birth. We analyzed the association of three MRI-quantified pelvic metrics, which represent the pelvic inlet and outlet, with a successful VBD in nulliparous women at term. Also, fetal outcomes were investigated associated with the respective mode of delivery.

Materials and methods

This cohort study was conducted between 01/2009 and 07/2017 after obtaining approval from the Ethics committee at the Johann-Wolfgang-Goethe University, Frankfurt (November 2011, # 420/11). Informed consent was waived because anonymized data - routinely collected during patient care - was analyzed.

After 34^{+0} weeks of gestation, nulliparous women with a breech presentation were counseled about an external cephalic version and the different modes of breech delivery. Patients who decided on vaginal breech delivery underwent MRI pelvimetry for the measurement of the obstetric conjugate (CVO), the intertuberous distance and the pubic angle. Inclusion criteria included intent for vaginal delivery, full term pregnancy (39^{+0} to 41^{+0} weeks of gestation), singleton, a minimum estimated fetal weight of 2500 g, adequate fetal weight gain and a CVO of 12 cm or greater [7,19]. Exclusion criteria were severe intrauterine growth retardation, lethal congenital malformations as well as contraindications for MRI imaging such as any kind of metal implants or severe claustrophobia. Counseling and care during delivery is highly standardized in our department, e.g. the majority of vaginal breech deliveries occurred in an upright position cared for by providers certified for 'Maternal-Fetal Medicine' by the German Medical Board [7]. The trial of labor was aborted and a CS was performed by a board-certified physician, e.g. due to non-reassuring or ominous fetal heart tone tracing.

During the examination of the bony pelvis (1.5-T MR scanner, Magnetom Espree, Erlangen, Germany), the women were in a supine dorsal position for 10–15 minutes. All digital images were analyzed using the software Advantage Workstation (GE Healthcare, London, UK). The CVO (distance from the sacral promontory to the backside of the bottom edge of the symphysis pubis (Fig. 1)) representing the pelvic inlet was quantified in the mid-sagittal plane. Two specialists in the fields of gynecology and radiology performed the investigation independently. The measurements were assessed for inter-observer reliability.

Retrospectively, one obstetrician who was blinded to the main outcome (mode of delivery) measured the angle of the public arch (public angle, between the bottom edge of the symphysis to the ischial tuberosity of same side of the pelvis, quantified in degrees, Fig. 3) as well as the intertuberous distance (distance between the right and left ischial tuberosity in cm, Fig. 2). These measurements representing the pelvic outlet were taken in an axial plane and investigated twice for intra-observer reliability. All distances were measured from the inner side of the respective bones. The fetal biparietal diameter, the femoral length, the head and abdominal circumferences were measured by sonography (GE or al Philips ultrasound system); the fetal weight was estimated using the Merz formula [33].

As primary outcome we assessed "birth by secondary CS" or "spontaneous vaginal breech delivery (VBD)". For secondary outcomes, we obtained numerous neonatal parameters including the pH values of the umbilical cord, base excess, 5-minute APGAR scores and admission to the neonatal intensive care unit (NICU) and compared these between the groups. Also, maternal and fetal characteristics were collected, e.g. Body Mass Index (BMI) between the 7–12 weeks of pregnancy [20], epidural anesthesia during birth, head circumference of the neonates. Data were collected from patients' records and the 'Perinatalerhebung Hessen' state database.

Statistical analysis

We compared baseline characteristics of women who experienced a CS to those with a VBD using the Fischer exact test for categorical variables (qualitative such as the sex of the neonate) and $\chi 2$ test for numerical variables. A p-value of 0.05 or less was considered as significant. The statistical calculations were carried out by the use of BiAS for Windows (version 11 © epsilon-Verlag 1989–2016, Frankfurt am Main, Germany).

The primary analyses included the different categories of CVO, intertuberous distance and the public angle and the outcome of vaginal birth. We estimated the odds ratios (OR) with 95% confidence interval (CI) by logistic regression for each variable of interest using Statistical Package for the Social Sciences (SPSS Version 23, STata Corp, College Station, TX, USA, IBM, USA) and BiAS for Windows.

The standard distribution (normality) of the study variables was investigated using the Kolmogorov-Smirnov test. Variables

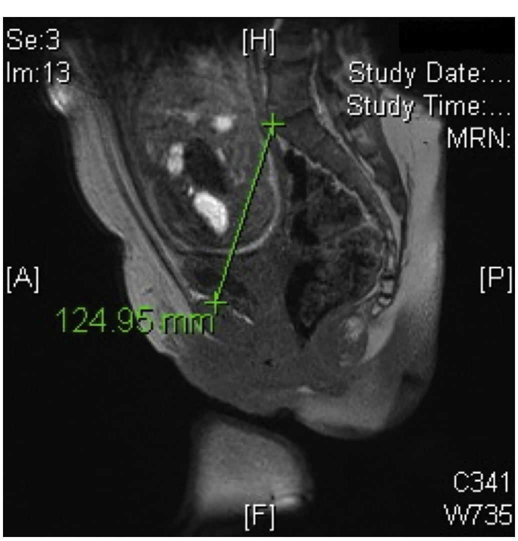


Fig. 1. Obstetric conjugate (CVO) [cm]: Sagittal distance, measured between the promontory and the dorsal surface of the symphysis.

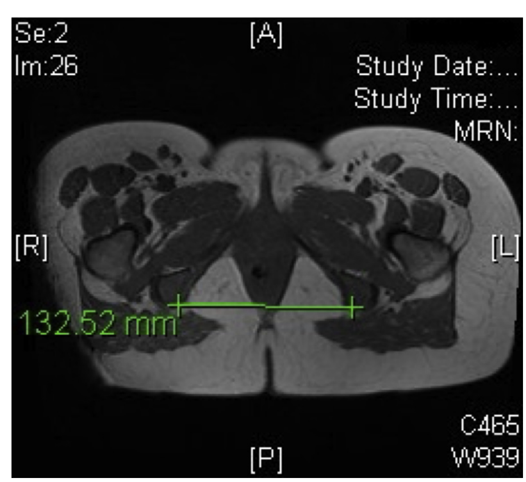


Fig. 2. Intertuberous distance in cm: axial diameter of the intertuberous distance between the right and left ischial tuberosity.

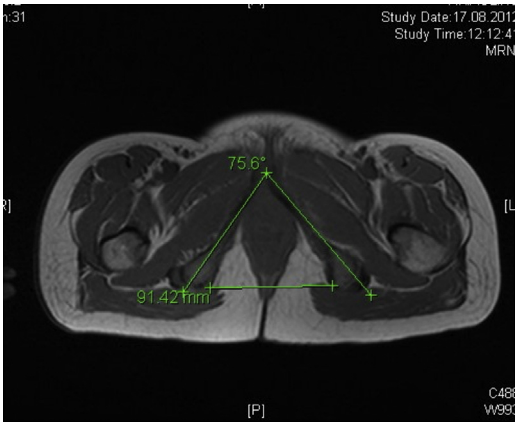


Fig. 3. Axial pubic angle (°): angle between the bottom edges of the symphysis to the ischial tuberosity of same side of the pelvis.

identified as distributed inhomogenously (tested previously with the Levene's test) were analyzed by the use of the Welch's test. A student *t*-test was performed to analyze all homogenously distributed parameters identified by the Levene's test. Although the prerequisites are violated, the *t*-test can be used with a large sampling range and good test stability [21,22]. All parameters that were statistically significant here were subsequently tested with a logistic regression.

Bivariate correlations were analyzed using a Pearson's correlation. The inter- and intraobserver variability was tested using the intraclass correlations (ICCs) and was calculated for each MRI parameter. We interpreted the ICCs as follows: good for ICCS $\geq$ 0.80 and excellent for ICCs $\geq$0.90. For all statistical analysis, we used the IBM SPSS Statistics Version 23 and BiAS for Windows.

Results

1448 mainly Caucasian nulliparous women with breech presentations were seen in our study center. We excluded 694 women expecting babies at $\leq 39^{+0}$ weeks of gestation and 121 women at $\geq 41^{+0}$ weeks of gestation and/or with multiples (287 patients). Of the eligible 633 patients, 266 decided to proceed with an elective CS. 367 were planning a vaginal breech birth and included in the study cohort. 335 of these participants had the required CVO of 12 cm or greater. In 32 cases, prepartal MRI pelvimetry revealed a CVO less than 12 cm, but the women nevertheless wanted to attempt a vaginal delivery.

Regarding the primary outcome, 241/367 women (65.7%) experienced a successful VBD. 126/367 women (34.3%) were subjected to secondary CS either for ominous fetal heart rate, arrest of labor during first or second stage of delivery, footling presentation, umbilical cord prolapse or maternal exhaustion (Fig. 7). For the secondary outcome, we found no significant differences of short-term outcomes (e.g. pH values of the umbilical cord or postpartum admission to the NICU) between the neonates of the vaginal delivery and the secondary CS groups (Tables 6 and 7). We observed no neonatal death.

The maternal age range spanned 18 years and 6 month to 40 years and 9 month at the delivery day. All maternal characteristics as well as pregnancy durations were not significantly different in patients who experienced a VBD versus a secondary CS. The babies delivered by CS had a significantly greater head circumference (35.8 ± 1.4 cm versus 35.3 ± 1.2 cm) and weight (3443.6 ± 435 g versus 3270.9 ± 356 g) than they counterparts (Table 1).

The mean CVO in both groups varied significantly (12.9 ± 0.8 cm in the VBD versus 12.6 ± 0.8 cm in the CS group). Although the differences in both groups were not significant for the intertuberous distance and the pubic angle, we could show the trend of an increasing vaginal birth-likelihood associated with an increasing intertuberous distance and pubic angle (Figs. 4–6). With an intertuberous distance of 10.9 cm or a pubic angle of <70° the secondary CS rate was 100% (Fig. 5). Table 2 shows a forest plot of the prevalence Odds Ratios (OR) in regards to the pelvimetric parameters. Using logistic regression analysis, maternal age and epidural anesthesia, fetal size, weight and head circumference as well as the CVO and the mother's age were significantly associated with birth outcomes (Tables 3–5). In addition, an epidural anesthesia correlates significantly with a successful VBD - even if the observed effect was small. The ICC coefficients for inter- and intraobserver variability showed excellent reproducibility for all MRI parameters. We documented a ICC of 0.95, 0.89 and 0.95 for the measurement of the CVO, intertubarous distance, and pubic angle, respecively.

Table 1
The characteristics of all study participants presented by outcome (vaginal delivery and secondary cesarean section).

	Vaginal delivery group n = 241	p	Ceasarean section group n = 126
Maternal parameters			
Maternal age	30.8 ± 3.9	**.004**	32.0 ± 3.7
Days of gestation at delivery	280.4 ± 4.1	.420	280.7 ± 4.4
Maternal height [cm]	169.4 ± 6.3	.596	169.1 ± 5.8
Maternal weight gain during pregnancy [kg]	13.5 ± 6.5	.993	13.5 ± 10.0
BMI	22.3 ± 2.8	.434	22.6 ± 3.9
Epidural anesthesia	159/241 (65.9%)	< **.001**	77/126 (61.1%)
Induction	22/241 (9.2 %)	**.013**	24/126 (19 %)
Fetal parameters			
Sex Male/Female	119/122	.975	62/64
Size at birth [cm]	52.0 ± 2.6	**.011**	52.8 ± 2.7
Birth weight [g]	3270.9 ± 356	< **.001**	3443.6 ± 435
Head circumference [cm]	35.3 ± 1.2	< **.001**	35.8 ± 1.4
MRI assessed parameters			
Pubic angle [°]	86.9 ± 6.5	.567	87.3 ± 6.7
Intertuberous distance [cm]	13.4 ± 1.1	.784	13.4 ± 1.2
Obstetric conjugate [cm]	12.9 ± 0.8	< **.001**	12.6 ± 0.8
Fetal outcome			
APGAR 5 minutes	9.6 ± 0.6	.400	9.5 ± 0.9
pH	7.16 ± 0.07	< **.001**	7.27 ± 0.07
Base excess	−7.6 ± 3.4	< **.001**	−3.1 ± 2.7

Bold values indicate statistical significance.

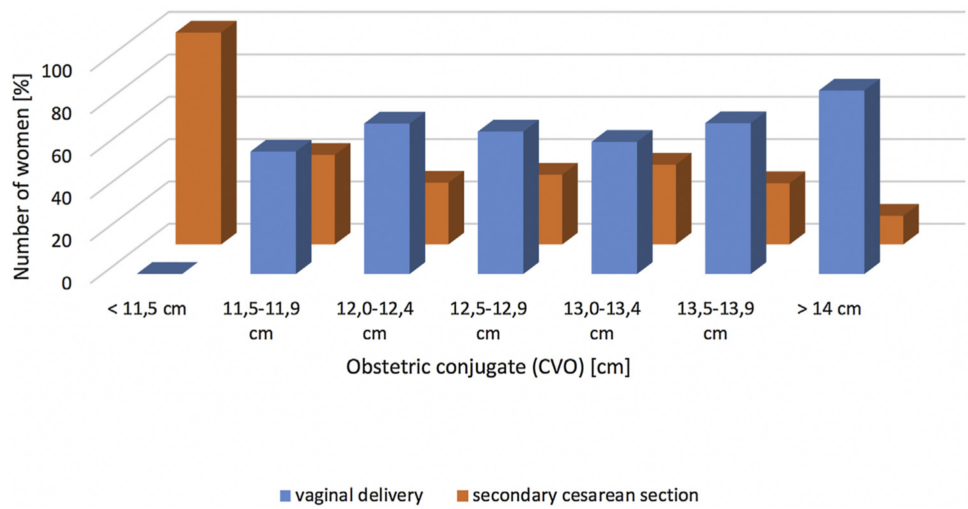


Fig. 4. Comparison of the vaginal and the secondary cesarean breech deliveries in association with the obstetric conjugate.

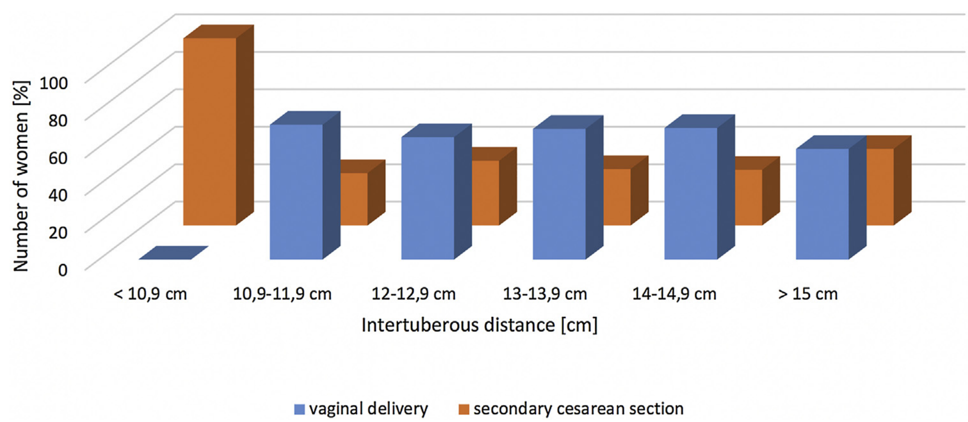


Fig. 5. Comparison of the vaginal and the secondary cesarean breech deliveries in association with the intertuberous distance.

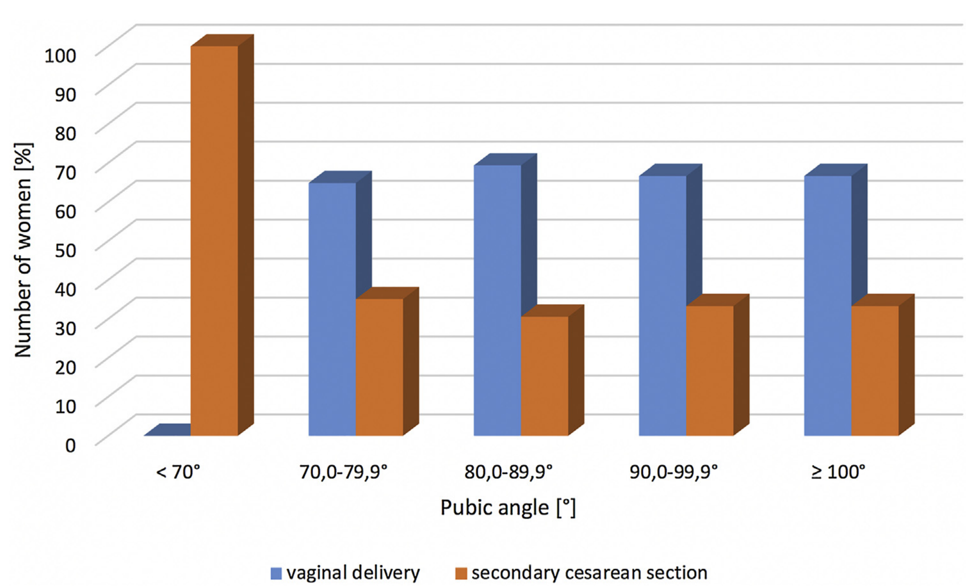


Fig. 6. Comparison of the vaginal and the secondary cesarean breech deliveries in association with the pubic angle.

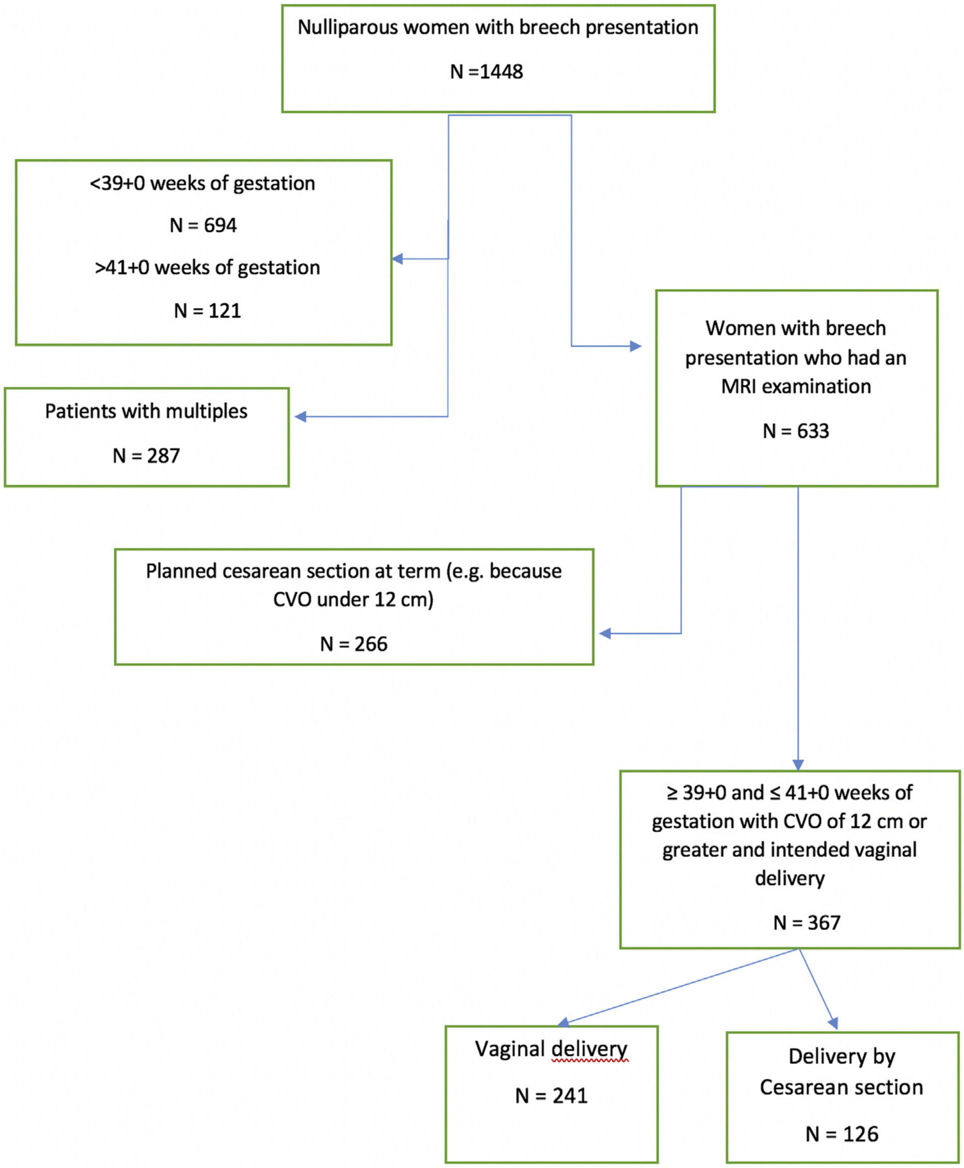


Fig. 7. Flow-chart illustrating case selection and different modes of delivery; n represents the number of included cases.

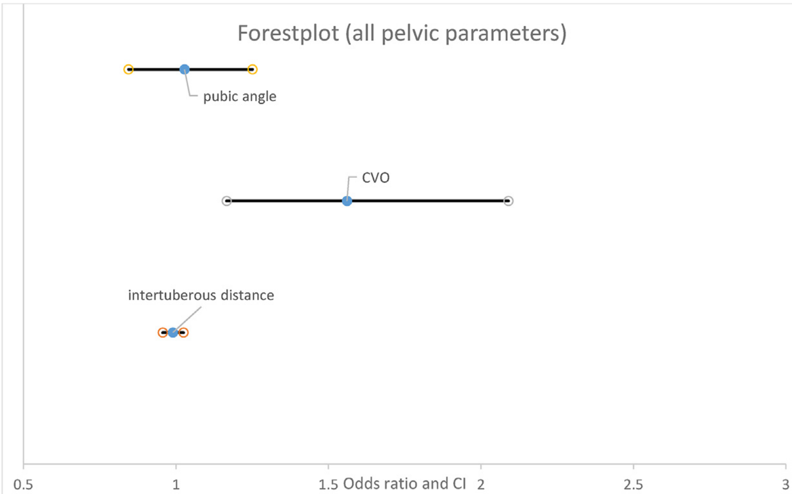
Comment

In this first prospective cohort study, we documented a significant linear correlation of the CVO distance (of 12 cm or greater) and the success of a VBD of singletons at term. The intertuberous distance and the pubic angle had shown no statistically significant correlation. But threshold values were established for both, which were 10.9 cm and 70° respectively, that were critical. Hence, a safe VBD without head intrapment was highly unlikely when the intertuberous distance and/or the pubic angle were below these values. In these cases, the patients would benefit from a planned CS.

MRI provides an easy, reliable and accurate method to evaluate the bony pelvis of pregnant women in a highly standardized fashion. Hence, prior studies evaluated the value of MRI-based pelvic metrics for patient preselection and the prediction of a successful VBD [15,23]. Historically, the CVO was the most commonly examined metric. Joyce et al. [31] described an association between the CVO and pelvic capacity in a cephalic versus breech trial of labor. The authors concluded that "a cephalic baby of 3400-g might pass through a pelvis with a minimum CVO of 10 cm, but would need an obstetric conjugate of 11.7 cm for a safe breech delivery." [31]. In the present study, we used a CVO of 12 cm representing a sufficient pelvic inlet as a cut-off when pre-selecting patients for a trial-of-labor. It is important to mention that a previous MRI imaging study showed an increase in pelvic parameters when women were in upright position [16]. Hence, a CVO of 12 cm or more - assessed by MRI in supine position – might be even greater in upright position explaining the favorable clinical outcomes when VBD is conducted in this fashion [7].

Franz et al. [32] support our data on the CVO as an important predictive pelvic metric; they also showed a positive significant correlation of the MRI-based CVO with successful vaginal births. It has to be mentioned that their patient collective was more heterogeneous than ours, e.g. multiparous patients and women expecting fetuses in vertex presentations were included. Hoffmann et al. [15] published evidence describing a significant association of the intertuberous and especially the interspinous distance with a successful vaginal breech birth [15]. These results differ from our findings since they could not underline the importance of the CVO for the prediction of the birth outcome. This difference might be

Table 2
Forrest plot for all pelvic parameters.



CVO: Obstetric conjugate in cm, CI: Confidence intervall.

Table 3
Logistic regression model (all parameters) for association of parameters with vaginal delivery versus secondary cesarean section.

Maternal parameters			Negelkerkes R^2
Parameter	OR (95% CI)	p	0.229
Maternal age	0.9253(0.8669-0.9877)	**.019**	
Days of gestation	0.9629(0.9107-1.0180)	.182	
increase in weight during pregnancy [g]	0.9956(0.9669-1.0251)	.766	
Maternal height [cm]	1.0152(0.9767-1.0552)	.445	
BMI	0.9882(0.9199-1.0616)	.745	
Epidural anesthesia	0.2857(0.1565-0.5217)	< **.001**	
Fetal parameters			
Sex (m/f)	0.9526(0.5932-1.5295)	.840	
Size at birth [cm]	0.9086(0.8292-0.9955)	**.039**	
Birthweight [g]	0.9990(0.9984-0.9996)	**.001**	
Head circumference [cm]	0.7563(0.6324-0.9047)	**.002**	
MRI assessed parameters			
Pubic angle [°]	0.9973(0.9613-1.0347)	.885	
Intertuberous distance [cm]	1.0417(0.8411-1.2901)	.708	
Obstetric conjugate [CVO, cm]	1.5582(1.1495-2.1120)	**.004**	

When all *parameters* were used, we should be able to explain at least 22.9% (Nagelkerkes $R^2 = .229$) of the variance delivering spontaneously or with secondary CS.
Bold values indicate statistical significance.

Table 4
Logistic regression model (all significant parameters) for association of parameters with vaginal delivery versus cesarean section. In a model using only the *significant* parameters we were able to explain at least 20.3% (Nagelkerkes $R^2 = .203$) of the variance delivering spontaneously or with secondary CS.

			Negelkerkes R^2
Maternal parameters	OR (95% CI_1)	p	0.203
Maternal age	0.9306(0.8763–0.9882)	**.018**	
Epidural anesthesia	0.2737(0.1532–0.4890)	< **.001**	
Fetal parameters			
Size at birth [cm]	0.8963(0.8210–0.9786)	**.014**	
Head circumference [cm]	0.7382(0.6198–0.8793)	< **.001**	
Birthweight [g]	0.9989(0.9983–0.9995)	< **.001**	
MRI assessed parameters			
Obstetric conjugate [CVO, cm]	1.5196(1.1455-2.0158)	**.003**	

[1]CI confindence intervall.
Bold values indicate statistical significance.

based on the investigated patient collective. For example, they included women at 35^{+0} weeks of gestation and later and excluded patients who expected babies with an estimated fetal weight of more than 3800 g (which we included). Overall, our data extend the results of this two descriptive studies since we did not only show an association between particular pelvic metrics and the likelihood of a spontaneous birth but could also attribute a likelihood for vaginal birth to a particular CVO range.

The precision and reliability of MRI imaging - independent from the examiner's experience to assess the female pelvis - is well described [25–27]. Our results supported this statement by demonstrating high inter- and intra-examiner reliabilities of our pelvic measurements. Particularly, we showed a very good reproducibility of the measurement of the intertuberous distance by MRI. These findings were similar to the results of Hoffmann et al. and differed from the reports published by Keller et al. [30], who had shown a large intra- and inter-observer variability for this specific metric.

In our study, the rate of aborted vaginal breech deliveries (34.3%) was substantially lower than in the Term Breech Trail (43.9%). We documented a small, but significant benefit of epidural anesthesia for a successful vaginal delivery outcome. Also, the neonatal short-term outcomes did not differ significantly between the secondary CS and the vaginal breech group. These favorable findings might be attributed (1) to the longstanding experience providers have regarding breech management in an upright position in our department and (2) to the rigorous process we followed to identify suitable patients for the vaginal delivery mode.

As a potential bias of our data, we acknowledge that this study was conducted with a specific patient collective. These women were highly motivated for a vaginal breech birth, were in constant contact to the medical system in a high-resource country and were cared for by health care providers with extensive experience in the field. Hence, the external validity of our study might be limited, and our results cannot be applied to patients in under-developed or developing countries or in underserved setting with a limited access to care. Also, we performed our investigation in a single center with the highest level of perinatal care and readily available MRI. Hence, we acknowledge that our approach is not generalizable and only feasible and reproducible in a limited set of hospitals. As important weaknesses of our study, we did not perform any blinding of patients or obstetricians, who both knew the results of the MRI-based CVO measurement. We also investigated only short-term outcomes of newborns, and did not additionally assess long-term outcomes.

Overall, our data support that the MRI-based pelvimetry is a valuable tool to support selection of adequate candidates for a trial-of-labor in a cohort of nulliparous women expecting term breech babies, who are suitable for vaginal delivery instead of being immediately subjected to elective CS. Hence, this imaging modality is clinically relevant and complements the clinical assessment. We do not regard an MRI is an absolute prerequisite for a spontaneous breech delivery. But during counseling the correlation of CVO distance and the increasing likelihood of vaginal birth might be especially helpful. Clinical management guided by this evidence might increase the safety of VBD in the future and reduce the numbers of unnecessary CS and associated adverse outcomes.

Table 5
Logistic regression model (all pelvic parameters) for association of parameters with vaginal delivery versus secondary cesarean section. Based on this model with *all pelvic parameters,* we were able to explain at least 3.9% (Nagelkerkes R^2 = .039) of the variance delivering spontaneously or with secondary CS.

Pelvic Parameter	OR (95% CI)	p	Negelkerkes R^2
Pubic angle [°]	0.9900(0.9566-1.0246)	.567	0.039
Obstetric conjugate [CVO, cm]	1.5612(1.1660-2.0904)	**.002**	
Intertuberous distance [cm]	1.0278(0.8444-1.2511)	.784	

Bold value indicate statistical significance.

Conflict of interest

All Authors declare that they have no conflict of interest.

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Table 6
Comparison of the neonatal outcome parameters between the vaginal and the secondary cesarean section groups.

Fetal Outcome Parameter	Vaginal delivery group n = 241	p	Cesarean section group n = 126
APGAR 5 minutes	9.6 ± 0.6	.400	9.5 ± 0.9
pH	7.16 ± 0.07	< **.001**	7.27 ± 0.07
Base excess	−7.6 ± 3.4	< **.001**	−3.1 ± 2.7

Bold values indicate statistical significance.

Table 7
Comparison of adverse neonatal outcome parameters between the vaginal and the secondary cesarean section groups.

Fetal Outcome Parameter	Vaginal delivery group n = 241	Secondary caesarean section group n = 126
APGAR (5`) < 7	0	1
(%)		(0.7)
pH < 7.10	40	6
(%)	(16.5)	(4.7)
pH < 7.05	16	1
(%)	(6.6)	(0.7)
Admission to NICU[a]	14	6
	(5.8)	(4.7)

[a] Reasons for admission to NICU: respiratory distress syndrom (RDS), infection or sepsis, hypoglycemia, perinatal adaptation problems.

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