Sonographic prediction of outcome of vacuum deliveries: a multicenter, prospective cohort study

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KEYWORDS: labor, vacuum extraction, sonography, transperineal ultrasound, transabdominal ultrasound, cesarean delivery, umbilical artery blood samples

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Abbreviations

OA, occiput anterior; HR, hazard ratio; ROC-curves, receiver-operating characteristics curves

Conflict of interest

There are no conflicts of interest

Abstract

BACKGROUND: Safe management of the second stage of labor is of great importance. Unnecessary interventions should be avoided and correct timing of interventions focused. Ultrasound assessment of fetal position and station has a potential to improve the precision in diagnosing and managing prolonged or arrested labors. The decision to perform vacuum delivery is traditionally based on subjective assessment by digital vaginal examination and clinical expertise and there is currently no method of objectively quantifying the likelihood of successful delivery. Prolonged attempts at vacuum delivery are associated with neonatal morbidity and maternal trauma, especially so if the procedure is unsuccessful and a cesarean is performed.

OBJECTIVES: The aim of the study was to assess if ultrasound measurements of fetal position and station can predict duration of vacuum extractions, mode of delivery and fetal outcome in nulliparous women with prolonged second stage of labor.

STUDY DESIGN: We performed a prospective cohort study in nulliparous women at term with prolonged second stage of labor in seven European maternity units from 2013-2016. Fetal head position and station were determined using transabdominal and transperineal ultrasound respectively. Our preliminary clinical experience assessing head-perineum distance prior to vacuum delivery suggested that we should set 25 mm for the power calculation, a level corresponding roughly to + 2 below the ischial spines. The main outcome was duration of vacuum extraction in relation to ultrasound measured head-perineum distance with a predefined cut-off of 25 mm, and 220 women were needed to discriminate between groups using a hazard ratio of 1.5 with 80% power and alpha 5%. Secondary outcomes were delivery mode and umbilical artery cord blood

samples after birth.

The time interval was evaluated using survival analyses, and the outcomes of delivery were evaluated using receiver-operating characteristics curves and descriptive statistics. Results were analysed according to intention to treat.

RESULTS**:** The study population comprised 222 women. The duration of vacuum extraction was shorter in women with head-perineum distance ≤25 mm (log Rank test <0.01). The estimated median duration in women with head-perineum distance ≤25 mm was 6.0 minutes (95% C1 5.2-6.8 minutes) vs. 8.0 minutes (95% CI 7.1-8.9 minutes) in women with head-perineum distance >25 mm. The head-perineum distance was associated with spontaneous delivery with area under the curve 83% (95% CI 77-89%) and was associated with cesarean with area under the curve 83% (95% CI 74 -92%). In women with head-perineum distance ≤35mm, 7/181 (3.9%) were delivered by cesarean versus 9/41 (22.0%) in women with head-perineum distance >35 mm (p <0.01). Ultrasound assessed position was occiput anterior (OA) in 73%. Only 3/138 (2.2%) of fetuses in OA position and head-perineum distance ≤35 mm versus 6/17 (35.3%) with non-OA position and head-perineum distance >35 mm were delivered by cesarean. Umbilical cord arterial pH <7.10 occurred in 2/144 (1.4%) women with head-perineum distance ≤35 mm compared to 8/40 (20.0%) with head-perineum distance >35mm (p <0.01).

CONCLUSION: Ultrasound has the potential to predict labor outcome in women with prolonged second stage of labor. The information obtained could guide as to whether vacuum delivery should be attempted or if cesarean were preferable, to determine whether senior staff should be in attendance and if the vacuum attempt should be

performed in the operating theatre.

The tension between optimizing neonatal outcome while promoting vaginal delivery is nowhere more pertinent than in the management of the second stage of labor. Prolonging the upper limit of what is acceptable for duration of the second stage of labor is found to reduce the frequency of cesarean delivery in nulliparous women.[1] While a higher likelihood of vaginal delivery represents a beneficial maternal outcome, this may not be without risk for the fetus and hence led to concerns from obstetricians.[2] Furthermore, equating vaginal delivery with optimal outcome is simplistic as complicated vaginal deliveries are associated to damage to the pelvic floor and anal sphincter ruptures.[3, 4] No choice is risk neutral and cesarean deliveries at low fetal head station is also associated with risk of maternal and fetal complications.[5-7] So, the goal of obstetric care in the second stage of labour must be to avoid cesarean deliveries where assisted or spontaneous vaginal delivery is likely to be safe and achievable. Unnecessary Cesarean delivery has a cumulative effect as it is widely accepted that prevention of the primary cesarean delivery will have an important influence on subsequent deliveries.[8] Sonography has the potential to be helpful in deciscion-making.[9]

There are 130 million births worldwide every year, and 3-14% are operative vaginal deliveries with highest rates in high-resource countries.[10, 11] Failed operative deliveries are reported to occur in 6.5% of vacuum extractions[12]. The determinants to achieve successful delivery and avoiding fetal and maternal complications rely on both accurate assessments of fetal position and station, and on operator skill.[12] A consensus of current guidance is that operative vaginal delivery is not recommended above station zero in relation to the ischial spines and that the duration of an operative vaginal delivery should not exceed 20 minutes.[13, 14] Obstetrics, however, remains a largely subjective art.

In clinical obstetrics the fetal head is considered engaged in the mother's pelvis when the leading part has reached the level of maternal ischial spine (station zero) based on digital examination.[15] Such clinical assessment is subjective, poorly reproducible and unreliable.[16]

Fetal head position is more precisely examined with ultrasound than with clinical examinations.[17, 18] In a transabdominal scan the fetal head is considered engaged when the biparietal diameter is below the maternal pelvic inlet.[19] Using transperineal ultrasound fetal station can be assessed as head-perineum distance [20-22] or angle of progression [23] The ischial spines cannot be seen on ultrasound, but station zero has been found to broadly correspond with head-perineum distance around 35 mm and angle of progression around 120 degrees.[24, 25]

Prolonged attempts at vaginal delivery and failed operative vaginal deliveries are associated with increased risk of fetal and maternal complications.[26, 27] Hence, greater diagnostic precision of fetal position,[18] descent[28] and attitude[29] is warranted, and the recently described techniques of intrapartum ultrasound have the potential to improve accuracy of assessments[30] and to predict delivery mode.[31] The aim of this study was to assess if ultrasound measurements of fetal position and station can predict duration of vacuum extractions, mode of delivery and fetal outcome in nulliparous women with prolonged second stage of labor.

MATERIALS AND METHODS

We conducted a prospective cohort study in nulliparous women with prolonged second stage of labor. Eligible for inclusion were those with a live singleton fetus in cephalic presentation and gestational age ≥37 weeks and <42 weeks. The second stage of labor was differentiated into a passive phase (<2 hours) and an active phase with pushing.

Women were included and examined with ultrasound when the birth attendant diagnosed prolonged second stage of labor after at least 45 minutes of active pushing and vacuum extraction was considered. Repeated ultrasound examinations were not performed. Women were not eligible when fetal compromise was suspected due to abnormal or non-reassuring cardiotocography.

From November 2013 until July 2016, 223 women were recruited at Stavanger University Hospital, Norway (n=135), University Hospital of Bologna, Italy (n= 34), Trondheim University Hospital Norway (n=16), Queen Charlotte's and Chelsea Hospital, Imperial College Healthcare NHS Trust, London, UK (n=14), Lund University Hospital, Sweden (n=9), Hvidovre University Hospital, Copenhagen, Denmark (n=9), and University Hospital of Parma, Italy (n=6). All participating centers had experience in transperineal scanning, and the ultrasound examiners were trained before start of the study. The ethics committees approved the study with reference numbers REK 2012/1865 in Norway, 3348/2013 in Italy, REC reference 15/LO/1341, IRAS project ID 169478 in UK, DNR 2012/808 in Sweden and H-4-2014-038 in Denmark. All women gave informed written consent and the study was registered in Clinical Trials with identifier NCT01878591.

First a transabdominal scan was performed. Fetal head position was defined using a transabdominal or transperineal scan and categorized into occiput anterior (OA) position (Figure 1 and video clip 1) or non-OA position (posterior or transverse position) (Figure 2 and 3 and video clips 2, 3 and 4). The position was described as a clock face with 12 hourly divisions; positions ≥10.00 and ≤2.00 were classified as occiput anterior.[32] Fetal station was assessed from the transperineal scan. The woman was placed in a semi

recumbent position with the legs flexed at the hips and knees at 45º and 90º angles respectively and a transperineal scan performed after ensuring the bladder was empty (Figure 4). Angle of progression was measured in the sagittal plane as the angle between the longitudinal axis of the pubic bone and a line joining the lowest edge of the pubis to the lowest convexity of the fetal skull (Figure 5 and video clip 5).[23] Head-perineum distance was measured in a transverse transperineal scan (in the axial plane) as the shortest distance from the outer bony limit of the fetal skull to perineum (Figure 6 and video clips 6 and 7). The transducer was placed between the labia majora (in the posterior fourchette), and the soft tissue compressed with firm pressure against the pubic bone without creating discomfort for the woman.[20, 22, 33, 34] The transducer was angled until the skull contour was as clear as possible, indicating that the ultrasound beam was perpendicular to the fetal skull. A cineloop was stored and used to identify the shortest distance possible to obtain between the transducer (perineum) and the fetal skull. This distance represents the remaining part of the birth canal for the fetus to pass. The transperineal measurements were done between contractions, and all ultrasound measurements were done online in 2D in the labor room. Neither the women nor the birth attendant were informed about the ultrasound results. The ultrasound operator was not involved in clinical decisions or management of labor. Both obstetricians and midwives performed ultrasound examinations.

The ultrasound devices used were GE Voluson *i* or GE Voluson S6 in Stavanger, GE Voluson *i* in Trondheim, Lund, Copenhagen and Bologna. In London, Samsung PT60A and Samsung HM70 were used, and in Parma a Samsung WS70. The Malmstrom vacuum cup was the preferred device used in Stavanger, Trondheim, Lund, London and

Copenhagen. In Bologna and Parma the Kiwi cup was used. Body mass index (BMI) was calculated from maternal height and pre-pregnant weight.

Cord blood was obtained by direct puncture of the umbilical artery without clamping of the cord, and acid–base analysis was performed immediately after collecting the samples. Umbilical artery pH <7.10, known to be associated with adverse neonatal outcome was used as the cut-off level. [35, 36]

The main outcome measure was duration of vacuum extractions. Secondary outcomes were frequencies of spontaneous deliveries, vacuum extractions, cesarean deliveries and umbilical artery blood samples after birth (pH and base excess).

Power analysis

Our preliminary clinical experience assessing head-perineum distance prior to vacuum delivery suggested that we should set 25 mm for the power calculation, a level corresponding approximately to + 2 below the ischial spines. The main outcome of the study was duration of vacuum extraction analysed using survival analyses. The main predictor variable was head-perineum distance with a predefined cut-off at 25 mm to discriminate between the groups. To identify a hazard ratio (HR) as low as 1.5 with 80% power, two sided test, with alpha 5%, one third of the women with distance >25 mm and two thirds with distance ≤25 mm, 220 women should be included when expecting 10% censoring. The calculations were based on Log-rank test using the Freedman method and performed in the statistical program Stata for Windows version 12.

Statistical analyses

Variables were compared using Chi-squared test and linear regression. To evaluate differences in the time interval from start of vacuum extraction to complete delivery

according to head-perineum distance and angle of progression, we used Kaplan Meier methods and Cox regression analyses[37]. The Kaplan Meier method was used to generate survival plots, and we used head-perineum distance 25 mm as cut-off value in accordance with the power analysis. Cox regression was used to calculate hazard ratios (HRs) as an estimate for relative risk of delivery. In the Cox regression analysis we controlled for fetal position, pre-pregnancy BMI, maternal age, induction of labor, epidural analgesia and augmentation with oxytocin, and in an additional analysis we also included institution as a covariate. Women with a spontaneous vaginal delivery were not included in the survival analyses and cesarean deliveries were right censored at the time of the decision to perform a cesarean delivery. Cox regression assumes proportional hazards, and this was evaluated by log minus log plots and tests of Schoenfeld residuals using the global and detailed ph test in Stata. The assumption was satisfied (p=0.66).

The association between head-perineum distance and delivery mode was analysed at five different cut-off levels, ≤20 mm, 20-25mm, 25-30mm, 30-35 mm and >35 mm. In a previous study 35 mm was found to correspond to station below zero by clinical examinations,[24] therefore, we focused on 35 mm as cut-off level and presented test characteristics related to this level. The association between angle of progression and delivery mode were analysed at cut-off levels, <120° mm, 120-130°, 130-140°, 140-150° and ≥150°. The associations between spontaneous delivery and cesarean delivery related to head-perineum distance and angle of progression as continuous variables were evaluated using receiver-operating characteristics curves. These analyses were first performed as intention to treat because cesarean deliveries done without a vacuum attempt were included. Thereafter, we did separate analyses that only included cesarean

deliveries performed after a vacuum attempt. The area under the curve was considered to have discriminatory potential if the lower limit of the CI exceeded 0.5. P<0.05 was considered statistically significant.[38] Data were analysed with the statistical software package SPSS statistics version 23.0 (IBM SPSS, Armonk, NY, IMB Corp, USA) and Stata for Windows (Version IC 13, StataCorp, College Station, Texas, USA).

RESULTS

Study population

A total of 223 women were included and one woman was excluded because information about the main outcome was missing, leaving 222 women in the study population. Figure 7 is a flow-chart illustrating delivery methods. Head-perineum distance was successfully measured in all women and angle of progression was successfully measured in 182/222 (82%). Characteristics of the study population differentiated between women with head-perineum distance ≤25 mm vs. head-perineum distance >25 mm are presented in Table 1.

Duration of vacuum extraction

Survival analyses were performed in women with a vacuum attempt. The duration of operative delivery was significantly shorter in women with head-perineum distance ≤25 mm (log Rank test <0.01), Figure 8. The estimated median duration (Kaplan Meier analyses) in women with head-perineum distance ≤25 mm was 6.0 minutes (95% C1 5.2-6.8 minutes) vs. 8.0 minutes (95% CI 7.1-8.9 minutes) in women with head-perineum distance >25 mm. The HR in Cox regression analyses was 0.56 (95% CI 0.41 – 0.78) and adjusted value 0.58 (95% CI 0.41-0.82). Head-perineum distance and angle of progression were analysed as continuous variables in separate analyses. They were both significantly associated with the duration of operative vaginal deliveries after adjusting

for co-variates. Adjusted HR was 0.96 (95% CI 0.94-0.98) for increasing head-perineum distance (Table 2) and 0.98 (95% CI 0.97 -0.996) for decreasing angle of progression. The center-adjusted HR estimate for increasing head-perineum distance was 0.93 (95%CI 0.91-0.96) when the centers were included in the analysis. Duration was >20 minutes in three women and three women had more than two cup detachments. The median duration from the ultrasound examination to delivery was 25 minutes (interquartile range 15-38 minutes).

Fetal station

Median head-perineum distance in women with fetal head station of zero from clinical examination was 36 mm, mean 34 mm, range 15-49 mm and interquartile range 7 mm. Median angle of progression in women with palpated station zero was 132°, mean 133°, range 112-164° and interquartile range 24°.

Delivery mode

Head-perineum distance and angle of progression were correlated (r=0.48). The associations between delivery mode and head-perineum distance and angle of progression were categorized into five different groups as presented in Figure 9 and 10. The frequency of cesarean deliveries was 1% (1/99) in women with head perineum distance ≤25 mm vs. 12% (15/122) in women with distance >25 mm ($p < 0.01$). Using head-perineum distance >35 mm as cut-off level, the sensitivity in predicting cesarean delivery was 56% (95% CI 33-77%), false positive rate 16% (95% CI 11-21%), positive predictive value 22% (12-33%) and negative predictive value 96% (95% CI 92-98%). Head-perineum distance and angle of progression were significantly associated to a spontaneous delivery with area under the ROC-curve 83% (95% CI 77-89%) (Figure 11)

and 75% (95% CI 66-85%) respectively, but only head-perineum distance was significantly associated with cesarean delivery; area under the ROC-curve was 83% (95% CI 74 -92%) for head-perineum distance (Figure 12) versus 56% (95% CI 42-69%) for angle of progression.

We separately analysed the association of cesarean delivery with head-perineum distance after a vacuum attempt. This occurred in 14/173 (8%) vacuum extractions and the results were similar to the intention to treat analyses. Head-perineum distance was associated with a cesarean with 83% (95% CI 73-93%) versus angle of progression with 52% (95% CI 38-66%).

Ultrasound assessed position was occiput anterior (OA) in 73%, and non-OA in 23% with missing information in 4%. In women with head-perineum distance ≤35mm 7/181 (3.9%) were delivered by cesarean delivery versus 9/41 (22.0%) in women with head-perineum distance >35 mm ($p < 0.01$). In fetuses with OA position 6/162 (3.7%) were delivered by cesarean compared to 10/50 (20.0%) in non-OA position ($p < 0.01$). Only 3/138 (2.2%) of fetuses in OA position in combination with head-perineum distance ≤35 mm were delivered by cesarean and 6/17 (35.3%) with non-OA position in combination with head-perineum distance >35 mm were delivered by cesarean.

Umbilical artery blood samples

pH and in the umbilical artery were measured in 184/222 (83%) cases. Only one new-born had pH <7.0 (pH 6.90 and base excess 18). This baby was delivered by vacuum and head-perineum distance before start of vacuum was 38 mm. pH <7.10 occurred in 10 new-borns, and head-perineum distance was >35 mm in 8/40 (20.0%) compared to 2/144 (1.4%) in cases with head-perineum distance ≤35 mm ($p < 0.01$). Base excess was >12 in

three cases of whom head-perineum distance was >35 mm in two.

COMMENT

Principal findings

The main finding in our study was a significant association between ultrasound assessed fetal station and duration of vacuum extraction. Fetal station assessed with head-perineum distance and angle of progression predicted the probability of a spontaneous delivery, but only head-perineum distance predicted cesarean delivery. We observed significant association between low umbilical cord pH and head-perineum distance >35 mm.

The importance of these findings differs in high and low resource countries. Firstly, the transperineal scan requires little training and can be undertaken with the type of ultrasound equipment that is frequently found in many delivery units worldwide. Thus, the technique is generalizable. In high income countries, the benefit of the technique is threefold: (1) a previously subjective and unreproducible measurement is converted into an objective and recordable measure; (2) knowledge of the likely difficulty and duration of labor will determine the seniority of the operator and the setting of the delivery; (3) the likelihood of cesarean delivery can be discussed with the woman and a decision made in advance not to proceed with a potentially futile attempt at vacuum delivery.

In many low- and mid-resource countries there is an increase in cesarean rates and declining use of operative vaginal deliveries including vacuum.[10, 39] In the US a declining trend is also observed.[40] In low resource countries cesarean delivery is associated with increased risk of maternal complications and high risk of uterine rupture in subsequent pregnancies.[41] Training of clinicians in vacuum deliveries might reduce the frequency of late stage cesarean deliveries[40, 42] and use of intrapartum ultrasound might add important

information and reassure clinicians that a vacuum attempt at low stations has low risk of failure. New studies in low-resource settings are necessary.

Clinical significance

We found that head-perineum distance ≤20 mm was associated with a high probability of a spontaneous delivery (Figure 2), and birth attendants might be patient in these situations as long as the fetal heart rate is normal. In a previous study head-perineum distance >35 mm corresponded to station at or above zero[24], and this finding agreed well with our new study (mean head-perineum distance 34 mm and median head-perineum distance 36 mm at clinical assessed station zero). It is usually not recommended to perform an operative vaginal delivery at levels above this station[13]. We found that the probability of cesarean in women with head-perineum distance >35 mm was 22% and 35% if it was combined with a non-OA position. A failed operative vaginal delivery is associated with risks for the mother and the fetus and a fearful experience for the woman. Our study confirms that vacuum deliveries at high station are associated with a high failure risk, but at head-perineum distance levels <35 mm there is very good chance (96%) of a vaginal delivery. Another important finding is that pH<7.10 was more commonly observed among cases with head-perineum distance >35 mm. Although our study did not include fetuses with suspected compromise before start of vacuum, a significantly lower pH in cases with greater head-perineum distance might be explained by the longer duration of vacuum extractions at higher levels.

Research implications

Labor progress in the second stage of labor is evaluated by fetal descent and traditionally assessed by clinical assessment of station.[43] In 1977 Lewin et al. assessed fetal head

station by ultrasound.[44] They measured the distance from the fetal head to the sacral tip. Barbera suggested angle of progression as a measure of head descent and found that an angle of >120° was associated with subsequent spontaneous vaginal deliveries.[23] Sonographically assessed head station has already been shown to be associated with duration of labor and delivery mode in nulliparous women with prolonged first stage.[33, 34] Kalache et al. evaluated 41 women with prolonged second stage of labor, but included only the 26 women with occiput anterior (OA) position in the final analyses. They found that angle of progression >120° was associated with a spontaneous delivery or an easy vacuum extraction.[45] Henrich et al. studied 20 women and found that head direction with respect to the long axis of the symphysis was associated with a successful operative vaginal delivery.[46] Sainz et al. found that angle of progression <105° and ‘‘head-down’’ direction before vacuum extraction was very unfavourable.[47] Bultez et al. measured angle of progression in 235 women immediately before vacuum extraction.[14] Duration of extraction exceeding 20 min or detaching of the vacuum cup more than three times were defined as failed vacuum extraction. The area under the ROC curve for predicting failure of vacuum extraction was 67% (95% CI, 57– 77%) with optimal cut-off at 146°. Our results cannot be directly compared with this study because our prespecified outcome was different. We found that head-perineum distance predicted cesarean delivery with area 83% (95% CI 74-92%) under the ROC curve. It should be noted that in our study the duration of vacuum extraction duration exceeded 20 minutes in only three women, three women experienced more than two detachments and that the frequency of cesarean after a vacuum attempt was 8%. In the original studies angle of progression was only used in OA fetuses. In our study, all positions were included. The third cardinal movement is

different in OP positions[48, 49] and this might explain why angle of progression did not predict cesarean. Because varying cut-off levels for the angle of progression in predicting cesarean deliveries are suggested in previous studies (from 120 degrees to 146 degrees),[14, 45] we decided to investigate angle of progression as a continuous variable.

Head-perineum distance is easy to measure and can be used at all stations. The transabdominal transducer should be placed in the posterior fourchette and pressed until resistance against the pubic arches is achieved. Repeatability has been investigated in a previous study. The intraobserver variation was within three mm in 87%, and the interobserver variation was within three mm in 61%. The limits of agreement for intraobserver variation were −3.0 to 5.3 mm, and for interobserver agreement −8.5 to 12.3 mm.[20] A randomized study is warranted, but it might be difficult to perform because adverse fetal outcomes are fortunately rare. It is shown that women prefer ultrasound examinations before vaginal examination,[50, 51] and maternal experiences of fear and pain might be preferred outcomes in a future randomized study.

Strengths and limitations

Strengths of this study are the multicentre design, inclusion of only nulliparous women with prolonged second stage in the active phase of labor, and that the ultrasound examiners and the birth attendants were blinded to each other findings. Limitations of the study were that some centres had few inclusions and that different vacuum devices were used. The study period was long with relatively few inclusions/month because it was often difficult to find ultrasound examiners not involved in the clinical care, and the integrity of the study relied upon study examinations not biasing clinical decisions.

In measuring angle of progression, the complete length of the symphysis and the skull

contour should be visualised on the same image, this failed in 18% of the cases. Women could be included after 45 minutes of active pushing. In the Norwegian guidelines operative delivery is recommended after one hour of active pushing.[52] This period differs from recommendations in many other countries and might affect the external validity of the study since the majority of participants were Norwegian women. The final decision of delivery method was based on subjective considerations of the responsible physician, and difficult to standardise. The study design was observational, and local guidelines should be followed.

Conclusion

In summary, ultrasound measurement in women with prolonged second stage of labor might predict duration of assisted vaginal delivery, the likelihood of cesarean delivery and was associated with fetal acid-base status. We did not examine the clinical impact of this information nor did we attempt to change clinical decision-making. This work sets the scene for further studies of management in prolonged second stage of labor.

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Table 1 Characteristics of the study population

	Median or n (%)	Range	Median or n (%)	Range
	Head-perineum distance ≤25 n=99		Head-perineum distance >25 n=123	
Maternal characteristics				
Maternal age (years)	29	20-43	30	17-41
Pre-pregnant body mass index	23	18-39	24	18-39
Gestational age (weeks)	40	38-42	40	37-42
Labor characteristics				
Induction of labor	30 (30)	-	43 (35)	-
Epidural analgesia	80(81)	-	95 (77)	-
Oxytocin augmentation	72 (73)	-	98(80)	-
Characteristics of the new-born				
Birthweight (g),	3660	2570-4665	3650	2152-4930
Apgar score 5 minutes	10	7-10	10	5-10
PH in umbilical artery (n=184)	7.24	7.09-7.43	7.24	6.90-7.40
Birth characteristics				
Bleeding ml	400	100-2000	400	100-3400
3^{rd} and 4^{th} degree anal sphincter tears	8 (8)		6 (5)	

Table 2 Cox regression analysis for predicting duration of vacuum extraction in nulliparous women with slow progress in the second stage of labor. Hazard ratios with CI intervals not crossing 1.0 were assumed significant.

	Unadjusted HR	(95% CI)	Adjusted HR	(95% CI)
Head-perineum distance*	0.96	0.94-0.98	0.96	0.94-0.98
Body mass index*	1.05	1.004-1.09	1.05	1.01-1.10
Maternal age*	0.99	0.97-1.03	1.00	0.96-1.03
Fetal position (n=212)				
Occiput anterior (reference)	1.00	-	1.00	-
Non-occiput anterior	0.46	0.32-0.68	0.56	0.38-0.84
Induction of labor				
No (reference)	1.00	-	1.00	-
Yes	0.97	0.69-1.36	1.10	0.76-1.60
Epidural analgesia				
No (reference)	1.00	-	1.00	-
Yes	0.69	0.47-1.03	0.73	0.49-1.10
Augmentation with oxytocin				
No (reference)	1.00	-	1.00	-
Yes	0.75	0.52-1.09	0.87	0.59-1.29

HR, hazard ratio; * analysed as continuous variable

Figure legends

Figure 1 Sagittal transabdominal image with the transducer in the midline and the occiput at 12 o'clock

Figure 2 Transverse transabdominal image with fetal nose at 10 and occiput at 4 o'clock

Figure 3 Transverse transabdominal image with occiput at 3 o'clock

Figure 4 The woman is placed in a semi recumbent position with the legs flexed at the hips and knees at 45º and 90º angles and the transducer was placed transverse in the posterior forchette (red line in right image) when head-perineum distance was measured and rotated to the sagittal plane when angle of progression was measured.

Figure 5 Sagittal transperineal image illustrating measurement of angle of progression

Figure 6 Transverse transperineal image (frontal plane related to the woman) illustrating measurement of head-perineum distance (double arrow). Head midline and molding are seen on the image.

Figure 7 Flow chart of the study population

Figure 8 Kaplan–Meier plot of time from start of vacuum extraction to delivery within 20 minutes differentiated into those with head-perineum distance ≤25 mm (blue) and head-perineum distance >25 mm (green). Women who were delivered by cesarean were censored at the time when decision to convert to cesarean was done ($p < 0.01$; log Rank test).

Figure 9 Distribution of spontaneous deliveries (green), operative vaginal deliveries (blue) and cesarean (red) in relation to head–perineum distance in nulliparous women with prolonged second stage of labor.

Figure 10 Distribution of spontaneous deliveries (green), operative vaginal deliveries (blue) and cesarean (red) in relation to angle of progression in nulliparous women with prolonged second stage of labor.

Figure 11 Receiver–operating characteristics curves for head–perineum distance in the prediction of spontaneous deliveries in women with prolonged second stage of labor.

Figure 12 Receiver–operating characteristics curves for head–perineum distance in the prediction of cesarean deliveries in women with prolonged second stage of labor.

Video clip 1 Sagittal transabdominal scanning with the transducer in the midline and the occiput at 12 o'clock

Video clip 2 Transverse transabdominal scanning with fetal nose at 10 and occiput at 4 o'clock

Video clip 3 Transverse transabdominal scanning. Position of the occiput is at 3 o'clock (observe the cerebral peduncles and cerebellum)

Video clip 4 Transverse transabdominal scanning. At low stations the midline structures might be difficult to see. The choroid plexus is seen on the image (diverging towards occiput)

Video clip 5 Sagittal transperineal scanning. The symphysis, fetal skull, urethra, vagina and rectum are seen on the video clip.

Video clip 6 Transverse transperineal scanning in early labor. The soft tissue is first compressed; thereafter the transducer is angled forwards until the pubic bones are seen. The head-perineum distance is measured as the shortest distance from the transducer to the outer boarder of the fetal skull. A cineloop is helpful in measuring the shortest head-perineum distance. The pubic bones should not be seen when head-perineum distance is measured.

Video clip 7 Transverse transperineal scanning in the second stage of labor. Caput succedaneum is seen on the video clip.

Figure 1

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Figure 2

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Figure 3

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Figure 4

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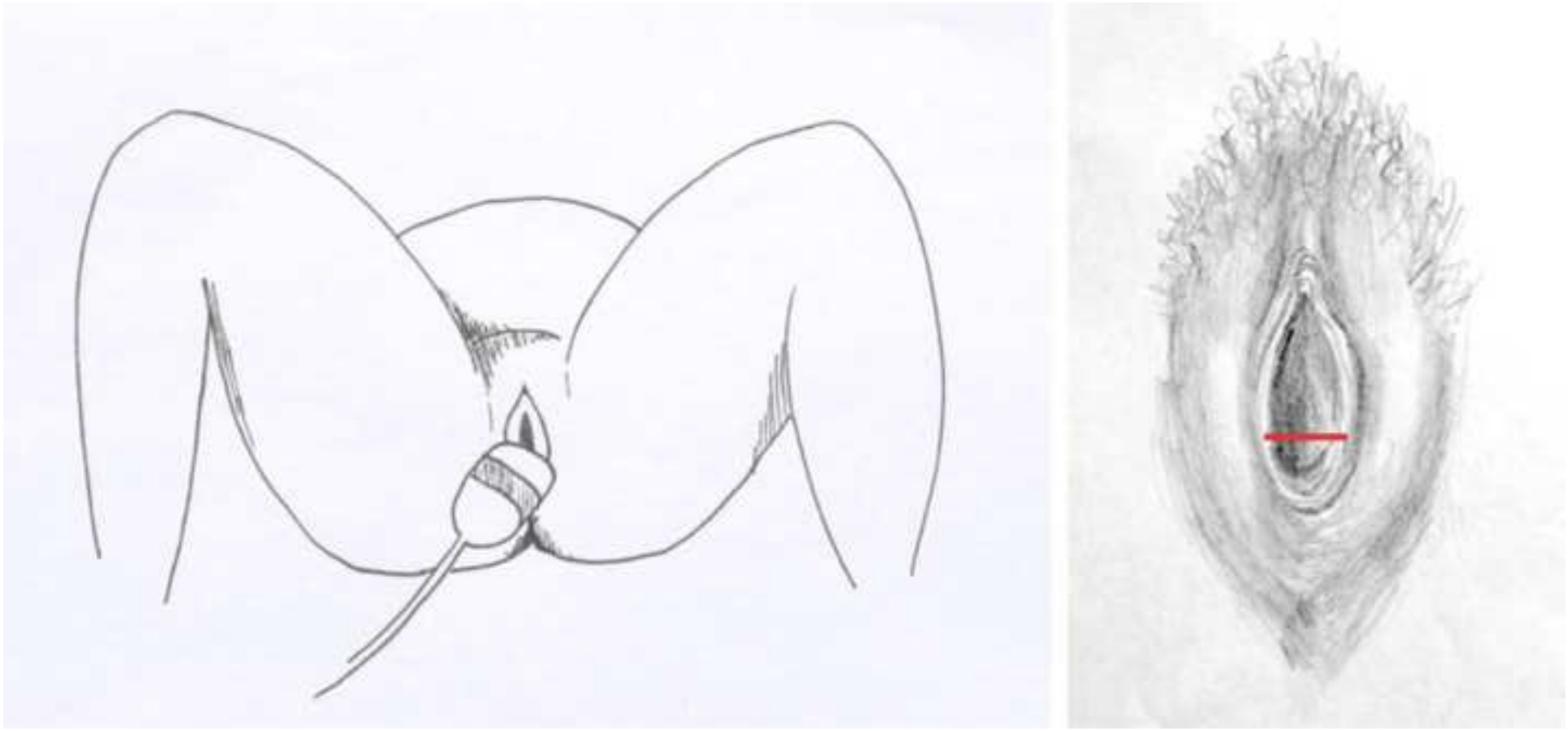

Figure 5

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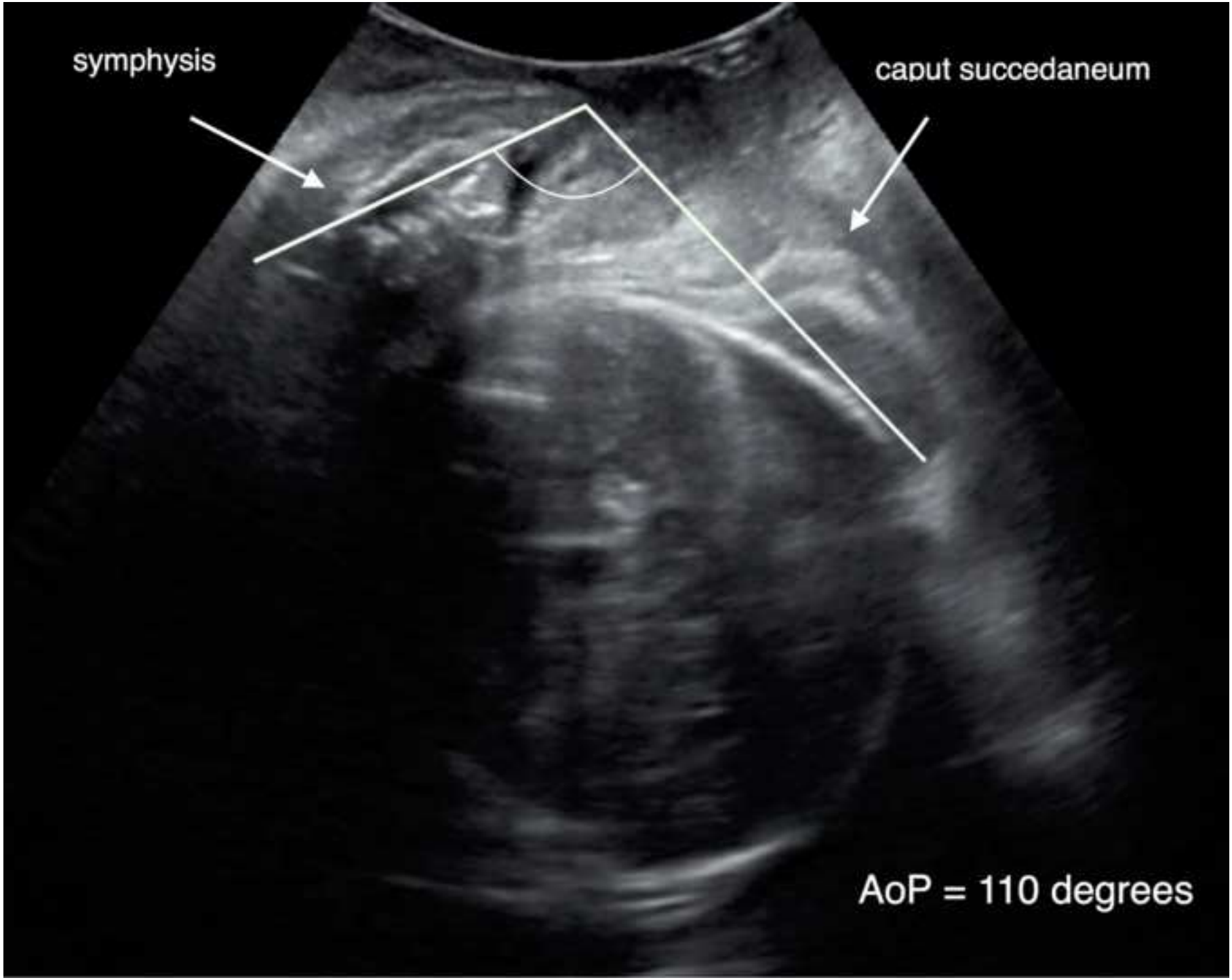

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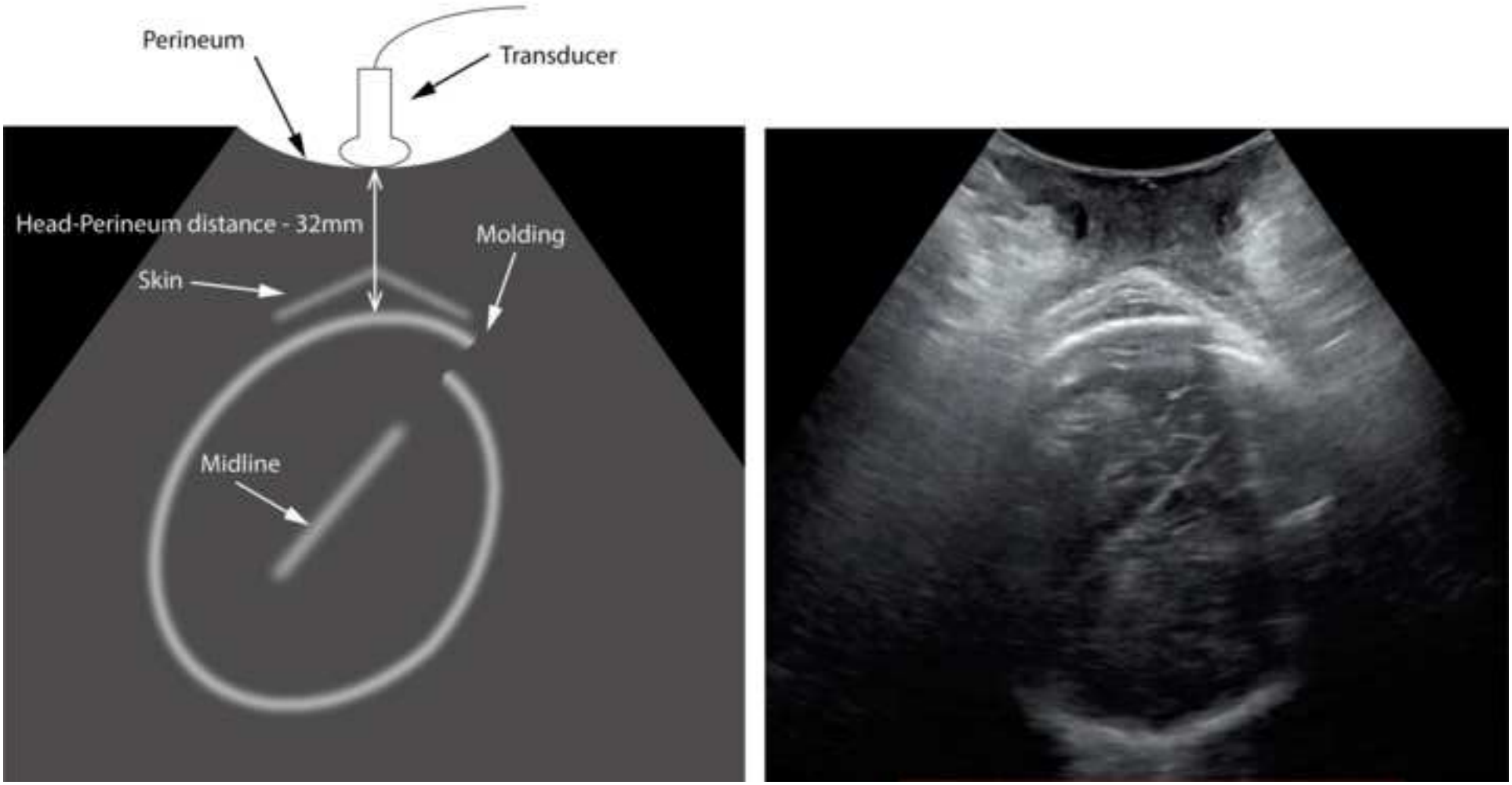

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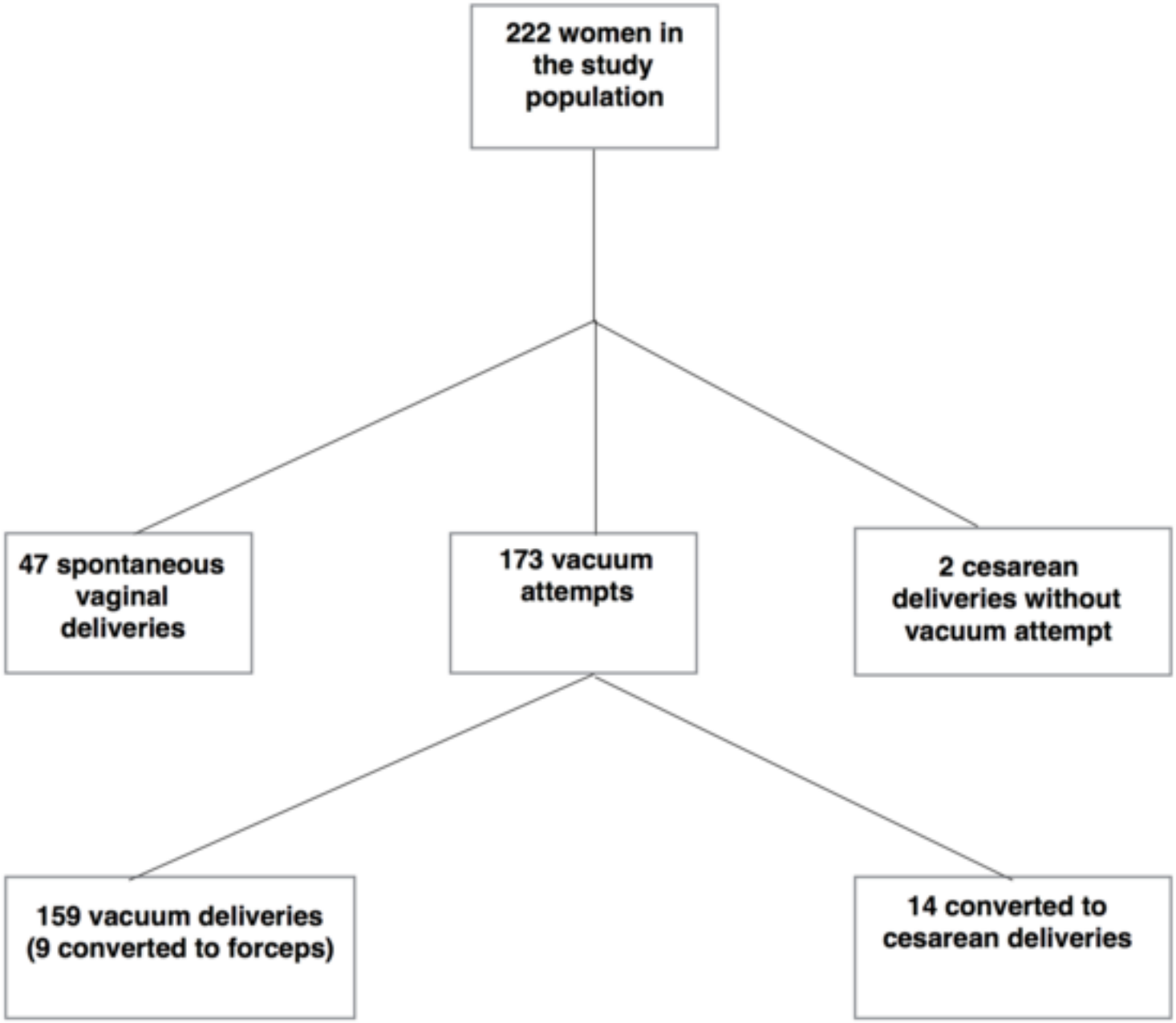

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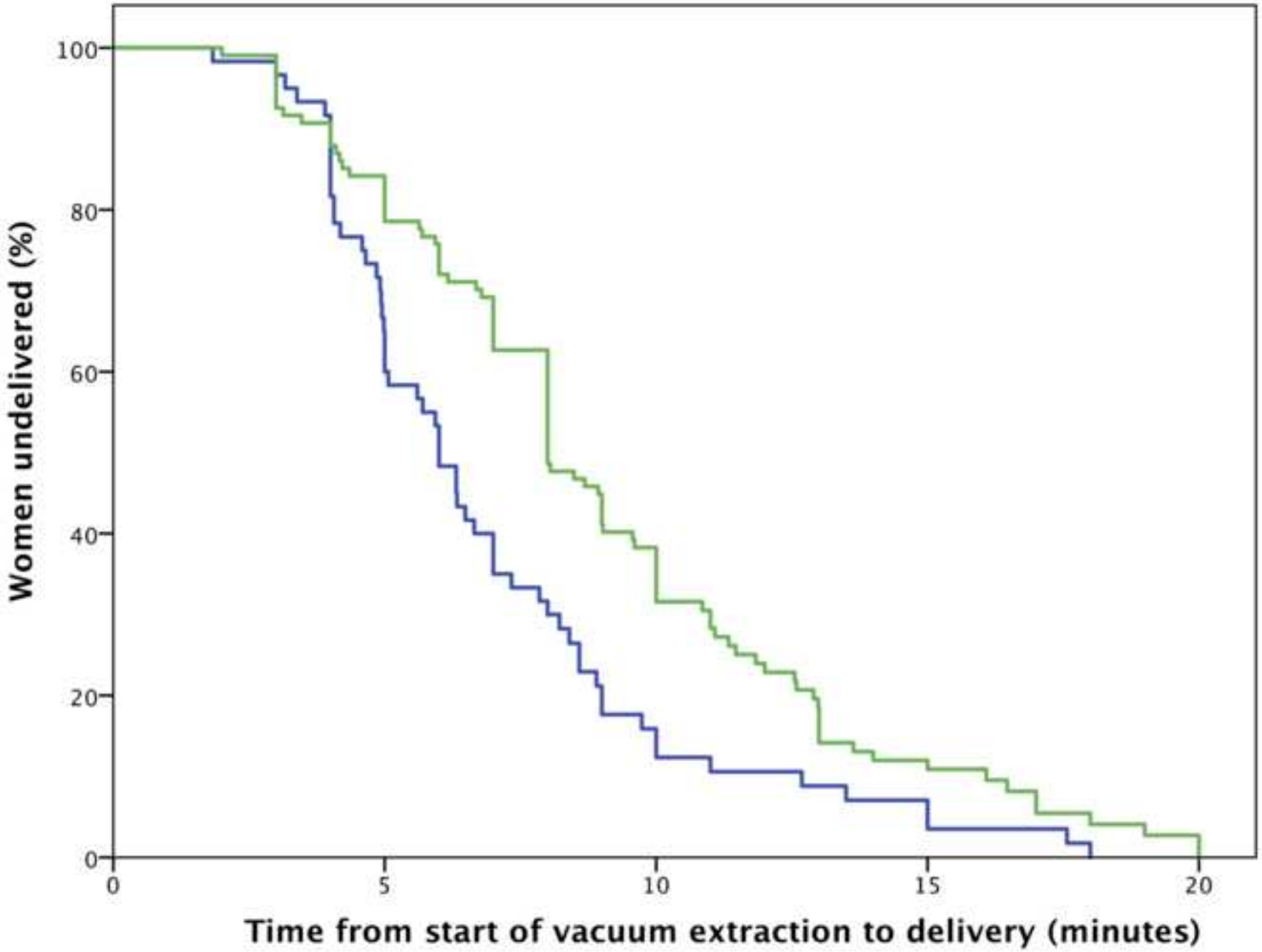

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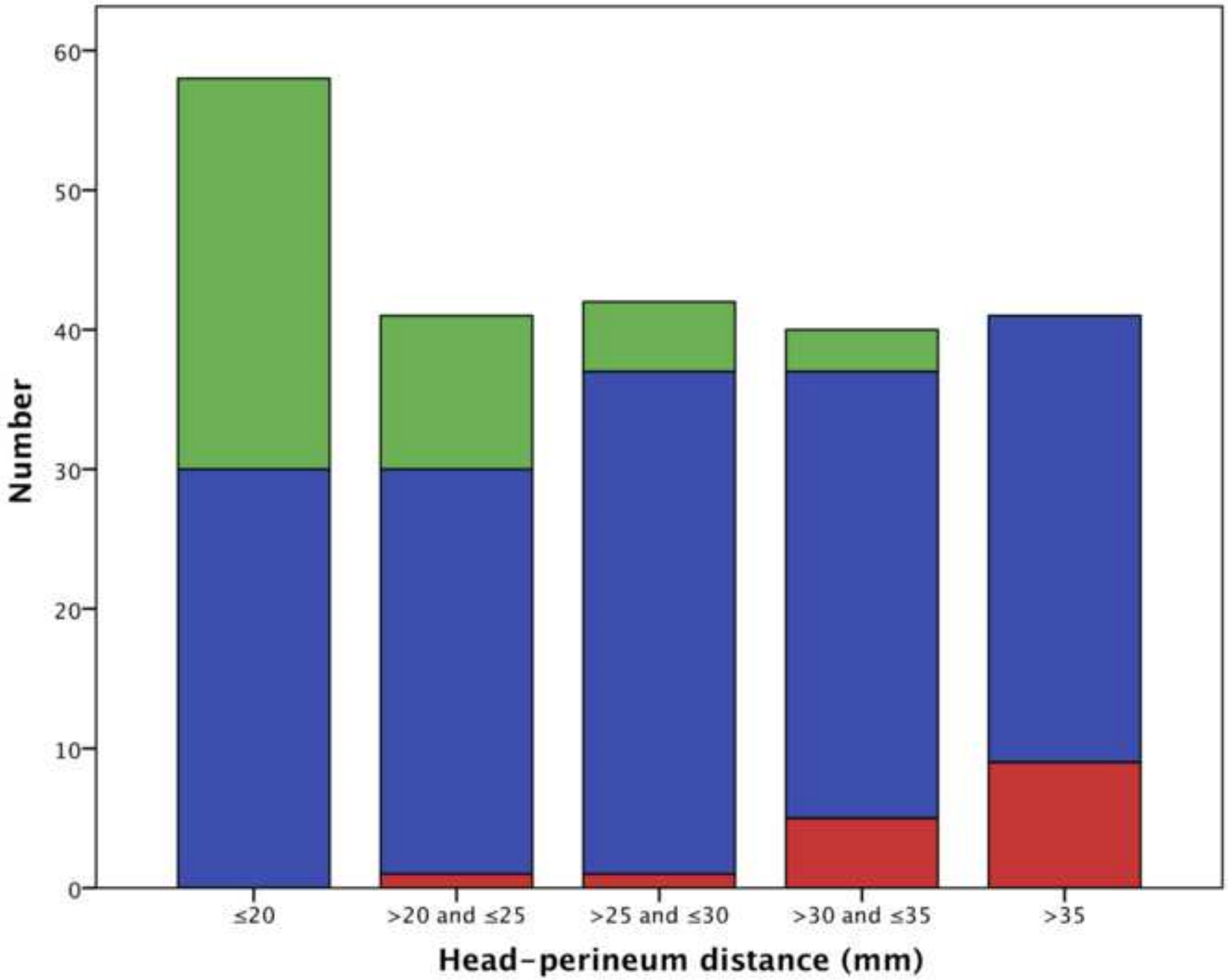

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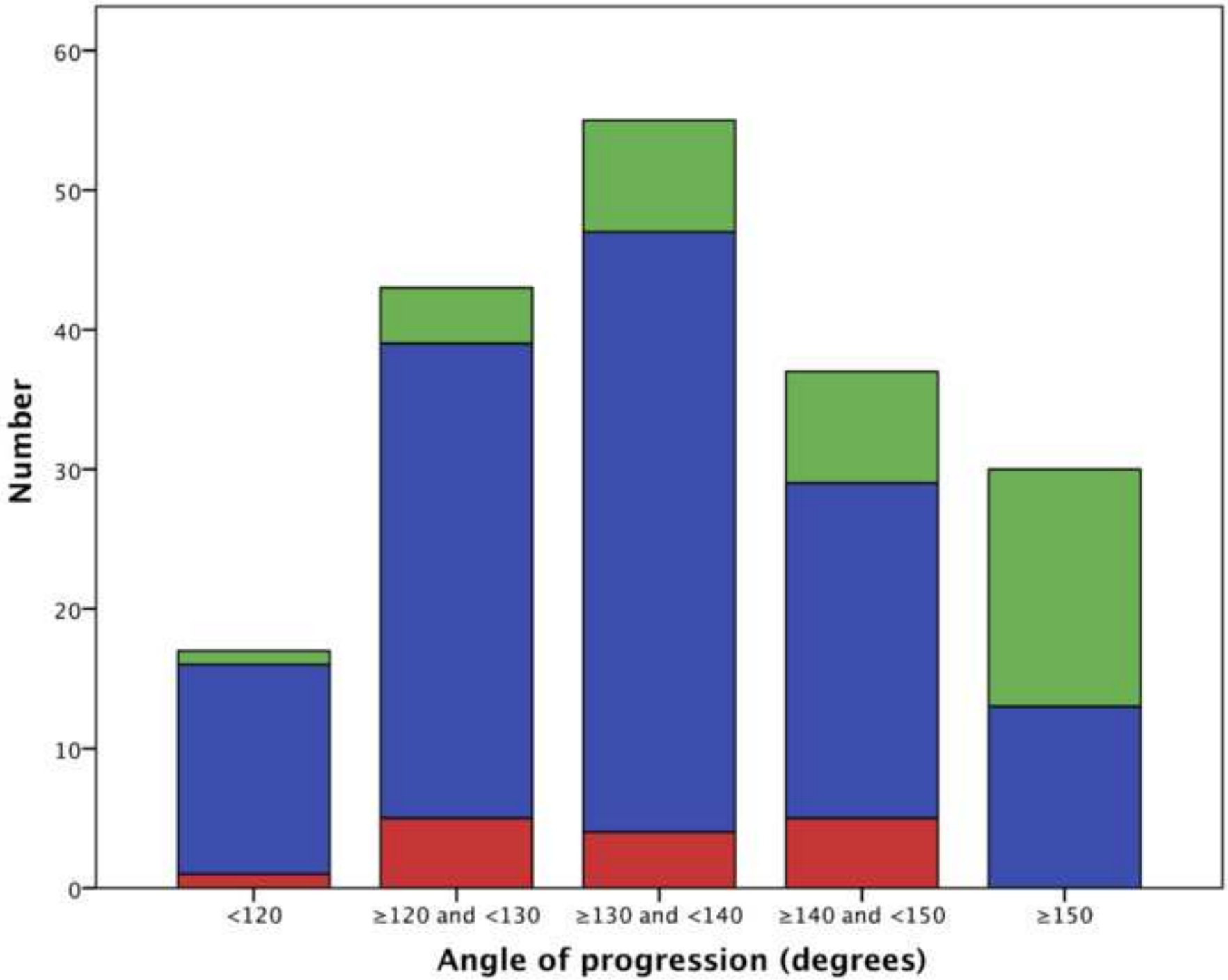

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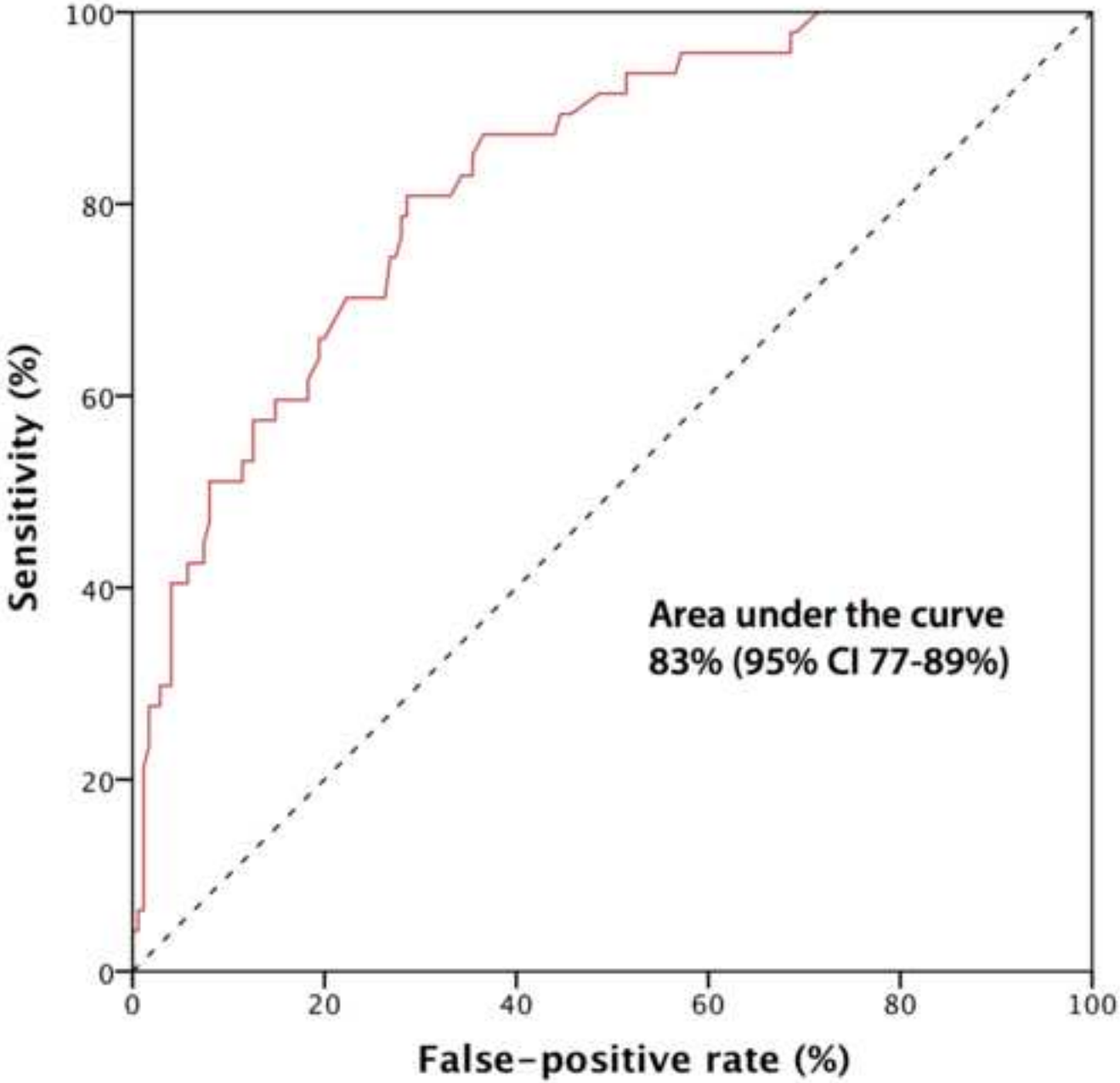

Figure 12

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