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Ultrasound diagnosis of placental and umbilical cord anomalies in singleton pregnancies resulting from invitro fertilization

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1 ULTRASOUND DIAGNOSIS OF PLACENTAL AND UMBILICAL CORD ANOMALIES IN SINGLETON PREGNANCIES RESULTING FROM IN-VITRO FERTILIZATION

2

3 Larcher L., Lenzi J., Morano D., Valeriani M., Michelli G., Farina A., Contro E.

4

5 INTRODUCTION

From the birth of the first IVF baby on the 25th of July 1978, the association between fertility 6 7 treatments and pregnancy complications have remained the topic of heated debates¹. 8 Overall, four decades of epidemiologic studies have shown that pregnancies resulting from 9 assisted reproductive technology (ART) are at higher risk than spontaneous conceptions (SC) for adverse perinatal outcomes, including perinatal mortality, preterm birth, low birth 10 weight and birth defects^{2–8}. These risks are partly attributable to infertility characteristics, 11 12 ART methods, embryo freezing, intracytoplasmic sperm injection (ICSI), maternal age and twinning^{5,6}. 13

ICSI, which was first introduced as an adjunct to IVF in the early 1990s⁹, has been 14 15 associated with controversial findings regarding the risk of birth defects. An early study found 16 no significant additional risks of major birth defects in pregnancies conceived with this 17 technique compared to standard IVF¹⁰ but recent systematic reviews have shown that, after 18 adjustment for confounding factors, IVF (with or without ICSI) increases the risk of congenital heart defects, when compared with SC ^{5,8}. By contrast, no increased risk of congenital 19 anomalies has been demonstrated after fresh versus frozen embryo transfer, IVF vs ICSI¹¹ 20 21 or after preimplantation genetic testing¹².

The use of ART has also been associated with an increased risk of disorder of placentation including placenta previa^{2,12–18}, umbilical cord anomalies^{19–21} and, more recently, placenta accreta spectrum (PAS)^{19–21}. The risk of placenta previa in singleton pregnancies was recently found to be higher after fresh blastocyst transfer compared to fresh cleavage stage transfer or SC¹⁷. A recent systematic review has shown that natural cycle frozen embryo transfer in singleton pregnancies conceived after IVF decreased the risk of PAS compared with artificial cycle frozen embryo transfer²². There are limited data on the impact of heterologous fertilization using donor oocytes on placentation^{23–25}. 30 Most studies on the association of IVF with placental/cord anomalies are 31 retrospective and small, or included in large epidemiologic studies with multiple confounding factors and none have studied the role of prenatal ultrasound imaging in IVF pregnancies. 32 Placental and umbilical cord anomalies can have an impact on both fetal and maternal 29 outcomes due to severe maternal haemorrhage, potentially requiring emergency 30 31 hysterectomy, and cord accidents that can lead to severe fetal neurological damage and/or 32 intrapartum demise. The aims of the present study are: to determine the incidence of placental and cord anomalies in singleton IVF pregnancies compared to spontaneous 33 34 pregnancies; to prospectively evaluate the role of antenatal ultrasound in the screening for these anomalies and to investigate if oocyte donor fertilization is an additional risk factor for 35 36 the development of placentation anomalies.

37

38 **METHODS**

39 This was a multicenter prospective cohort study involving two tertiary centers (Sant'Orsola 40 Hospital, University of Bologna and Institute for Women's Health and University College of London). Patients with a singleton pregnancy conceived with IVF and patients with a SC 41 42 (controls), matched with a 1:1 ratio for the number of prior cesarean deliveries (CDs), were consecutively recruited between 1st May 2019 to 31st March 2021. Random matches were 43 44 performed by generating pseudorandom-number functions using Stata 15, and unmatched spontaneous pregnancies were discarded from the analysis. IVF pregnancies were defined 45 46 homologous or heterologous in base of the oocyte. Homologous if the oocyte is obtained 47 from the women, heterologous if the oocyte is donated from another women.

All patients received antenatal care using a similar clinical protocol, which included ultrasound examinations at 11-14 weeks (nuchal translucency scan), 19-22 weeks (detailed fetal anatomy scan) and 32-35 weeks (fetal wellbeing and growth scan). All ultrasound examinations were carried out transvaginally and/or transabdominally by experienced

operators using a high-resolution ultrasound equipment (GE Voluson[®] E10, Voluson 730 52 53 and E8 Expert, GE Medical Systems, Milwaukee, WI, USA). Ultrasound findings of placental 54 and/or umbilical cord abnormalities were recorded in each case using a standardized 55 reporting protocol including placental shape, placental location, cord insertion location and 56 number of cord vessels. We defined a placenta as "low lying" if the inferior edge was located 57 at 0.5-2 cm from the internal os of the uterine cervix. When the placenta was <0.5cm from 58 the internal os, or completely covering it, it was classified as placenta previa (marginal or complete)²⁶. Ultrasound signs of PAS were recorded using the standardized description 59 60 proposed by the European Working Group on Abnormally Invasive Placenta EW-AIP²⁷ 61 including for grey scale imaging: loss of clear zone, myometrial thinning, the presence of 62 placental lacunae; bladder wall interruption; placental bulge and focal exophytic mass and for CDI: utero-vesical hypervascularity; subplacental hypervascularity; bridging vessels and 63 64 lacunae feeder vessels. Additional transabdominal and transvaginal sonographic (TVS) 65 examinations of the placental location and cord insertion were performed at 28-30 weeks 66 and 36-37 weeks when required for the timing of delivery (Figures 1 and 2).

67 Women unmatched by prior CD, or requiring emergency delivery before 32 weeks ultrasound examination, were excluded from the study (Supplementary Figure S1). When a 68 69 patient in either subgroup was excluded from the study, her match in the spontaneous 70 control group was excluded from the final analysis (Supplementary Figure S1). All patients 71 were managed according to local protocols. Patients' demographic data, previous obstetric 72 and gynecological history, clinical findings, ultrasound data/images and symptoms at the 73 time of the first examination were recorded and stored in a specialized database (Viewpoint 74 Version 5, Bildverargeritung GmbH, Munich, Germany). All placentas and umbilical cords in 75 both groups were examined macroscopically at delivery by the obstetric team and the 76 findings recorded using a standard protocol. Full histopathological evaluation was carried 77 out when clinically indicated.

Institutional ethical committee approval was obtained prior to the start of this study, UK NHS Health Research Authority (HRA). Research Ethical committee approval reference 18/WM/0328. The protocol and a waiver of consent were granted a favorable opinion as all ultrasound records were examined within the center and basic clinical data were collected using a standard clinical audit protocol and all data and images were fully anonymized for further analysis.

84 Sample size determination

Assuming that the proportion of placental or cord anomalies was 0.20 in spontaneous pregnancies and 0.30 in pregnancies conceived with heterologous or autologous IVF^{13,28}, a total sample of 588 individuals (294 per group) had to be obtained to detect an absolute difference of 0.10 between the two proportions with 80% power and 5% significance level. Hypothesizing an attrition rate of 7%, the final sample size was augmented from 588 to 634 (317 per group).

91 Statistical analysis

92 Stata 15 (StataCorp. 2017. *Stata Statistical Software: Release 15.* College Station, TX: 93 StataCorp LP) and R version 4.1.0 (R Core Team. 2021. *R: A language and environment* 94 *for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing) were used 95 to analyze the data. Q–Q plot analysis confirmed the normal distribution of continuous 96 variables, and data are therefore presented as mean and standard deviation. Categorical 97 variables are presented as counts and percentages.

98 Univariate comparisons of demographic and clinical characteristics between IVF and 99 spontaneous pregnancies were performed with the Pearson's chi-squared test, Fisher's 100 exact test or Student's *t*-test, where appropriate. Differences in the rate of placental and cord 101 anomalies in the study groups (IVF versus spontaneous pregnancies) and subgroups 102 (heterologous versus homologous) were calculated using the chi-squared test or Fisher's

exact test, where appropriate. Post-hoc pairwise comparisons were performed with the
 Fisher's exact test, using the Simes' method for false discovery rate control²⁹.

105 The multivariable (adjusted) association between patient characteristics (mode of 106 conception, maternal age, prior CD, parity and gravidity) and specific ultrasound findings 107 (low-lying/placenta previa and velamentous cord insertion) was estimated with a logistic 108 regression model using Firth's method, a technique equivalent to penalization of the log-109 likelihood by the Jeffreys prior that reduces the bias of maximum likelihood estimates and 110 represents a solution to the problem of separation and rare events. Results are presented 111 as odds ratios (OR) and 95% Confidence intervals (CI). P values to test their significance were computed by penalized profile likelihood³⁰. A *P* value <0.05 was considered significant. 112

113

114 **RESULTS**

115 **Cohort demographics**

116 There were 654 singleton pregnancies assessed for eligibility during the study period. After 117 exclusion of prior-CD unmatched pregnancies and GAs at delivery <32 weeks, a total of 317 118 pregnancies resulting from IVF were enrolled in the study, including 6 (1.9%) with a history 119 of two prior CDs, 32 (10.1%) with a history of one prior CD, and 279 (87.7%) nulliparous or 120 primiparous/multiparous with a prior vaginal birth (Supplementary Figure S1). Of these 317 121 pregnancies, 237 (74.8%) resulted from autologous oocyte IVF cycles and 80 (25.2%) from 122 heterologous (oocyte donor) IVF cycles. The SC group was constituted by 317 spontaneous 123 pregnancies, including 6 (1.9%) with a history of two prior CDs, 32 (10.1%) with one prior 124 CD, and 279 (87.7%) nulliparous or with prior vaginal. Table 1 displays and compares the demographic and clinical characteristics of the study groups. Maternal age was significantly 125 126 (P<0.001) higher in patients with IVF pregnancies than those with spontaneous pregnancies. There were significantly more patients of Caucasian ethnicity, nulliparous and 127 primigravid in the IVF pregnancy group than in the SC group. There were no differences in 128

129 body max index (BMI) and smoking status between the groups.

130 Ultrasound findings

131 All patients with placenta and umbilical cord anomalies were identified at the 20-22 weeks ultrasound examination and confirmed at the 33-35 weeks scan and at birth (Figures 1-3). 132 Except for the examinations of the placental location and cord insertion that were performed 133 134 at 28-30 week and 36-37 weeks when required for the timing of delivery. There were two 135 cases of placenta previa with ultrasound signs suggesting accreta placentation in the heterologous IVF subgroups. Both patients had an elective cesarean section with abnormal 136 attachment of part the placenta into the scar area of prior lower segment of prior CD. Partial 137 myometrial resection was required and these cases were classified placenta adherenta. 138

139 There was no case of vasa previa in either subgroup.

140 Table 2 shows the distribution of the different anomalies of the placenta and umbilical cord in both groups and between the heterologous and autologous IVF subgroups (all 141 142 combinations of placental and/or umbilical cord anomalies observed in the study sample are showed in Supplementary Table S1). The overall incidence of combined placental and cord 143 144 anomalies was significantly higher in the IVF group than in the SC group (97 [30.6%] vs 62 [19.6%]; P<0.001). A significantly higher incidence of low-lying placenta (P<0.001), placenta 145 previa (P=0.012), bilobed placenta (P<0.001) and velamentous cord insertion (VCI) 146 147 (P=0.001) was found the IVF compared to the SC group. There was no difference between the two groups for the incidence of marginal cord insertion and single umbilical artery cord. 148 149 The incidence of placenta previa accreta was significantly higher (*P*=0.016) in heterologous 150 IVF pregnancies compared with homologous and spontaneous pregnancies.

151 Number of prior CDs was a significant (*P*=0.014) risk factor for the development of 152 placenta previa in the whole cohort (Supplementary Table S2).

The results of the multivariable logistic regression analysis are presented in Table 3.
 After adjusting for maternal age, prior CDs, parity and gravidity, IVF conception remained a

significant (P<0.001) risk factor for low-lying/placenta and autologous IVF conception for VCI (P=0.037). The OR (95% CI) for low-lying/placenta previa and VCI was 9.99 (CI 2.84– 53.25) and 5.44 (CI 1.10–53.82), and 18.58 (CI 3.53–129.68) and 7.44 (CI 0.96–96.73) in the autologous and heterologous IVF subgroup, respectively.

159

160 **DISCUSSION**

Our data add to previous epidemiologic studies showing that IVF conceptions are associated with a higher incidence of placental and cord implantation anomalies and indicate that these anomalies are independent of a history of prior CD and can be accurately identify before birth using standardized ultrasound imaging protocols allowing for individual patient management and thus reducing the corresponding maternal and fetal mortality and morbidity risks.

167

168 **Comparison with other studies**

Romundstad et al¹³ were the first to report on the risk of placenta previa in singleton 169 170 pregnancies conceived by ART. This nationwide population-based study, and more recent studies^{15,16} found that the risk of placenta previa was nearly three-fold higher in ART 171 pregnancies compared with SP. Most of epidemiologic studies do not provide data on the 172 type of ART technique used for conception or mode of delivery and none describe the 173 174 ultrasound criteria used for the diagnosis of placenta previa. A prior CD is the main independent confounding factor for placentation in the lower segment in subsequent 175 176 pregnancies¹⁸. After exclusion of a prior CD and other independent risk factors such as 177 multiple pregnancies for low placentation, our data confirms that a low-lying placenta is the most common placenta anomaly associated with IVF (Table 2). The multivariable logistic 178 179 regression analysis indicated higher OR for low placental insertion in the heterologous than

in the autologous IVF subgroup (Table 3), suggesting an impact of the IVF technique onplacentation.

182 There is a strong correlation between the shape of the placenta at the end of the first trimester and that at term³¹, suggesting that events during the first trimester are critical. 183 There is limited evidence on an association between IVF and anomalies of the placental 184 185 shape. A retrospective study of 47 cases of succenturiate lobes of the placenta found an 186 association with IVF³². A recent study of 1057 live births following IVF treatment found that 187 after adjustment for potential confounding factors associated with placental pathology features, female gender was associated with bilobed placenta³³. In the present study, the 188 189 incidence of bilobed placenta was 3.8% (Table 2) in the IVF group, with a similar incidence in the heterologous and autologous IVF subgroups; no case was found in the SC group. 190

191 In our study, two patients with placenta previa in the heterologous subgroups were 192 classified as high-risk of PAS at ultrasound and confirmed as having an abnormally adherent placenta accreta (stage I of the FIGO classification)³⁴ at CS. Uncomplicated term ART 193 194 pregnancies have a higher risk of operative delivery, retained placenta and PPH¹⁴. IVF has 195 also been associated with the subsequent development of accreta placentation, but the 196 association is indirect and mainly due to the increase rate of low placentation following embryo transfer^{18,19,35}. Heterogeneity in results is due to variation in the ultrasound criteria 197 198 used for the diagnosis of placenta previa and the lack of detailed confirmation of the accreta 199 grade at birth³⁶. Further studies are therefore required to confirm the association between 200 ART and PAS.

VCI and marginal cord insertion are found in approximately 1.5% and 6% of singleton births and their incidence is increased with other risk factors, including twinning, IVF, advanced maternal age³⁷. In the present study, a VCI was the only umbilical cord anomaly found with a higher incidence in the IVF pregnancy group (3.8%) compared to 0.3% in the SC group, but no difference was found for the incidence of marginal cord insertion between

the two groups (Table 2). The OR for VCI was higher in the autologous than in heterologous
 subgroup (Table 3) suggesting an impact of the IVF technique on the blastocyst rotation at
 implantation^{18,19}.

209

210 Clinical implications

Reporting on the placental position has been an integral part of the detailed anomaly scan in most countries around the world for at least three decades^{38,39}. Anyway, none of the previous studies on the association between ART and placenta previa provided data on the ultrasound method used, the gestational age at diagnosis or postnatal confirmation of placental abnormalities¹³⁻¹⁷. All the patients in our study had the diagnosis of low-lying placenta by TVS at 32-35 weeks.

VCI is associated with adverse perinatal outcomes, mainly premature rupture of the 217 218 membranes, spontaneous pre-term birth, short cord and risk of need for manual removal of the placenta^{40,41}. Around 3-4% of women with VCI also have vasa previa⁴²; when this 219 condition is diagnosed during labor, the perinatal death rate is reported as at least 60%⁴³. A 220 recent prospective population-based cohort Australian study using the found that out of 63 221 222 cases with confirmed vasa previa at birth, there were no perinatal deaths in the 58 cases 223 diagnosed prenatally⁴⁴. These data support the need to include the location of the cord insertion at the routine mid-trimester ultrasound examination. None of the patients with a 224 225 VCI in our study presented with vasa previa at the 32-35 weeks and were allowed to deliver 226 at term.

227

228 Strengths and Limitations

Our study has several strengths. To the best of our knowledge, this is the largest prospective
study addressing the prenatal diagnosis of placental and cord anomalies in IVF pregnancies.
This is also the first study where IVF and spontaneous pregnancies were matched for a

history of prior CD and which compares the data from heterologous and autologous IVF pregnancies. Our study has the same limitation as any study performed in specialist centers and thus our data may not be representative of the general population. In addition, we did not have access to data on embryo freezing and/or the use of ICSI in all cases, which may both have an impact on placentation. Our analysis was not powered to detect significant differences in the proportions of single placental or umbilical cord anomalies, nor between heterologous vs autologous pregnancies.

239

240 **Conclusions**

IVF, in particular IVF with oocyte-donor cycle, is associated with an increased risk of placentation and cord implantation anomalies. Ultrasound has a high diagnostic accuracy in detecting these anomalies prenatally. Adequately powered studies for different IVF techniques including frozen embryos and ICSI cycles are needed to accurately evaluate the risks of abnormal placentation and develop standardized ultrasound screening strategies targeted at high-risk patients.

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Mode of conception			
IVF (<i>n</i> = 317)	SC (<i>n</i> = 317)	Ρ	
38.4 (5.5)	33.5 (5.2)	<0.001	
22.7 (3.5)	23.0 (4.2)	0.384	
297 (93.7%)	266 (83.9%)		
3 (0.9%)	24 (7.6%)		
11 (3.5%)	16 (5.0%)		
3 (0.9%)	6 (1.9%)		
3 (0.9%)	5 (1.6%)	<0.001	
17 (5.4%)	21 (6.6%)	0.503	
239 (75.4%)	171 (53.9%)		
64 (20.2%)	103 (32.5%)		
14 (4.4%)	43 (13.6%)	<0.001	
146 (46.1%)	120 (37.9%)		
171 (53.9%)	197 (62.1%)	0.036	
279 (88.0%)	279 (88.0%)		
32 (10.1%)	32 (10.1%)		
6 (1.9%)	6 (1.9%)	1.000	
	IVF $(n = 317)$ 38.4 (5.5) 22.7 (3.5) 297 (93.7%) 3 (0.9%) 11 (3.5%) 3 (0.9%) 11 (3.5%) 3 (0.9%) 17 (5.4%) 239 (75.4%) 64 (20.2%) 14 (4.4%) 146 (46.1%) 171 (53.9%) 279 (88.0%) 32 (10.1%) 6 (1.9%)	IVF $(n = 317)$ SC $(n = 317)$ 38.4 (5.5) 33.5 (5.2) 22.7 (3.5) 23.0 (4.2) 297 (93.7%) 266 (83.9%) 3 (0.9%) 24 (7.6%) 11 (3.5%) 16 (5.0%) 3 (0.9%) 6 (1.9%) 3 (0.9%) 5 (1.6%) 17 (5.4%) 21 (6.6%) 17 (5.4%) 171 (53.9%) 64 (20.2%) 103 (32.5%) 14 (4.4%) 43 (13.6%) 146 (46.1%) 120 (37.9%) 171 (53.9%) 197 (62.1%) 279 (88.0%) 279 (88.0%) 32 (10.1%) 32 (10.1%) 6 (1.9%) 6 (1.9%)	

382
Table 1. Demographic and clinical characteristics of the study groups.

383 384 385 IVF= In-vitro fertilization; SC= Spontaneous conception; CD= caesarean delivery; BMI= Body mass index.

Table 2. Distribution of placental and cord anomalies in the heterologous and autologous

388	IVF	pregnancies	and in	spontaneous	pregnancies.
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	Mode of conception			
Placental/cord anomalies	Heterologous	Autologous	SC	P value
	IVF (<i>n</i> = 80)	IVF (<i>n</i> = 237)	(<i>n</i> = 317)	
<u>Number of patients with</u> anomalies [*]	32 (40.0%)	65 (27.4%)	62 (19.6%)	<0.001
Placental anomalies	13 (16.3%)ª	21 (8.9%)ª	2 (0.6%)	<0.001
Low-lying placenta	4 (5.0%)ª	9 (3.8%) ^a	0 (0.0%)	<0.001
Placenta previa	4 (5.0%) ^a	7 (3.0%) ^a	2 (0.6%)	0.012
Bilobed placenta	5 (6.3%) ^a	7 (3.0%) ^a	0 (0.0%)	<0.001
Placenta previa accreta	2 (2.5%) ^a	0 (0.0%) ^{a,b}	0 (0.0%) ^b	0.016
<u>Cord anomalies</u> Marginal cord insertion VCI Single umbilical artery	25 (31.3%) ^{a,b} 20 (25.0%) ^{a,b} 5 (6.3%) ^a 1 (1.3%) ^{a,b}	54 (22.8%) ^{a,c} 47 (19.8%) ^{a,c} 7 (3.0%) ^a 1 (0.4%) ^{a,c}	60 (18.9%) ^{b,c} 55 (17.4%) ^{b,c} 1 (0.3%) 5 (1.6%) ^{b,c}	0.057 0.288 0.001 0.410

389

 390 ^{*}Including 8, 10 and 1 patient with \geq 2 combined anomalies in the heterologous, autologous and SC subgroups, respectively.

392 *Note:* Categories denoted with the same letter are not significantly different from each other (post-393 hoc pairwise comparison).

394 *IVF= In-vitro fertilization; SC= Spontaneous conception; VCI= Velamentous cord insertion.*

Variable	Low-lying/placenta previa		Velamentous cord i	nsertion
vanapie	OR (95% CI)	P value	OR (95% CI)	P value
Mode of conception				
SC	1.00 (ref.)		1.00 (ref.)	
Autologous IVF	9.99 (2.84–53.25)	<0.001	5.44 (1.10–53.82)	0.037
Heterologous IVF	18.58 (3.53–129.68)*	<0.001	7.44 (0.96–96.73)†	0.059
Maternal age, 1-y increase	1.003 (0.92–1.10)	0.932	1.06 (0.94–1.21)	0.349
Number of prior CDs				
0	1.00 (ref.)		1.00 (ref.)	
1	3.25 (0.85–14.01)	0.086	0.72 (0.06–5.53)	0.756
2	2.43 (0.27–22.50)	0.417	1.15 (0.01–233.79)	0.948
Parity				
0	1.00 (ref.)		1.00 (ref.)	
1	1.06 (0.22–4.37)	0.938	1.32 (0.21–6́.34)	0.743
≥2	3.45 (Ò.49–18.87́)	0.194	1.05 (Ò.01–12.54́)	0.974
Gravidity				
1	1.00 (ref.)		1.00 (ref.)	
>2	0.92(0.29-2.70)	0.876	1.16 (0.31–4.39)	0.819

395 Table 3. Multivariable logistic regression of risk factors for low-lying/placenta previa and 396 velamentous cord insertion.

398 +OR (95% CI) = 1.37 (0.31–5.58) when autologous IVF is used as the reference group (P = 0.668). 399 OR= odds ratio; CI= confidence interval; SC= Spontaneous conception; IVF= In-vitro fertilization;

CD= caesarean delivery. 400