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Prevention of stillbirth: impact of two-stage screening for vasa previa

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KEYWORDS: adverse pregnancy outcome; bilobed placenta; first-trimester ultrasound; stillbirth; vasa previa; velamentous cord insertion

CONTRIBUTION

What are the novel findings of this work?
This study has demonstrated the feasibility of introducing a two-stage screening program for diagnosis of vasa previa based on transvaginal sonography at 20–22 weeks' gestation for pregnancies with velamentous cord insertion at the routine 11–13-week scan and those with low-lying placenta at the routine 20–22-week scan.

What are the clinical implications of this work?
Accurate and effective prenatal diagnosis of pregnancies with vasa previa can be achieved by a two-stage screening protocol. Appropriate monitoring and delivery of such pregnancies can potentially reduce the overall rate of stillbirth by about 10%.

ABSTRACT

Objectives *To examine the feasibility and effectiveness of a two-stage ultrasound screening strategy for detection of vasa previa and to estimate the potential impact of screening on prevention of stillbirth.*

Methods *This was a retrospective study of data from prospective screening for vasa previa in singleton pregnancies, undertaken at the Fetal Medicine Unit at Medway Maritime Hospital, UK, between 2012 and 2018. Women booked for prenatal care and delivery in our hospital had routine ultrasound examinations at 11–13 and 20–22 weeks' gestation. Those with velamentous cord insertion at the inferior part of the placenta at the first-trimester scan and those with low-lying placenta at the second-trimester scan were classified as high-risk for vasa previa and had transvaginal sonography searching specifically for vasa previa, at the time of the 20–22-week scan. The management and outcome of cases with suspected vasa previa is described. We excluded cases of miscarriage or termination at < 24 weeks' gestation.*

Results *The study population of 26 830 singleton pregnancies included 21 (0.08%; 1 in 1278) with vasa previa. In all cases of vasa previa, the diagnosis was made at the 20–22-week scan and confirmed postnatally by gross and histological examination of the placenta. At the 11–13-week scan, cord insertion was classified as central in 25 071 (93.4%) cases, marginal in 1680 (6.3%), and velamentous in 79 (0.3%). In 16 (76.2%) of the 21 cases of vasa previa, cord insertion at the first-trimester scan was classified as velamentous at the inferior part of the placenta, in two cases (9.5%) as marginal and in three cases (14.3%) as central. The 21 cases of vasa previa were managed on an outpatient basis with serial scans for measurement of cervical length and elective Cesarean section at 34 weeks' gestation; all babies were liveborn but there was one neonatal death. In the study population, there were 83 stillbirths, none of which had evidence of vasa previa on postnatal examination. On the assumption that, if we had not diagnosed prenatally all 21 cases of vasa previa in our population, half of these cases would have resulted in stillbirth, then the potential impact of screening is prevention of 10.6% (10/94) of stillbirths.*

Conclusion *A two-stage strategy of screening for vasa previa can be incorporated into routine clinical practice, and such a strategy could potentially reduce the rate of stillbirth.*

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INTRODUCTION

Vasa previa is defined as presence of fetal blood vessels, arterial or venous, unsupported by the placenta or umbilical cord, in close proximity to the internal cervical os[1–3]. These vessels are at risk of rupture, in association with spontaneous or iatrogenic rupture of amniotic membranes, resulting in hemorrhagic fetal death. There is some evidence that, in cases of undiagnosed vasa previa, there is a high risk of stillbirth, neonatal death and neonatal morbidity, whereas these risks can to a great extent be prevented if the condition is diagnosed prenatally[4–10]. The Society of Obstetricians and Gynaecologists of Canada recommends that, if the placenta is found to be low lying at the routine second-trimester ultrasound examination, further evaluation for placental cord insertion should be performed. Transvaginal ultrasound examination may be considered in order to evaluate the internal cervical os in women at high risk for vasa previa, including those with low or velamentous insertion of the cord, bilobed or succenturiate placenta, or vaginal bleeding[11]. The Royal College of Obstetricians and Gynaecologists in the UK acknowledges that the performance of ultrasound in diagnosing vasa previa at the time of the routine fetal anomaly scan has a high diagnostic accuracy with a low false-positive rate (FPR), but concludes that there is insufficient evidence to support universal screening for vasa previa at the time of the routine midpregnancy fetal anomaly scan in the general population and that, although targeted ultrasound screening of pregnancies at higher risk of vasa previa may reduce perinatal loss, the balance of benefit *vs* harm remains undetermined and further research in this area is required[12].

The objectives of this study were to examine the feasibility and effectiveness of a two-stage ultrasound screening strategy for detection of vasa previa and to estimate the potential impact of screening on prevention of stillbirth. In the first stage, a high-risk group is identified by, first, the presence of velamentous cord insertion at the inferior part of the placenta at the 11–13-week scan and, second, the presence of low-lying placenta at the 20–22-week scan. In the second-stage, the high-risk group is examined by transvaginal sonography with color Doppler to diagnose or exclude vasa previa at the time of the 20–22-week scan.

METHODS

Study population

This was a retrospective study of data from prospective screening for vasa previa undertaken at the Fetal Medicine Unit at Medway Maritime Hospital, Gillingham, UK, between January 2012 and June 2018. All women booking for their pregnancy care in our hospital are offered a routine ultrasound examination at 11–13 weeks' gestation for dating of the pregnancy by measurement of fetal crown–rump length, combined screening for fetal aneuploidy, systematic examination of fetal anatomy[13–15] and determination of position of umbilical cord attachment to the placenta; the latter is recorded as central, marginal or velamentous (Figure 1). A second routine scan is offered at 20–22 weeks' gestation and this includes assessment of fetal growth and anatomy, placental localization and determination of the position of umbilical cord attachment to the placenta; the scan is carried out transabdominally, but, in cases of suspected low-lying placenta, the diagnosis is confirmed by transvaginal sonography.

In this study, we included all singleton pregnancies that were booked in our unit for their pregnancy care prior to 14 weeks' gestation. We excluded cases of miscarriage

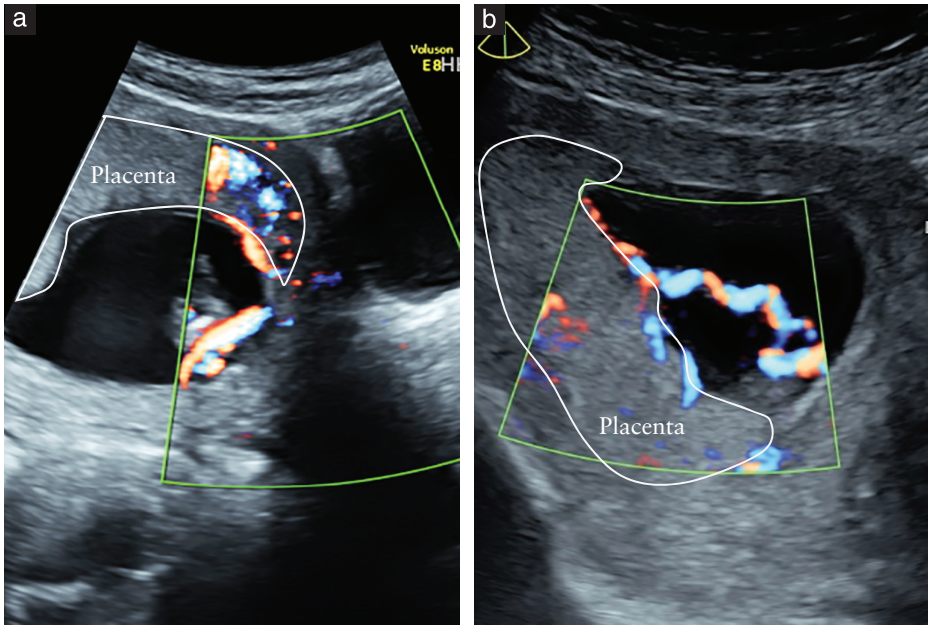

Figure 1 Ultrasound images showing velamentous (a) and central (b) cord insertion into placenta at 11–13-week scan.

or termination at < 24 weeks' gestation and those that were lost to follow-up. The protocol for this study was approved by the National Research Ethics Committee (REC reference number 19/LO/0413). The study was registered with ISRCTN (ISRCTN registry number 11893931).

Screening and management of pregnancies with vasa previa

Screening for vasa previa was based on a two-stage strategy. In the first stage, a high-risk group was identified by, first, the presence of velamentous cord insertion at the inferior part of the placenta at the 11–13-week scan and, second, the presence of low-lying placenta at the 20–22-week scan. In the second-stage, the high-risk group is examined by transvaginal sonography with color Doppler to diagnose or exclude vasa previa at the time of the 20–22-week scan by identifying vessels within 5 cm of the internal os.

Pregnancies with vasa previa were managed on an outpatient basis with transvaginal ultrasound scans for measurement of cervical length and confirmation of vasa previa every 2 weeks until 28 weeks' gestation and every 1 week thereafter until delivery, which was planned at 34–35 weeks by elective Cesarean section. Women were hospitalized if they had regular uterine contractions, short cervix < 15 mm, evidence of progressive cervical shortening or polyhydramnios. In all pregnancies with vasa previa, a sticker was placed on the front of their notes to ensure that all staff were aware of the diagnosis if they presented to the labor ward with contractions or vaginal bleeding.

Outcome measures

Data regarding maternal demographic characteristics, medical history, ultrasound findings and pregnancy outcome were recorded on an electronic database (ViewPoint version 5.6; GE Healthcare, Zipf, Austria). In all pregnancies with a prenatal diagnosis of vasa previa, we carried out a postnatal confirmation of the diagnosis by examination of the placenta, amniotic membranes and umbilical cord insertion (Figure 2). Similarly, gross and histological examination of the placenta and umbilical cord was carried out in all cases of stillbirth.

The following adverse outcomes were examined: first, stillbirth; second, early preterm birth at < 32 weeks' gestation; third, small-for-gestational-age (SGA) neonate with birth weight < 5th percentile[16]; fourth, elective or emergency Cesarean section; fifth, postpartum hemorrhage with estimated blood loss of > 1 L[17]; sixth, admission to the neonatal intensive care unit (NICU) and total length of stay in the neonatal unit; seventh, hypoxic ischemic encephalopathy, which was diagnosed when there was abnormal neurological function with evidence of perinatal hypoxia, supported by neuroimaging evidence of

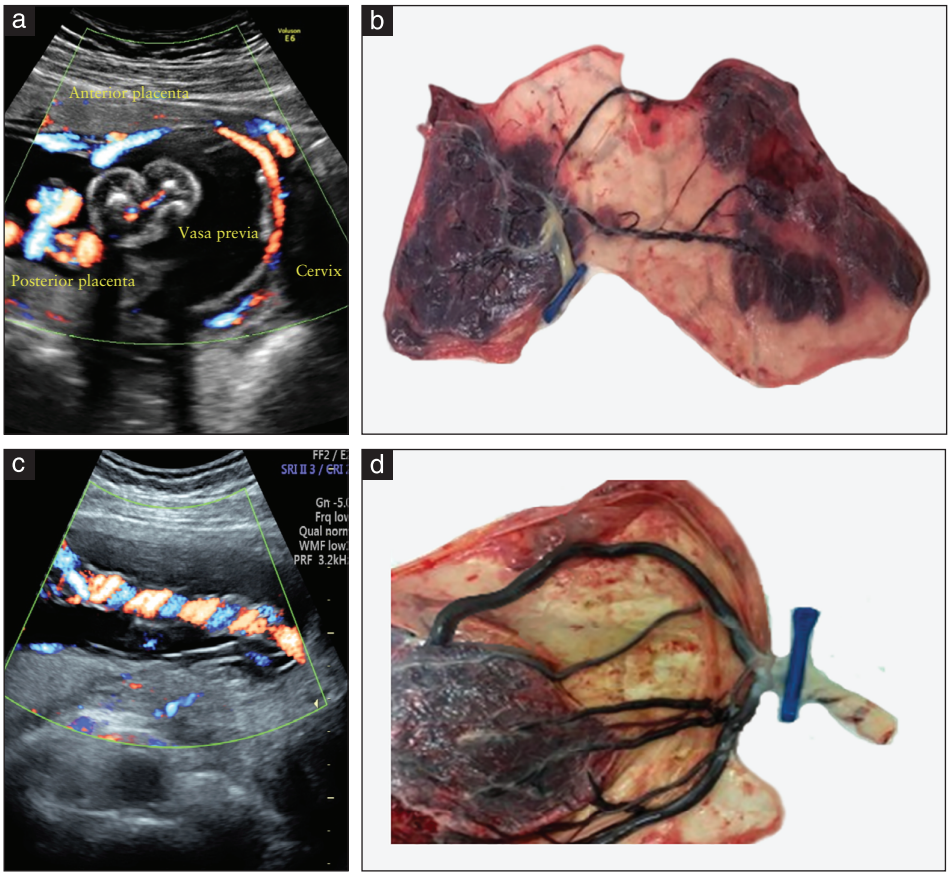

Figure 2 Vasa previa with bilobed placenta (a,b) and velamentous cord insertion (c,d), demonstrated by color Doppler ultrasound images (a,c) and gross placental appearance (b,d).

acute brain injury[18]; eighth, neonatal blood transfusion; and, ninth, neonatal death within 1 week after delivery.

Statistical analysis

Comparison of maternal and pregnancy characteristics between those with and those without vasa previa was by the χ^2 test or Fisher's exact test for categorical variables and Mann–Whitney *U*-test for continuous variables. Significance was assumed at 5% and *post-hoc* Bonferroni correction was used to adjust for multiple comparisons when necessary. Univariable and multivariable logistic regression analyses were used to determine which of the maternal and pregnancy characteristics had a significant contribution in prediction of vasa previa. The effect size of characteristics associated with vasa previa was expressed as odds ratio (OR) with 95% CI. The performance of screening for vasa previa was assessed by estimating the detection rate (DR), FPR, positive and negative likelihood ratios and positive (PPV) and negative (NPV) predictive values. The statistical package SPSS version 24.0 (IBM Corp., Armonk, NY, USA) and MedCalc statistical software version 18.5 (MedCalc Software, Ostend, Belgium; http://www.medcalc.org) were used for data analyses.

RESULTS

Study population

During the study period, 28 526 women with a singleton pregnancy were booked for delivery in our hospital. We excluded 1696 pregnancies (5.9%), including 408 that were terminated, 332 with miscarriage and 956 with missing follow-up data. The study population of 26 830 singleton pregnancies included 22 with suspected vasa previa (Figure 3) but, in one of these cases, subsequent scans at 24 and 26 weeks showed that there was no vasa previa. Therefore, the incidence of vasa previa in our population was 0.08% (21/26 830; 1 in 1278).

Maternal and pregnancy characteristics associated with vasa previa

The maternal and pregnancy characteristics in the study population are shown in Table 1. In pregnancies with, compared to those without, vasa previa, there was a higher prevalence of conception by *in-vitro* fertilization, velamentous cord insertion at the 11–13-week scan and low-lying placenta and bilobed placenta at the 20–22-week scan.

Maternal and neonatal outcomes in pregnancies with vasa previa

In pregnancies with a prenatal diagnosis of vasa previa, there were no stillbirths (Table 2). In pregnancies with, compared to those without, vasa previa, there was a higher prevalence of preterm birth < 32 weeks, delivery of a SGA neonate, emergency Cesarean section, postpartum hemorrhage, admission to NICU, neonatal blood transfusion and neonatal death and earlier gestational age at delivery and longer length of stay in the neonatal unit. In the vasa previa group, 71% (15/21) of pregnancies were delivered by elective Cesarean section at a median gestational age of 34.2 (interquartile range, 32.9–35.1) weeks; six women had spontaneous onset of uterine contractions, of whom five (83.3%) had emergency Cesarean section, whereas one had vaginal birth at 24.9 weeks' gestation following precipitous labor. Two of the neonates in the vasa previa group required blood transfusion for

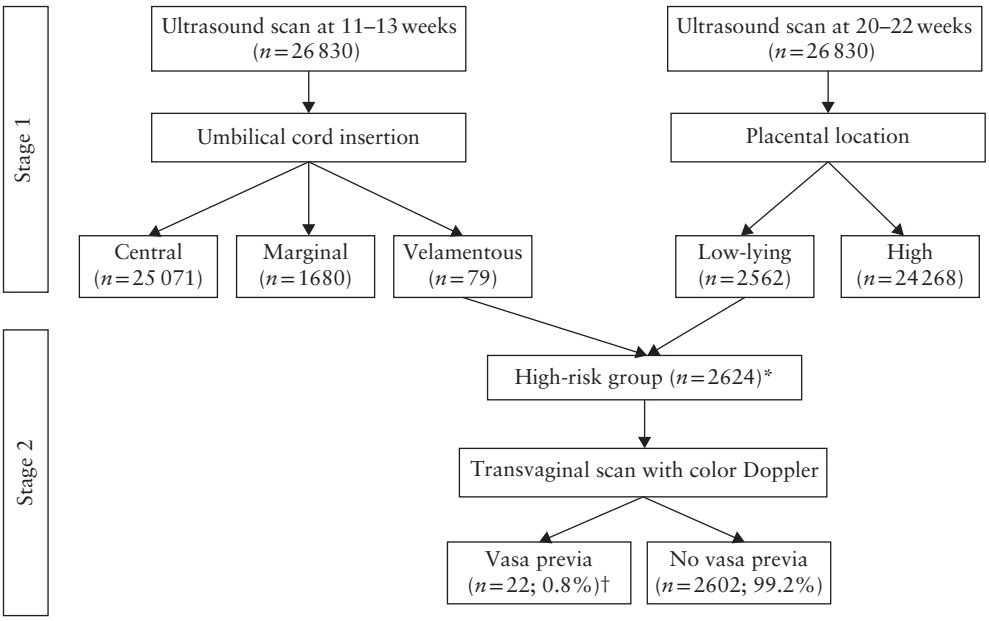

Figure 3 Flowchart summarizing two-stage screening for vasa previa in 26 830 singleton pregnancies. *Seventeen cases had both velamentous insertion in first trimester and low-lying placenta in second trimester. †In one case, subsequent scans at 24 and 26 weeks showed absence of vasa previa.

anemia due to presumed hemorrhage from rupture of the fetal vessels; one case had vaginal birth at 24.9 weeks and the other had emergency Cesarean section for fetal distress after spontaneous labor at 34.3 weeks. In cases of elective Cesarean section in the vasa previa group, regression analysis demonstrated that there was a linear relationship between serial cervical-length measurements and gestational age: expected cervical length in mm = 39.92 − 0.275 × gestational age in weeks; adjusted $R^2 = 0.101$ and $P < 0.0001$ (Figure 4a). This was used to determine the 5th, 50th and 95th percentiles at different gestational ages. At 22 weeks, the respective values were 29, 34 and 38 mm, whereas at 34 weeks, these values were 26, 31 and 35 mm. Serial measurements of cervical length in the five cases requiring emergency Cesarean section because of spontaneous onset of labor or rupture of membranes are shown in Figure 4b; in all cases, onset of labor or membrane rupture was preceded by cervical shortening to below the 5th percentile.

Table 1 Maternal and pregnancy characteristics in 26 830 singleton pregnancies, according to diagnosis of vasa previa

Characteristic	*No vasa previa (n = 26 809)*	*Vasa previa (n = 21)*
Maternal age (years)	29.0 (25.0–33.0)	32.4 (27.1–35.6)
Maternal weight (kg)	68.0 (59.0–80.1)	67.9 (57.9–76.5)
Maternal height (cm)	165 (160–169)	164 (160–169)
Racial origin		
Caucasian	24 422 (91.1)	17 (81.0)
Afro-Caribbean	787 (2.9)	0 (0)
South Asian	1161 (4.3)	3 (14.3)
East Asian	123 (0.5)	0 (0)
Mixed	316 (1.2)	1 (4.8)
Conception		
Spontaneous	26 288 (98.1)	17 (81.0)
In-vitro fertilization	354 (1.3)	4 (19.0)**
Ovulation-induction drugs	167 (0.6)	0 (0)
Cigarette smoking	4475 (16.7)	1 (4.8)
History of medical disorder		
Chronic hypertension	286 (1.1)	0 (0)
Diabetes mellitus	223 (0.8)	1 (4.8)
Nulliparous	11 117 (41.5)	13 (61.9)
US findings at 11–13 weeks		
Velamentous cord insertion	63 (0.2)	16 (76.2)**
Marginal cord insertion	1678 (6.3)	2 (9.5)
Central cord insertion	25 068 (93.5)	3 (14.3)
US findings at 20–22 weeks		
Low-lying placenta	2550 (9.5)	12 (57.1)**
Bilobed placenta	86 (0.3)	8 (38.1)**

Data are given as median (interquartile range) or *n* (%). **$P < 0.01$. US, ultrasound.

Table 2 Adverse outcome in 26 830 singleton pregnancies, according to diagnosis of vasa previa

Outcome	*No vasa previa (n = 26 809)*	*Vasa previa (n = 21)*
Stillbirth	83 (0.3)	0 (0)
Preterm birth < 32 weeks	256 (1.0)	4 (19.0)**
BW < 5th percentile	1641 (6.1)	4 (19.0)*
Elective CS	3051 (11.4)	15 (71.4)**
Emergency CS	4303 (16.1)	5 (23.8)**
Postpartum hemorrhage	1859 (6.9)	7 (33.3)**
GA at delivery (weeks)	39.6 (38.6–40.5)	34.2 (32.9–35.1)**
BW percentile	52.9 (26.1–77.9)	40.6 (8.3–68.1)
Admission to NICU	4451 (16.6)	21 (100)**
Length of stay in NNU (days)†	4.0 (3.0–7.0)	9.0 (7.0–16.0)**
HIE	60 (0.2)	0 (0)
Neonatal blood transfusion	125 (0.5)	2 (9.5)**
Neonatal death	12 (0.04)	1 (4.8)**

Data are given as *n* (%) or median (interquartile range).
†Calculated only for neonates admitted to neonatal unit (NNU).
*$P < 0.05$. **$P < 0.01$. BW, birth weight; CS, Cesarean section; GA, gestational age; HIE, hypoxic ischemic encephalopathy; NICU, neonatal intensive care unit.

Prediction of vasa previa from maternal and pregnancy characteristics

Univariate and multivariate logistic regression analyses demonstrated that significant independent contribution to prediction of vasa previa was provided by conception by *in-vitro* fertilization, velamentous cord insertion at 11–13 weeks, and bilobed placenta and low-lying placenta at 20–22 weeks ($R^2 = 0.634$; $P < 0.0001$) but not from maternal age, weight, height, racial origin, cigarette smoking, parity or maternal diabetes (Table 3).

The performance of screening for vasa previa by *in-vitro* fertilization, velamentous cord insertion, bilobed placenta and low-lying placenta is shown in Table 4. Velamentous cord insertion had a DR of 76%, FPR of 0.2% and PPV of 20%, implying that about 3 in 4 pregnancies with vasa previa have velamentous insertion but only about 1 in 5 of those with velamentous cord insertion would have vasa previa. Bilobed placenta had a DR of 38%, FPR of 0.3% and PPV of 9%, suggesting that 2 in 5 pregnancies with vasa previa have a bilobed placenta but only about 1 in 10 of those with a bilobed placenta would have vasa previa. Similarly, a low-lying placenta at the 20–22-week scan had a DR of 57%, but with a relatively higher FPR of 10% and a low PPV of 0.5%, implying that, while 3 in 5 pregnancies with vasa previa have a low-lying placenta, only 1 in 200 of those that have a low-lying placenta would have vasa previa. Similarly, about 1 in 5 pregnancies with vasa previa are conceived by *in-vitro* fertilization but only 1 in 100 of those conceived by *in-vitro* fertilization would have vasa previa.

Stillbirths and neonatal deaths in the study population

In pregnancies with vasa previa, there were no antenatal or intrapartum stillbirths, but there was one neonatal death attributable to vasa previa-related hemorrhage in a case which presented with spontaneous preterm labor, antepartum hemorrhage and fetal bradycardia requiring emergency Cesarean section. None of the 83 pregnancies

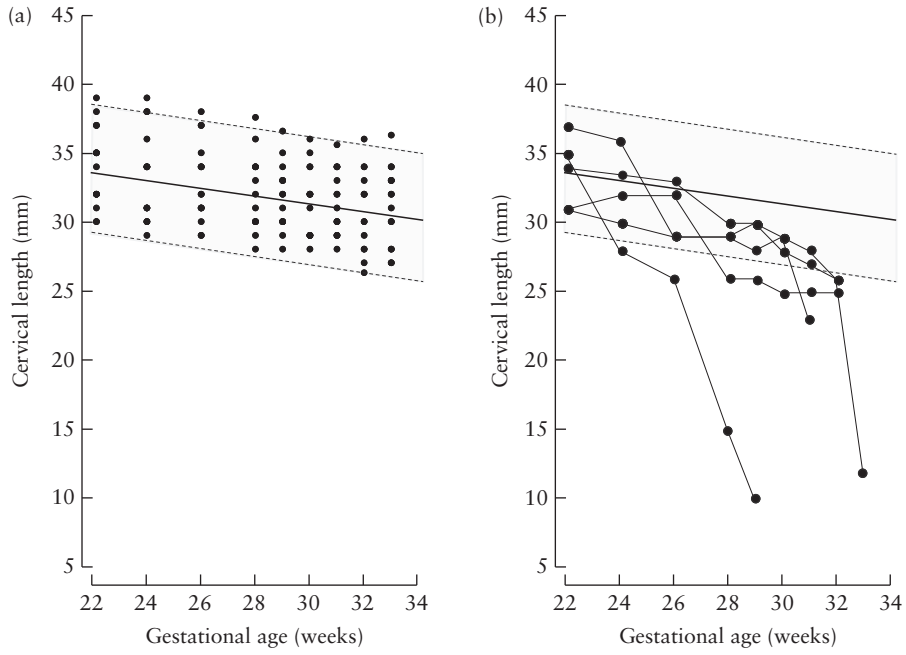

Figure 4 Serial cervical-length measurements, according to gestational age, in 15 cases of vasa previa that had elective Cesarean section (a) and five cases of vasa previa which required emergency Cesarean section because of spontaneous onset of labor or rupture of membranes (b). Note, there are overlapping data points. Dashed lines represent 5th and 95th percentiles and solid lines represent 50th percentile.

Table 3 Univariate and multivariate logistic regression analyses demonstrating association of maternal and pregnancy characteristics with vasa previa

Characteristic	*Univariate*	*Multivariate*
Maternal age – 30 (in years)	1.07 (0.99–1.16)	—
Maternal weight – 70 (in kg)	0.98 (0.96–1.01)	—
Maternal height – 164 (in cm)	0.98 (0.92–1.05)	—
Racial origin		
Caucasian	1.00 (reference)	—
Afro-Caribbean	—	—
South Asian	3.71 (1.09–12.69)*	—
East Asian	—	—
Mixed	4.55 (0.60–34.25)	—
Conception		
Spontaneous	1.00 (reference)	—
In-vitro fertilization	17.47 (5.85–52.19)**	10.35 (1.69–63.32)*
Ovulation-induction drugs	—	—
Cigarette smoking	0.25 (0.03–1.86)	—
History of medical disorder		
Chronic hypertension	—	—
Diabetes mellitus	5.96 (0.80–44.61)	—
Nulliparous	2.29 (0.95–5.54)	—
Ultrasound findings at 11–13 weeks		
Velamentous cord insertion	1358.53 (482.99–3821.22)**	706.55 (217.63–2293.81)**
Marginal cord insertion	2.50 (0.74–8.48)	—
Ultrasound findings at 20–22 weeks		
Low-lying placenta	12.68 (5.34–30.13)**	19.85 (5.81–67.78)**
Bilobed placenta	191.22 (77.29–473.07)**	39.09 (8.83–173.07)**

Data are odds ratio (95% CI). *$P < 0.05$. **$P < 0.01$.

with stillbirth had postpartum findings suggestive of undiagnosed vasa previa. On the assumption that, if we had not diagnosed prenatally all 21 cases of vasa previa in our population half of these cases would have resulted in stillbirth, then the potential impact of screening is prevention of 10.6% (10/94) of stillbirths.

DISCUSSION

Principal findings

This study has demonstrated the feasibility of introducing a two-stage screening program for diagnosis of vasa previa based on transvaginal sonography at 20–22 weeks'

Table 4 Performance of screening for vasa previa according to pregnancy characteristics

Parameter	*Conception by IVF*	*Velamentous cord insertion*	*Bilobed placenta*	*Low-lying placenta*
DR (%)	19.05 (5.45–41.91)	76.19 (52.83–91.78)	38.10 (18.11–61.56)	57.14 (34.02–78.18)
FPR (%)	1.32 (1.19–1.46)	0.23 (0.18–0.30)	0.32 (0.26–0.40)	9.51 (9.16–9.87)
LR+	14.43 (5.94–35.05)	324.22 (229.96–547.12)	118.76 (66.18–213.09)	6.01 (4.14–8.72)
LR−	0.82 (0.67–1.01)	0.24 (0.11–0.51)	0.62 (0.44–0.87)	0.47 (0.29–0.78)
PPV (%)	1.12 (0.46–2.67)	20.25 (15.26–26.37)	8.51 (4.93–14.30)	0.47 (0.32–0.68)
NPV (%)	99.94 (99.92–99.95)	99.98 (99.96–99.99)	99.95 (99.93–99.97)	99.96 (99.94–99.98)

Values in parentheses are 95% CI. DR, detection rate; FPR, false-positive rate; IVF, *in-vitro* fertilization; LR+/−, positive/negative likelihood ratio; NPV, negative predictive value; PPV, positive predictive value.

gestation for those with velamentous cord insertion at the routine 11–13-week scan and low-lying placenta at the 20–22-week scan. We found that, first, the prevalence of vasa previa in a routinely screened population is about 1 in 1300 pregnancies, second, risk factors for vasa previa are conception by *in-vitro* fertilization, velamentous cord insertion, bilobed placenta and a low-lying placenta; third, all pregnancies with a prenatal diagnosis of vasa previa resulted in live birth; and, fourth, effective prenatal diagnosis of vasa previa can potentially contribute to prevention of about 10% of all stillbirths.

Comparison with other studies

Our results on perinatal survival in cases of vasa previa are consistent with those of previous studies which reported that prenatal diagnosis of vasa previa is associated with survival rates of 97–100%, compared to < 50% in those that were not detected[4–10,19,20]. A multicenter study of 155 pregnancies with vasa previa reported that perinatal survival was 97% (59/61) in those diagnosed prenatally compared to 44% (41/94) in those without a prenatal diagnosis[5].

Our findings on risk factors for vasa previa are consistent with those of a systematic review of 13 studies on 569 410 pregnancies, including 325 cases of vasa previa, which identified five risk factors, namely conception by assisted reproductive techniques, bilobed placenta, second-trimester placenta previa, first-trimester cord insertion in the lower third of the uterus and velamentous cord insertion[21].

Implications for clinical practice

The results of our study demonstrate that accurate and effective prenatal diagnosis of pregnancies with vasa previa can be achieved by a two-stage screening protocol to identify a high-risk group in need of transvaginal color Doppler assessment at 20–22 weeks' gestation. Although findings such as velamentous cord insertion, bilobed placenta and low-lying placenta are risk factors for vasa previa, the majority of pregnancies with these findings do not have vasa previa and can therefore be reassured after assessment at the 20–22-week scan. Our findings suggest that prenatal diagnosis of vasa previa and appropriate monitoring and delivery of such pregnancies can potentially reduce the overall rate of stillbirth by about 10%.

Strengths and limitations

The main strengths of our study are, first, prospective examination of a large unselected population of pregnancies attending for routine ultrasound scans at 11–13 and 20–22 weeks' gestation, and, second, postnatal confirmation of all cases of suspected vasa previa and exclusion of vasa previa in all cases of stillbirth. A limitation of the study is that postnatal examination of the placenta and membranes was not carried out in all pregnancies and it is therefore possible that some cases of vasa previa that had live birth may have been undetected by prenatal ultrasound. Another limitation is that the study was confined to singleton pregnancies.

Conclusion

A two-stage strategy of screening for vasa previa can be incorporated into routine clinical practice and such a strategy could potentially reduce the rate of stillbirth. The feasibility and cost-effectiveness of such a strategy requires investigation in prospective multicenter studies in hospitals providing routine pregnancy care.

REFERENCES

1. McNair AJ. Placenta praevia, with vasa praevia; Caesarean section. *Proc R Soc Med* 1921; **14**: 195–196.
2. Alment EA. Vasa praevia simulating antepartum hemorrhage. *Br Med J* 1949; **2**: 1273.
3. Sinkey RG, Odibo AO, Dashe JS. Diagnosis and management of vasa previa. Society of Maternal-Fetal (SMFM) Publications Committee. *Am J Obstet Gynecol* 2015; **213**: 615–619.
4. Oyelese KO, Turner M, Lees C, Campbell S. Vasa previa: an avoidable obstetric tragedy. *Obstet Gynecol Surv* 1999; **54**: 138–145.
5. Oyelese Y, Catanzarite V, Prefumo F, Lashley S, Schachter M, Tovbin Y, Goldstein V, Smulian JC. Vasa previa: the impact of prenatal diagnosis on outcomes. *Obstet Gynecol* 2004; **103**: 937–942.
6. Kanda E, Matsuda Y, Kamitomo M, Maeda T, Mihara K, Hatae M. Prenatal diagnosis and management of vasa previa: a 6-year review. *J Obstet Gynaecol Res* 2011; **37**: 1391–1396.
7. Catanzarite V, Cousins L, Daneshmand S, Schwendemann W, Casele H, Adamczak J, Tith T, Patel A. Prenatally Diagnosed Vasa Previa: A Single-Institution Series of 96 Cases. *Obstet Gynecol* 2016; **128**: 1153–1161.
8. Sullivan EA, Javid N, Duncombe G, Li Z, Safi N, Cincotta R, Homer CSE, Halliday L, Oyelese Y. Vasa Previa Diagnosis, Clinical Practice, and Outcomes in Australia. *Obstet Gynecol* 2017; **130**: 591–598.
9. Baulies S, Maiz N, Muñoz A, Torrents M, Echevarría M, Serra B. Prenatal ultrasound diagnosis of vasa praevia and analysis of risk factors. *Prenat Diagn* 2007; **27**: 595–599.

10. Kulkarni A, Powel J, Aziz M, Shah L, Lashley S, Benito C, Oyelese Y. Vasa Previa: prenatal diagnosis and outcomes: thirty-five cases from a single maternal-fetal medicine practice. *J Ultrasound Med* 2018; **37**: 1017–1024.
11. Gagnon R. No. 231-Guidelines for the Management of Vasa Previa. *J Obstet Gynaecol Can* 2017; **39**: e415–e421.
12. Jauniaux E, Alfirevic Z, Bhide AG, Burton GJ, Collins SL, Silver R; Royal College of Obstetricians and Gynaecologists. Vasa Praevia: Diagnosis and Management: Green-top Guideline No. 27b. *BJOG* 2019; **126**: e49–e61.
13. Robinson HP, Fleming JE. 1975. A critical evaluation of sonar crown rump length measurements. *Br J Obstet Gynaecol* 1975; **182**: 702–710.
14. Nicolaides KH. Screening for fetal aneuploidies at 11 to 13 weeks. *Prenat Diagn* 2011; **31**: 7–15.
15. Syngelaki A, Hammami A, Bower S, Zidere V, Akolekar R, Nicolaides KH. Diagnosis of fetal non-chromosomal abnormalities on routine ultrasound examination at 11–13 weeks' gestation. *Ultrasound Obstet Gynecol* 2019; **54**: 468–476.
16. Nicolaides KH, Wright D, Syngelaki A, Wright A, Akolekar R. Fetal Medicine Foundation fetal and neonatal population weight charts. *Ultrasound Obstet Gynecol* 2018; **52**: 44–51.
17. Mavrides E, Allard S, Chandraharan E, Collins P, Green L, Hunt BJ, Riris S, Thomson AJ on behalf of the Royal College of Obstetricians and Gynaecologists. Prevention and management of postpartum haemorrhage. *BJOG* 2016; **124**: e106–e149.
18. Douglas-Escobar M, Weiss MD. Hypoxic-ischemic encephalopathy: a review for the clinician. *JAMA Pediatr* 2015; **169**: 397–403.
19. Rebarber A, Dolin C, Fox NS, Klauser CK, Saltzman DH, Roman AS. Natural history of vasa previa across gestation using a screening protocol. *J Ultrasound Med* 2014; **33**: 141–147.
20. Smorgick N, Tovbin Y, Ushakov F, Vaknin Z, Barzilay B, Herman A, Maymon R Is neonatal risk from vasa previa preventable? The 20-year experience from a single medical center. *J Clin Ultrasound* 2010; **38**: 118–122.
21. Ruiter L, Kok N, Limpens J, Derks JB, de Graaf IM, Mol B, Pajkrt E. Incidence of and risk indicators for vasa praevia: a systematic review. *BJOG* 2016; **123**: 1278–1287.

