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The natural history and management of vasa previa: a single institution's 15-year experience managing patients remote from labor and delivery

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Abstract

Introduction Vasa previa (VP) is a diagnosis with potential catastrophic obstetric outcomes. We describe the outcomes of VP managed at our institution, which uniquely provides inpatient monitoring on an antepartum unit located remotely from labor and delivery (L&D).

Methods Retrospective study of singleton pregnancies diagnosed with VP at a single institution. VP was diagnosed prenatally by ultrasound if one or more fetal vessels unsupported by underlying placenta were coursing within 2 cm of the internal os. Most cases were admitted for inpatient monitoring; however, patients were counseled that high-quality data were lacking demonstrating superiority of inpatient admission compared to outpatient management. Descriptive analyses were performed to compare outcomes in patients with resolved vs. persistent VP as well outpatient versus inpatient management among those with persistent VP. Results are reported as median (range).

Results Fifty patients were diagnosed with VP at a gestational age of 22.9 weeks (18.0–34.3) with 38 (76.0%) VP persisting until delivery. There was an outpatient group (8, 21.0%) who declined hospital monitoring, and an inpatient group (30, 79.0%). The admission GA for the inpatient group was 31.2 weeks (25.6–34.3) for a duration of 19.5 days (2–52). The majority (70%) of patients required at least one transfer from the antepartum unit to L&D. There was no difference in urgent or emergent cesarean deliveries among patients managed outpatient vs. inpatient [3 (37.5%) vs 13 (43.3%), $p = 0.547$]. There were no cases of neonatal anemia related to VP or perinatal deaths.

Conclusion Admitting patients with VP to a location separate from the L&D operating rooms was not associated with adverse pregnancy or neonatal outcomes. Monitoring of patients with vasa previa in a location remote from L&D was not associated with worse pregnancy outcomes.

Keywords Vasa previa, Fetal vessel, Cervical length, Fetal bleeding, Placenta previa, Low lying placenta

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Background

Vasa previa (VP) is a condition in which fetal vessels course within the fetal membranes near the internal cervical os, unsupported by placental tissue. The prevalence of VP ranges from 1/1200 to 1/2500 pregnancies depending on specific antenatal screening protocols [1, 2]. Risk factors for VP include velamentous cord insertion, low-lying placenta or placenta previa, succenturiate placenta, assisted reproductive technology, and multiple gestations [3–5]. Historically, perinatal mortality ranged from 40–75% with a 59% rate of postnatal blood transfusion due to fetal exsanguination when the membranes ruptured [6, 7]. In modern obstetrics, the perinatal mortality rate is low (0–3%) due to prenatal ultrasound diagnosis and cesarean delivery ideally before, or at the time of onset of labor or membrane rupture [1, 2, 6, 8–11].

However, there is a gap in evidence supporting the optimal management of VP. Neither the American College of Obstetricians & Gynecologists (ACOG) or the Society for Maternal–Fetal Medicine (SMFM) provide specific details on antenatal surveillance, and there is no published Level 1 evidence [12]. As a result, antepartum management varies widely. Hospital admission with inpatient monitoring and planned cesarean delivery is often advised, but not universally recommended [12, 13]. There is no consensus on the specific methods or frequency of inpatient monitoring such as location [labor and delivery (L&D) versus antepartum], fetal heart rate (FHR) monitoring (continuous versus non-stress tests), and ultrasounds (serial cervical lengths). Furthermore, robust data are lacking demonstrating inpatient management as superior to outpatient surveillance in reducing perinatal mortality.

Our objective was to study the outcomes of patients with VP managed at our institution, which uniquely provides inpatient admission with monitoring on the antepartum unit located on a separate floor from the L&D operating rooms (ORs).

Methods

A retrospective cohort study was performed of patients with a singleton pregnancy diagnosed with VP by ultrasound at any gestational age at our institution from 2008 to 2023. Patients with multiple gestations were excluded. All patients underwent a detailed ultrasound examination including endovaginal ultrasound to evaluate the lower uterine segment and cervix. VP was diagnosed if one or more fetal vessels unsupported by underlying placenta were coursing within 2 cm of the internal os. VP was classified as Type I, II, or III based on ultrasound findings as previously described [1, 4, 14–16]. Type I vasa previa occurs when fetal vessels from a velamentous placental cord insertion site traverse near the cervix. Type II refers to fetal vessels that connect to a succenturiate (accessory) placental lobe. Type III occurs when fetal vessels 'boomerang' (exit and re-enter) the single placenta near the cervix.

Patients diagnosed with VP underwent antenatal management by a maternal–fetal medicine (MFM) specialist, with the majority recommending inpatient admission to monitor for signs of labor, vaginal bleeding, non-reassuring fetal status, and ultimately a scheduled cesarean delivery. However, patients were counseled that high-quality data were lacking demonstrating superiority of inpatient admission compared to outpatient management. Over the course of the study period, there was a gradual shift from recommending admission conservatively between 28–32 weeks of gestation to a later gestational age range of 30–34 weeks of gestation [12]. For the subset of patients undergoing outpatient management, the antenatal management was individualized on a case-by-case basis. Factors such as history of spontaneous preterm birth, distance from the hospital, and antenatal complications (e.g., contractions, vaginal bleeding, etc.) were considered by the primary MFM providers. Antenatal management strategies including betamethasone administration, frequency of non-stress tests, and the use of cervical lengths was similarly at the discretion of the MFM provider.

VP patients were admitted to the antepartum unit, one floor above the L&D ORs. During admission, patients were transferred to L&D if they required more than 1 h of FHR monitoring or had signs and/or symptoms of labor. The decisions regarding the timing of corticosteroid administration, antenatal monitoring, cervical length surveillance, and gestational age at delivery were left to the discretion of the MFM physicians. Most patients received betamethasone within 24 h of admission, underwent daily non-stress tests, and ultrasound surveillance approximately every 2 to 4 weeks. A rescue course of betamethasone was considered on a case-by-case basis (e.g., vaginal bleeding, contractions, fetal heart rate decelerations, etc.) if at least 14 days had passed since the initial course and the patient was less than 34 weeks of gestation. Regardless of inpatient or outpatient management, cesarean delivery was recommended between 34 and 37 weeks for patients with persistent VP. Patients with an antenatal event such as vaginal bleeding or preterm contractions who later stabilized were advised to consider delivery closer to 34 to 35 weeks' gestation to potentially avoid a recurrent event prompting an emergent delivery. Per institutional policy, any neonate delivered prior to 35 weeks' gestation was routinely admitted to the neonatal intensive care unit (NICU) for initial observation (temperature control, respiratory difficulties, etc.).

Maternal, pregnancy, delivery, and neonatal characteristics were extracted from the patients' electronic health record. Maternal characteristics included were age (in years), body mass index (categorized as under/normal weight [< 25 kg/m^2], overweight [25–29.9 kg/m^2], obese [≥ 30 kg/m^2], or unknown), residence in Oregon (yes vs. no), education (less than a 4-year degree, 4-year degree or more, or unknown), insurance status (private or public; no included patient was uninsured), marital status (married, single, or domestic partnership), gravity (multi vs. primigravida), use of assisted reproductive technology (yes vs. no), tobacco use during pregnancy (yes vs. no), any prior cervical surgery, obstetric history (previous preterm birth, preterm labor, vaginal bleeding, placental insufficiency, cesarean delivery, dilation & curettage/evacuation, or uterine surgery). We also extracted patient race and ethnicity; patients could report multiple racial and ethnic identities, selected options included Asian, Black/African American, Hispanic/Latinx, Native Hawaiian/Pacific Islander, and White.

Pregnancy and delivery characteristics extracted included gestational age at vasa previa diagnosis (in weeks), vasa previa type (I, II, or III), cervical length (in cm), presence of placenta previa at time of initial vasa previa diagnosis, whether the placenta previa resolved (yes vs. no), presence of low-lying placenta or succenturiate placenta, fetal growth restriction (yes, no, or no data), gestational age at vasa previa resolution (in weeks), gestational age at delivery (in weeks), and mode of delivery (vaginal vs. cesarean).

For patients with persistent vasa previa, additional delivery characteristics were extracted including gestational age at admission for delivery (in weeks), number of transfers to L&D (categorized as 0, 1, 2, or ≥3), maternal length of stay (in days), any preterm labor symptoms (yes vs. no), type of tocolysis medication used, use of betamethasone (yes vs. no), preterm premature rupture of membranes (PPROM) and gestational age at time of PPROM (in weeks), presence of vaginal bleeding (yes vs. no), hysterotomy type (low transverse, vertical 'classical', or T incision), urgency of delivery (urgent/emergent vs. scheduled), and indication for delivery.

Neonatal characteristics extracted included sex, birthweight (in grams), Apgar scores at 1 and 5 min, NICU admission (yes vs. no), length of NICU stay (in days), and any neurologic, respiratory, cardiac, gastrointestinal, and hematologic complications. Neonatal anemia from prematurity related causes was differentiated from anemia resulting from injury of the vasa previa vessels.

This descriptive analysis used two independent variables to compare patient characteristics. First, maternal and pregnancy characteristics were compared by VP resolution status (resolved vs. persistent) for the full cohort (n = 50). Second, delivery and neonatal characteristics were compared by admission status (not admitted vs. admitted) among patients with persistent vasa previa (n = 38). Due to the small sample size and the skewed data distributions of several of the continuous variables, Fisher's exact test was used to compare categorical variables and the non-parametric Wilcoxon's rank-sum test was used to compare continuous variables, which are reported as median (range). All analyses were performed using Stata 17.0 (StataCorp LLC, College Station, TX) using a confidence level of 0.05.

Results

Fifty patients were diagnosed with vasa previa: 9 (18.0%) Type I, 23 (46.0%) Type II, and 18 (36.0%) Type III (Table 1). The median maternal age was 33.5 years (18.0–41.0) and 5 (10.0%) of the pregnancies were conceived by in vitro fertilization. The majority (80.0%) reported at least some White racial identity. Maternal characteristics did not differ between those patients with resolved and persistent VP except for prior dilation & curettage procedures (0% vs 31.6%, p = 0.047). Of the 50 patients with an initial diagnosis of VP, 12 (24.0%) resolved and 38 (76.0%) persisted until delivery.

The median gestational age (GA) at diagnosis of VP was 22.9 weeks (18.0–34.3). At the time of initial diagnosis, there was either a placenta previa or low-lying placenta in 42.0% and 28.0% of cases, respectively (Table 2). Among the 12 patients with spontaneous resolution of the VP to delivery, the interval from diagnosis to resolution was 7.9 weeks (4.3–15.6). At the time of initially being informed of resolution of the VP (a distance of more than 2 cm away from the internal cervical os), 7 (58.3%) patients had fetal vessel(s) between 2 and 5 cm from the cervix. Four out of 7 patients still had fetal vessels between 2 and 5 cm on the ultrasound performed most proximal to delivery (2.6, 2.7, 3.1, and 4.1 cm from the internal os). Only 1 (8.3%) of the patients with eventual resolution of the VP (fetal vessel 3.1 cm from the cervix) was admitted to the antepartum unit due to preterm contractions and managed akin to a vasa previa. The delivery GA for patients with resolved VP was 37.8 weeks (32.2–41.0) with 7 (58.3%) undergoing a cesarean delivery. The indications for cesarean delivery included elective in the setting of resolved vasa previa but with fetal vessels between 2 and 5 cm of the cervix (n = 2), preterm labor (n = 2), non-reassuring fetal status (n = 2), and placenta previa (n = 1). The two patients who underwent elective cesarean delivery at 35w3 d and 37w0 d had unprotected fetal vessels measuring 3.1 cm and 2.6 cm from the cervix, respectively. The median birthweight in the resolved VP group was 3093 g (1688–3790) and 3 of 12 (25.0%) of these infants required NICU admission (Table 2). Two

Table 1 Maternal characteristics of patients diagnosed with vasa previa. Data are n (%) or median (range)

Characteristics	Vasa Previa Resolved (*n* = 12)	Vasa Previa Persisted (*n* = 38)	Overall (*n* = 50)	*p*-value
Age (years)	34 (18–41)	33 (23 –41)	33.5 (18–41)	1.000
BMI				0.058
Underweight/Normal weight	5 (41.7)	9 (23.7)	14 (28.0)	
Overweight	7 (58.3)	15 (39.5)	22 (44.0)	
Obese	0 (0.0)	13 (34.2)	13 (26.0)	
Unknown	0 (0.0)	1 (2.6)	1 (2.0)	
State of residence				0.314
In-state	12 (100)	32 (84.2)	44 (88.0)	
Out-of-state	0 (0.0)	6 (15.8%)	6 (12.0%)	
Race and Ethnicity[a]				
White	9 (75.0)	31 (81.6)	40 (80.0)	0.686
Hispanic/Latinx	2 (16.7)	7 (18.4)	9 (18.0)	1.000
Asian	1 (8.3)	4 (10.5)	5 (10.0)	1.000
Black/African American	0 (0.0)	1 (2.6)	1 (2.0)	1.000
Native Hawaiian/Pacific Islander	0 (0.0)	1 (2.6)	1 (2.0)	1.000
Unknown	1 (8.3)	1 (2.6)	2 (4.0)	0.426
Education				0.263
Less than 4-year degree	0 (0.0)	7 (18.4)	7 (14.0)	
4-year degree or more	5 (41.7)	16 (42.1)	21 (42.0)	
Unknown	7 (58.3)	15 (39.5)	22 (44.0)	
Insurance status				0.304
Private	10 (83.3)	25 (65.8)	35 (70.0)	
Public	2 (16.7)	13 (34.2)	15 (30.0)	
Marital status				0.862
Married	10 (83.3)	27 (71.1)	37 (74.0)	
Single	2 (16.7)	8 (21.1)	10 (20.0)	
Domestic Partnership	0 (0.0)	3 (7.9)	3 (6.0)	
Gravity				0.424
Multi-gravida	8 (66.7)	31 (81.6)	39 (78.0)	
Primigravida	4 (33.3)	7 (18.4)	11 (22.0)	
Assisted Reproductive Technology	1 (8.3)	4 (10.5)	5 (10.0)	1.000
Tobacco use during pregnancy	1 (8.3)	2 (5.3)	3 (6.0)	1.000
Prior cervical surgery				
LEEP[b]	2 (16.7)	0 (0.0)	2 (4.0)	0.054
Cryosurgery	1 (8.3)	0 (0.0)	1 (2.0)	0.240
None	10 (83.3)	37 (97.4)	47 (94.0)	0.139
Unknown	0 (0.0)	1 (2.6)	1 (2.0)	1.000
Previous preterm birth[c]	0 (0.0)	4 (10.5)	4 (8.0)	0.560
Preterm labor	0 (0.0)	2 (50.0)	2 (4.0)	
Vaginal bleeding	0 (0.0)	1 (25.0)	1 (2.0)	
Placental insufficiency	0 (0.0)	2 (50.0)	2 (4.0)	-
Previous cesarean deliveries	1 (8.3)	7 (18.4)	8 (16.0)	0.661
Prior D&C/D&E[d]	0 (0.0)	12 (31.6)	12 (24.0)	0.047
Previous uterine surgeries	0 (0.0)	3 (7.9)	3 (6.0)	1.000

[a] Patients could report all applicable racial and ethnic groups. Results do not sum to 100%

[b] LEEP – Loop electrosurgical excision procedure

[c] Among patients with a previous preterm birth

[d] D&C/D&E = dilation & curettage/evacuation

Table 2 Pregnancy characteristics. Data are n (%) or median (range)

Characteristics	Vasa Previa Resolved ($n=12$)	Vasa Previa Persisted ($n=38$)	Overall ($n=50$)	*p*-value
Gestational age at diagnosis (weeks)	21.8 (18.0–29.8)	23.0 (19.9–34.3)	22.9 (18.0–34.3)	0.093
Vasa previa type				0.256
I	3 (25.0)	6 (15.8)	9 (18.0)	
II	3 (25.0)	20 (52.6)	23 (46.0)	
III	6 (50.0)	12 (31.6)	18 (36.0)	
Cervical length (cm)	4.1 (3.3–6.0)	4.0 (2.1–5.8)	4.0 (2.1–6.0)	0.856
Placenta previa at initial diagnosis	4 (33.3)	17 (44.7)	21 (42.0)	0.526
Placenta previa resolved[a]	1 (25.0)	8 (47.1)	9 (42.9)	0.603
Low-lying placenta	3 (25.0)	11 (29.0)	14 (28.0)	1.000
Succenturiate placenta	3 (25.0)	20 (52.6)	23 (46.0)	0.112
Fetal growth restriction				1.000
No	12 (100)	36 (94.7)	48 (96.0)	
Yes	0 (0.0)	1 (2.6)	1 (2.0)	
No data	0 (0.0)	1 (2.6)	1 (2.0)	
Gestational age at vasa previa resolution (weeks)	30.3 (24.9–34.2)	N/A	-	-
Interval from diagnosis to resolution (weeks)	7.9 (4.3–15.6)	N/A	-	-
Gestational age at delivery (weeks)	37.8 (32.2–41.0)	34.0 (28.0–36.6)	34.2 (28.0–41.0)	< 0.001
Mode of delivery				< 0.001
Vaginal	5 (41.7)	0 (0.0)	5 (10.0)	
Cesarean	7 (58.3)	38 (100)	45 (90.0)	
Birthweight (g)	3093 (1688–3790)	2294 (968–3340)	2441.5 (968–3790)	< 0.001
NICU[b] admission	3 (25.0)	30 (79.0)	33 (66.0)	0.001

[a] Among patients with placenta previa at initial diagnosis

[b] NICU – neonatal intensive care unit

neonates were admitted due to complications related to prematurity. The other neonate was born at 38 weeks' gestation and admitted to the NICU with issues related to polysubstance use disorder and placental abruption.

Of the 38 patients with persistent VP, 8 (21.1%) declined inpatient admission and 30 (78.9%) underwent planned admission before delivery (Table 3). Betamethasone was administered in 36/38 (94.7%) patients: 3 received only the 1st dose due to vaginal bleeding prompting delivery prior to the 2nd dose, 23 completed a full course, and 10 received an additional rescue course either electively ($n=6$) or for an inciting antenatal event ($n=4$). Two patients did not receive betamethasone: one patient delivered at 36w2d with type II diabetes mellitus and was managed during a period in which late preterm steroids were not considered, and the other patient unexpectantly delivered at 30w4d shortly after arriving to L&D for a scheduled admission and therefore did not have adequate time to receive betamethasone. Among the 38 patients, 14 (36.8%) had preterm labor symptoms and/or spontaneous membrane rupture, and 8 (21.1%) had vaginal bleeding. Comparing patients remaining outpatient to those admitted, the delivery GA was not significantly different [34.5 weeks (28.0–36.6) vs. 34.0 weeks (28.3–36.2), $p=0.408$]. There was also no difference in the need for urgent or emergent cesarean delivery among patients managed outpatient vs inpatient [37.5% ($n=3$) vs. 43.3% ($n=13$), $p=0.547$]. Neonatal complications were not statistically different between the two groups (Table 4).

Among the 30 patients admitted prior to delivery, the GA at admission was 31.2 weeks (25.6–34.3). Twenty-one (70.0%) patients required at least one transfer between antepartum and L&D due to symptoms related to preterm labor, vaginal bleeding, and/or abnormal antenatal testing findings. Of these patients, 14 (46.7%) had one transfer, 4 (13.3%) had two transfers, and 3 (10.0%) had three or more transfers. The length of hospitalization prior to delivery was 19.5 days (2–52) (Table 3).

Among the 8 patients electing for outpatient management, 2 (25.0%) patients experienced vaginal bleeding prior to delivery. Delivery indications included 4 (50.0%) scheduled, 2 (25.0%) preterm labor, 1 (12.5%) membrane rupture, and 1 (12.5%) acute on chronic maternal heart failure. The 1 patient who experienced rupture of

Table 3 Characteristics of patients with vasa previa managed in the outpatient and inpatient setting. Data are n (%) or median (range)

Characteristics	Not admitted (*n* = 8)	Admitted (*n* = 30)	Overall (*n* = 38)	*p*-value
Gestational age at admission for delivery (weeks)	34.5 (26.3 – 36.6)	31.2 (25.6 – 34.3)	31.8 (25.6 – 36.6)	0.005
Number of transfers to Labor & Delivery				0.006
0	8 (100)	9 (30.0)	17 (44.7)	
1	0 (0.0)	14 (46.7)	14 (36.8)	
2	0 (0.0)	4 (13.3)	4 (10.5)	
3 +	0 (0.0)	3 (10.0)	3 (7.9)	
Maternal length of stay (days)	-	19.5 (2 – 52)	-	NA
Preterm labor symptoms	2 (25.0)	12 (40.0)	14 (36.8)	0.684
Tocolysis medication				0.831
Nifedipine	1 (12.5)	7 (23.3)	8 (21.1)	
Magnesium sulfate	0 (0.0)	3 (10.0)	3 (7.9)	
None	7 (87.5)	20 (66.7)	27 (71.1)	
Betamethasone	7 (87.5)	29 (96.7)	36 (94.7)	0.381
PPROM[a]	1 (12.5)	1 (3.3)	2 (5.3)	0.381
Gestational age at PPROM (weeks)	34.0	30.6	32.3 (30.6 – 34.0)	0.317
Vaginal bleeding	2 (25.0)	6 (20.0)	8 (21.1)	1.000
Gestational age at delivery (weeks)	34.5 (28.0 – 36.6)	34.0 (28.3 – 36.2)	34.0 (28.0 – 36.6)	0.408
Mode of delivery				
Vaginal	0 (0.0)	0 (0.0)	0 (0.0)	
Cesarean	8 (100)	30 (100)	38 (100)	
Hysterotomy type				1.000
Low transverse	8 (100)	28 (93.3)	36 (94.7)	
Vertical classical	0 (0.0)	1 (3.3)	1 (2.6)	
T incision	0 (0.0)	1 (3.3)	1 (2.6)	
Urgency of delivery				0.547
Urgent/Emergent	3 (37.5)	13 (43.3)	16 (42.1)	
Scheduled	5 (62.5)	17 (56.7)	22 (57.9)	
Indication for delivery				0.746
Scheduled	4 (50.0)	16 (53.3)	20 (52.6)	
Preterm labor	2 (25.0)	7 (23.3)	9 (23.7)	
Vaginal bleeding	0 (0.0)	3 (10.0)	3 (7.9)	
Ruptured membranes	1 (12.5)	1 (3.3)	2 (5.3)	
Fetal heart rate abnormalities	0 (0.0)	1 (3.3)	1 (2.6)	
Other[b]	1 (12.5)	2 (6.7)	3 (7.9)	

NA Not applicable

[a] PPROM – preterm premature rupture of membranes

[b] Other indications included preeclampsia with severe features; acute on chronic heart failure; adnexal torsion

membranes incidentally happened to already be in L&D triage undergoing scheduled admission at 30 3/7 weeks gestation. Once preterm premature rupture of membranes was diagnosed, the patient underwent emergent cesarean delivery under general anesthesia.

All 38 patients with persistent VP were delivered by cesarean delivery at a median gestational age of 34.0 weeks (range 28.0–36.6 weeks). The uterine incision performed during cesarean varied with 36 (94.7%) low transverse, 1 (2.6%) vertical 'classical' in the setting of placenta accreta spectrum disorder, and 1 (2.6%) 'T' incision due to difficulty delivering the fetal head at 29 weeks' gestation after initially performing a low transverse incision. There were no cases of injury to the unsupported fetal vessels at the time of cesarean delivery. The neonatal NICU admission rate was 30/38

Table 4 Neonatal characteristics of patients delivered in the setting of persistent vasa previa. Data are n (%) or median (range)

Characteristics	Not admitted (*n* = 8)	Admitted (*n* = 30)	Overall (*n* = 39)	*p*-value
Sex				0.440
Female	6 (75.0)	17 (56.7)	23 (60.5)	
Male	2 (25.0)	13 (43.3)	15 (39.5)	
Birthweight (g)	2040 (968–3340)	2318.5 (1064–3040)	2294 (968–3340)	0.308
Apgar score: 1 min	7 (3 – 9)	8 (1 – 9)	8 (1 – 9)	0.673
Apgar score: 5 min	8 (6 – 9)	8.5 (6 – 9)	8 (6 – 9)	0.310
NICU[a] admission	7 (87.5)	23 (76.7)	30 (79.0)	0.660
Length of NICU stay (days)	21 (3 – 76)	18 (3 – 74)	19 (3–76)	0.750
Neurologic complications	0 (0.0)	1 (3.3)	1 (2.6)	1.000
Intraventricular hemorrhage	0 (0.0)	1 (3.3)	1 (2.6)	1.000
Respiratory complications[b]	7 (87.5)	22 (73.3)	29 (76.3)	0.650
Respiratory distress syndrome	7 (87.5)	21 (70.0)	28 (73.7)	0.653
Apnea	3 (37.5)	8 (26.7)	11 (29.0)	0.667
Intubation	1 (12.5)	6 (20.0)	7 (18.4)	1.000
Surfactant	1 (12.5)	5 (16.7)	6 (15.8)	1.000
Transient tachypnea of the newborn	1 (12.5)	4 (13.3)	5 (13.2)	1.000
Bronchopulmonary dysplasia	0 (0.0)	1 (3.3)	1 (2.6)	1.000
Pneumothorax	0 (0.0)	1 (3.3)	1 (2.6)	1.000
Cardiac complications[b]	0 (0.0)	3 (10.0)	3 (7.9)	1.000
Patent ductus arteriosus	0 (0.0)	2 (6.7)	2 (5.3)	1.000
Bradycardia	0 (0.0)	2 (6.7)	2 (5.3)	1.000
Gastrointestinal complications[b]	6 (75.0)	20 (66.7)	26 (68.4)	1.000
Feeding difficulties	6 (75.0)	20 (66.7)	26 (68.4)	1.000
Hyperbilirubinemia	3 (37.5)	10 (33.3)	13 (34.2)	1.000
Total parental nutrition needed	1 (12.5)	9 (30.0)	10 (26.3)	0.653
G tube placement	2 (25.0)	3 (10.0)	5 (13.2)	0.279
Hypoglycemia	1 (12.5)	4 (13.3)	5 (13.2)	1.000
Necrotizing enterocolitis	0 (0.0)	0 (0.0)	0 (0.0)	-
Hematologic complications[b]	3 (37.5)	5 (16.7)	8 (21.1)	0.327
Anemia of prematurity	3 (37.5)	5 (16.7)	8 (21.1)	0.327
Neonatal blood transfusion	1 (12.5)	3 (10.0)	4 (10.5)	1.000
Thrombocytopenia	0 (0.0)	1 (3.3)	1 (2.6)	1.000
Polycythemia	0 (0.0)	6 (75.0)	0 (0.0)	-
Retinopathy	0 (0.0)	4 (13.3)	4 (10.5)	0.560
Sepsis	0 (0.0)	0 (0.0)	0 (0.0)	-
30-day survival	8 (100)	30 (100)	38 (100)	-

[a] NICU- Neonatal Intensive Care Unit

[b] More than one complication may apply. Does not sum to 100%

(79.0%) with a length of stay of 19.0 days (3.0–76.0) (Table 4).

All NICU admissions were related to complications of prematurity with most common being feeding difficulties followed by respiratory distress syndrome. Neonatal anemia related to prematurity occurred in 8/38 (21.1%) neonates, and no cases of anemia were directly caused by the VP. In this study, neonatal survival was 100%. The study was approved by the Institutional Review Board of Oregon Health & Science University (eIRB#25038).

Discussion

Prior reported rates of unplanned and unscheduled deliveries in patients with a prenatal diagnosis of VP range from 7–47% [6, 17–20]. Variation in the reported rates of unscheduled deliveries is attributable to non-uniform

criteria for 'emergent' delivery. SMFM recommends that patients with known VP who experience prelabor rupture of membranes or labor undergo cesarean delivery as perinatal death secondary to VP-related hemorrhage can occur [4, 12]. Vaginal bleeding with VP is a clinical dilemma as many patients with VP have co-existing low-lying placenta or placenta previa. In our cohort, 34/50 (70%) patients with VP had either a low-lying placenta or placenta previa during the pregnancy. Historically, a bedside alkali denaturation (Apt) test was performed to differentiate fetal from maternal blood. Currently, either emergency cesarean delivery (after 34 weeks) or continuous FHR monitoring (less than 34 weeks) with urgent delivery for abnormalities is performed [1]. Of note, not all VP-associated deaths are due to fetal exsanguination, with some due to fetal head compression of the aberrant, unprotected vessel [21].

Despite the improved pregnancy and neonatal outcomes with prenatal diagnosis of VP, there are no randomized trials comparing different management approaches for VP persisting into the third trimester of pregnancy. Thus, patients with VP may be managed as outpatient or inpatient based on obstetrical risk factors and other circumstances such as living location [22, 23].

The timing of admission can be tailored based on individual risk factors. For hospitals that do not have the ability to perform emergency cesarean delivery twenty-fours a day, seven days a week, patients should be transferred to another facility that could provide these services. For admitted patients in appropriately resourced hospitals, a common strategy is daily FHR and contraction monitoring. In a recent international expert consensus, endovaginal cervical length measurements were thought to have a role in the management of VP and could be individualized according to institutional protocols [13]. Expert reviews [1, 13] and current VP guidelines [12] do not provide specific recommendations on the logistics of hospitalization.

To our knowledge, our study is the first to investigate the nuances of the location of the patient during antepartum surveillance in the setting of VP. At our institution, there is a team of obstetrics & gynecology resident and attending physicians providing twenty-fours a day, seven days a week, in-house coverage. Expediated transfer from the antepartum unit to L&D for emergent delivery requires coordinated care with the nursing team, obstetricians, anesthesia team, and neonatology team. This transfer requires transporting the patient on a bed off the antepartum unit, into patient transport service elevators, traveling down one floor to L&D, and rolling down a hall to the operating room. This process takes approximately 5 to 10 min depending on the location of the patient and the preparedness of the teams. Although there were no cases of neonatal anemia attributed to fetal vessel laceration in our cohort, the time required to transport the patient to the operating room could potentially lead to catastrophic fetal exsanguination. For instance, at 34 week's gestation with an estimated fetal weight of 2400 g, the total fetal blood volume of 240 mL (assuming fetal blood volume is 100 mL/kg) could be lost during the 5 to 10-min transfer. The risks and benefits of having a patient with VP admitted to L&D versus the antepartum unit should be considered based on an institution's available resources and limitations. Ideally, the antepartum room for patients with VP would be located within L&D such that the patient is in closest proximity to the operating room. Many hospitals have separate antepartum units and, since most patients will not have continuous fetal monitoring during the admission, occupying an L&D room in a high-volume unit for several weeks is not feasible. However, a high-risk subgroup of patients such as those with vaginal bleeding or preterm contractions should remain on L&D until clinically stable.

In the current study, 8 patients elected to undergo outpatient management through shared decision-making. There was no significant difference in the need for urgent or emergent cesarean delivery in the outpatient compared to the inpatient management group (37.5% vs 43.3%, $p = 0.547$). In addition, there was no significant difference in neonatal complications. This finding is similar to a recent meta-analysis in which there were no significant differences in perinatal mortality or morbidity rates between inpatient versus outpatient managed asymptomatic patients with antenatally diagnosed VP [24]. For patients declining admission to the hospital, serial cervical length measurements and uterine contraction monitoring may identify asymptomatic patients who are at increased risk for preterm birth [4, 13, 19].

The GA at delivery for patients with persistent VP in the current study was 34.0 weeks (28.0–36.6). Delivery between 34 and 37 weeks of gestation is recommended [1, 10, 12, 25, 26] and should be planned prior to the onset of labor while taking individual patient factors into consideration [27]. In our cohort, 79% of the neonates from patients with persistent VP were admitted into the NICU for 18.5 (3–76) days with several experiencing respiratory (76.3%) and gastrointestinal (68.4%) complications. For this reason, the risks of late prematurity (34–36 weeks) should also be considered when deciding delivery timing [28–30].

In our study, there were no cases of injury to the unprotected fetal vessels at the time of cesarean delivery. Some authors have suggested careful gradual deepening of the hysterotomy to allow the membranes to remain intact and bulge through the hysterotomy in order to avoid amniotomy in a location that may result in tearing of the

fetal vessel [31–33]. Alternatively, the technique of delivering the fetus *en caul* with intact membranes has been reported [34]. In certain scenarios, a hysterotomy other than a low transverse incision may be created to avoid rupture of the fetal membranes at the time of cesarean section [35]. The 2 (5.3%) patients in the current study who underwent a non-low transverse hysterotomy (1 vertical, 1 'T' incision) had indications for alternative incisions that were unrelated to the VP diagnosis. Intraoperative ultrasound with color Doppler technique can also be considered to delineate the course of the vasa previa vessels, to plan and create the hysterotomy appropriately. It should be acknowledged that even if inadvertent laceration of the fetal vessel was to occur at the time of cesarean delivery, the volume of fetal blood loss would likely be low given the time to cord clamping would be on the order of seconds. Nevertheless, any hospital managing patients with VP should have the appropriate neonatal resources available at the time of delivery including preparedness for immediate volume replacement and lifesaving blood product transfusion to reduce the risk of hypovolemic and hypoxic neonatal injury [1, 12].

In our cohort, the spontaneous resolution rate of VP prior to delivery was 24% which falls within the range of previously reported rates of 24–39% [6, 8]. Given the median time from VP diagnosis to resolution was 7.9 weeks at a gestational age of 30.3 weeks, such patients were managed akin to a VP until resolution occurred. For study purposes, the resolution of VP was defined as the distance of the fetal vessel(s) greater than 2 cm away from the internal cervical os. Some experts have suggested that the definition of VP includes vessels within a distance of 5 cm of the internal os since the cervix dilates to 10 cm during labor and such vessels are potentially at risk of rupture [1, 36]. Therefore, patients with unprotected fetal vessels between 2 and 5 cm of the cervix can be offered antenatal management akin to a VP after an informed discussion about the risks and benefits, and the limitations of available data informing this option.

Future studies examining pregnancy outcomes of patients with unprotected of fetal vessels within 2 to 5 cm of the cervix will help guide management. In addition, a national multi-institutional registry of vasa previa cases with varying management strategies and outcomes would further advance our understanding of this condition.

This study has limitations inherent to the retrospective design. First, while acknowledging vasa previa as a rare obstetrical condition, the relatively small sample size makes it difficult to interpret the results. Certain complications such as neonatal anemia and perinatal demise likely are under reported thereby further limiting our ability to make comparisons between outpatient and inpatient management. However, Second, patients at our institution do not undergo universal endovaginal cervical length screening. Therefore, the number of patients with VP may be underestimated. Fetal exsanguination from VP historically has occurred during labor with artificial rupture of the membranes. Importantly, of all published case reports of fetal loss due to VP, none occurred in cases when VP was prenatally diagnosed. In cases where vasa previa is identified sonographically, clinical management is altered, and the risk of fetal loss is minimized by performing cesarean delivery. Therefore, *simply having the* a priori *knowledge of vasa previa reduces fetal risk and avoids fetal loss in virtually all cases.* Third, the management of patients with VP involved several different MFM providers which introduced variations in practice (e.g., antenatal surveillance techniques) similar to other academic institutions with trainees and faculty members cross covering the antepartum service [13]. During the study period of 15 years, changes also occurred at our institution with practice patterns (e.g., admission at a later gestational age), resource allocation, obstetric nursing workflows, NICU protocols, and overall obstetrical volume. These variations during this wide time interval should be taken into consideration when interpreting the study results. In addition, it is important to acknowledge that while our institution being a quaternary level academic center has sufficient resources to provide continuous antenatal monitoring and clinical obstetric interventions, we recognize that many institutions—particularly in under-resourced areas—are unable to provide the same degree of individual management. This necessarily affects the process by which providers manage a case of vasa previa. Fourth, the patient-level costs (e.g., lost wages from hospitalization, recovery from cesarean delivery, psychological burden) imposed on hospitalized patients were not captured. We attempted to extract surrogate measures of mental health using the Edinburgh Perinatal/Postnatal Depression Scale (EPDS), but there was not enough consistency to make meaningfully interpretation of the data. In a recent systematic review evaluating reported outcomes of published studies on the diagnosis and management of VP, only 3 of 160 (1.9%) studies reported outcomes related to life impact, maternal social and emotional functioning, perceived delivery of care, or resource utilization [37]. A trauma-informed approach can assist clinical teams in addressing behavioral health-related challenges unique to VP diagnosis [38]. Prolonged hospitalization for VP can be costly [39] and ultimately still requires the patient to undergo a late-preterm or early-term cesarean delivery. Fetoscopic laser ablation of VP types II and III is an emerging, novel treatment option with the goal of surgical resolution, avoidance of prolonged hospitalization, and an opportunity for a full-term vaginal delivery [40, 41].

Conclusions

In summary, patients with VP admitted to a hospital location separate from L&D did not experience adverse pregnancy outcomes directly related to this separation. Monitoring of patients with VP remote from L&D remains a reasonable approach for institutions with a clear pathway or protocol for prompt delivery, as well as 24/7 coverage with obstetrics, nursing, and anesthesia teams. Although there were no perinatal deaths related to VP in our cohort, there remains a poorly defined burden to the patient and healthcare system of prolonged hospitalization. As guidelines for screening of VP continue to be refined, so should antenatal management strategies.

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Authors' contributions
M.R. Conceptualization, Methodology, Writing – Original Draft, Writing – Review & Editing. Created tables 1–4 H.R. Methodology, Writing – Original Draft, Writing – Review & Editing E.B. Methodology, Writing – Original Draft, Writing – Review & Editing L.P. Writing – Original Draft, Writing – Review & Editing R.D. Writing – Original Draft, Writing – Review & Editing S.H. Writing – Original Draft, Writing – Review & Editing A.H. Writing – Original Draft, Writing – Review & Editing R.C. Writing – Original Draft, Writing – Review & Editing R.S. Writing – Original Draft, Writing – Review & Editing A.C. Conceptualization, Methodology, Writing – Original Draft, Writing – Review & Editing, Created tables 1–4 All authors reviewed the manuscript.

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Not applicable.

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Competing interests
The authors declare no competing interests.

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