J. Fetal Med. (December 2019) 6:183–189
https://doi.org/10.1007/s40556-019-00217-7

REVIEW ARTICLE

Umbilical Cord Abnormalities and Pregnancy Outcome

Waleed Elsayed[1] · **Anita Sinha**[2]

Received: 18 June 2019 / Accepted: 6 September 2019 / Published online: 20 September 2019

Abstract Umbilical cord anomalies can be related to its morphology (coiling, length and thickness); placental insertion (marginal and velamentous insertion); in utero distortion (knotting, torsion and nuchal cord) vascular abnormalities (single umbilical artery) and primary tumours or masses (haemangioma and teratoma). Some of these conditions may be associated with other foetal abnormalities or aneuploidy. On the other hand, several prenatal complications including intrauterine growth restriction IUGR and stillbirth can be attributed to cord accidents or abnormalities. Early detection and close follow up of umbilical cord abnormalities can reduce the risk of morbidity and mortality and assist in decision making. To understand the normal development of the umbilical cord and discuss several pathologic processes which are involved in different cord abnormalities.

Keywords Umbilical cord · Perinatal outcome · Vasa praevia · Screening

Introduction

The umbilical cord could be affected by a wide range of anomalies that may lead to adverse pregnancy outcomes. These umbilical cord variations may be morphological, mechanical, vascular, tumours, or related to placental insertion. Some cord lesions may cause compromise of blood flow through umbilical blood vessels and threaten foetal life e.g. true knot or vasa praevia. Others may be less harmful, but could be a sign of more sinister associated conditions e.g. single umbilical artery. Due to the recent advance in prenatal ultrasound, umbilical cord abnormalities are increasingly being diagnosed. Diagnosis of such conditions may provide clues to the general foetal well-being and also predicts potential complications that might arise at time of delivery [1].

Anatomy and Development of Umbilical Cord

Despite its paramount importance, the umbilical cord is a simple structure formed of two arteries and one vein surrounded by Wharton jelly. One end of the umbilical cord inserts into the placenta and the other end into the foetal abdomen. As gestational age advances, the umbilical cord develops more coils. Coiling is a mechanism to protect the vessels in the cord from being compressed [2].

The umbilical cord is developed from a stalk of the yolk sac. During this early stage of development, the primitive cord contains allantois with allantoic vessels and vitaline duct with omphalomesenteric vessels. Allantoic vessels will then develop into two umbilical arteries and two veins. Later on, umbilical veins will form the venous plexus with omphalo-mesenteric veins in the developing liver to establish the umbilical-portal venous connection.

By the eight week of gestation, one umbilical vein, commonly the right one regresses. The remaining vein continues to enlarge to accommodate the increasing blood flow. At the same time, umbilical cord coiling starts to develop. The mechanism of coiling remains unclear however, the most likely explanation is that cord twisting

✉ Waleed Elsayed
Waleed_ahe@hotmail.com

Anita Sinha
anita.sinha1@nhs.net

[1] The Great Western Hospital NHS Trust, Swindon, UK

[2] The Great Western Hospital, Swindon, UK

occurs due to discordant vessels' growth that happens simultaneously with the regression of the umbilical vein [3].

Abnormalities in the Cord Length

The length of umbilical cord at term shows a great variation. At birth, the mature cord is approximately 50–60 cm long. A long cord is defined as being longer than 100 cm and a short cord is the one measures less than 30 cm [4].

Short umbilical cord is thought to be associated with disorders of foetal movement and intrauterine growth restriction. There is also an increased risk of placental abruption, cord rupture, and emergency caesarean section for abnormal fetal heart rate pattern [5].

Data from 530 emergency caesarean deliveries for non-reassuring foetal heart rate were reviewed for presence of short cord (i.e. less than 50 cm) and the result was compared with 530 normal deliveries. Short cords were more common in emergency caesarean section group ($P = 0.004$) [5].

It has been thought that short cords may interfere with vaginal delivery however; a study performed to determine the shortest umbilical cord length that will permit spontaneous vaginal delivery showed that vaginal delivery took place in 2 cases with extremely short cord of 13 cm [6].

On the other hand, the risk of all cord complications rises with the increase in cord length. Long cords are reported to be associated more with loops around neck, foetal entanglement, cord prolapse, true knots and also with increased fetal heart rate changes [1, 4].

Coiling

Umbilical cord is characterised by the helical pattern of its vessels. Coiling makes the umbilical cord flexible and provides it with the strength to resist compression that could affect blood flow through its vessels [7].

The mechanism of cord coiling is poorly understood and several theories have been developed to explain how coiling takes place. Rotation of the Foetus around its umbilical cord axis is one of the possible explanations [8]. Other theories include the difference in the growth rate of umbilical blood vessels [9] and the characteristic muscle fibres arrangement in the wall of umbilical arteries [10].

In order to unify the way of description of cord coiling, Strong et al. [11] in 1994 introduced the term 'umbilical coiling index' (UCI), which is defined as the number of coils in the cord divided by the total cord length in centimetres (Fig. 1) [12]. The normal value of UCI is 0.2–0.24 coils/cm i.e. one coil every 5 cm [13].

In a study of 1329 umbilical cords [14], 13% of cords were found to be hypo-coiled and 21% were hyper-coiled. The presence of hypo-coiled and hyper-coiled cords was associated with foetal death (21% and 37%, respectively), foetal intolerance of labour (15% and 14%, respectively), and intrauterine growth restriction (29% and 10%, respectively).

Umbilical Cord Thickness

Wharton's jelly protects the cord vessels from being compressed so; a reduction in its amount with subsequent reduction in cord thickness may predispose these vessels to compression or impaired circulation [15].

Several studies have shown that lean cords are associated with intrauterine growth restriction (IUGR), low birth weight, oligohydramnios, preeclampsia and meconium stained liquor [16–18]. On the other hand, Cromi et al. [19] found that the proportion of large umbilical cords is significantly higher among macrosomic foetuses than in foetuses with normal weight.

Furthermore, some studies [20, 21] have concluded that aneuploid foetuses have thicker umbilical cords than euploid ones although the underlying mechanism of such association remains unexplained.

Abnormalities in Cord Insertion

The umbilical cord normally inserts into the central part of the placenta. Variations of the site of insertion include marginal, velamentous and furcate insertion.

Marginal insertion, sometimes referred to as battledore placenta, is defined as the insertion of the cord within 2 cm from the placental edge [22]. This condition is seen most frequently in multi-foetal pregnancy particularly those conceived by IVF. It is a common insertion variant (approximately 7%) that rarely causes problems but, occasionally the cord may be snapped off during delivery of the placenta [23]. Other reported complications include IUGR, preterm labour and velamentous insertion of the cord [22].

Velamentous insertion is the variant with considerable clinical significance in which the cord is inserted into membranes rather than the placental tissue. It is characterised by divergence of the umbilical vessels just before the insertion of the cord into the placenta, being surrounded by foetal membranes only with no Wharton's jelly. Because of the absence of the Wharton's jelly protection, umbilical vessels are vulnerable to compression and rupture. This risk increases if they are present in the membranes that cover the internal cervical os [24].

The incidence of velamentous insertion is approximately 1% [25]. It is associated with increased risks of preterm delivery, low birth weight, pre-labour rupture of

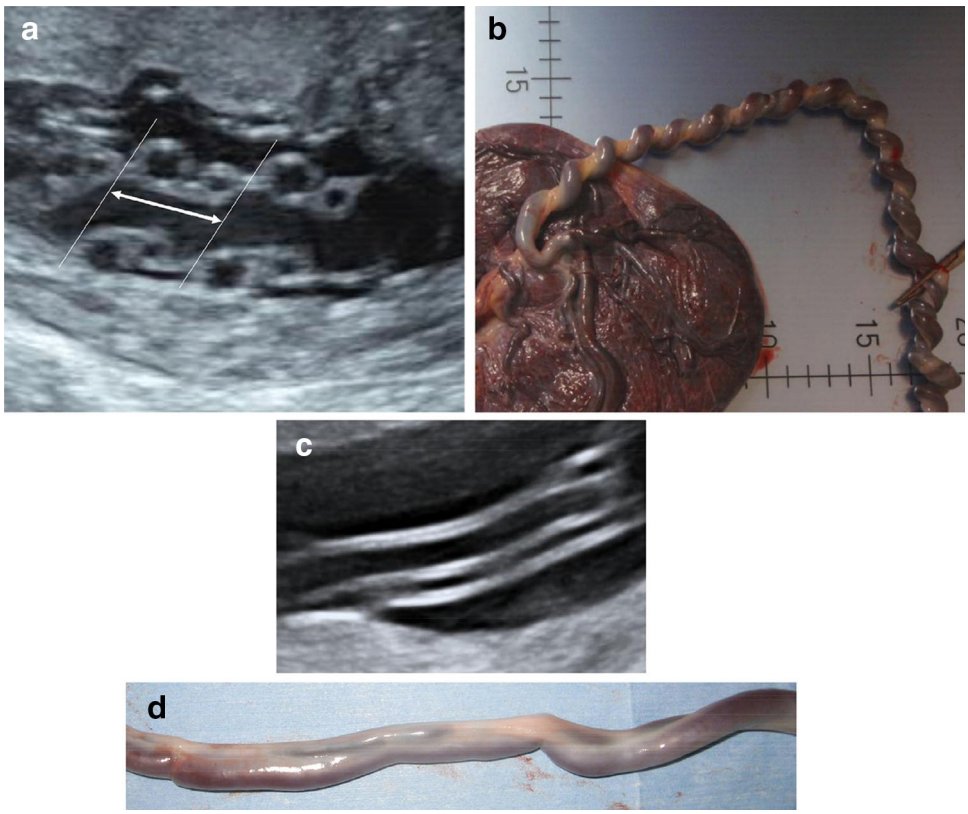

Fig. 1 Ultrasonographic image of a hyper-coiled cord (**a**). The antenatal umbilical coiling index (aUCI) is ultrasonographically calculated by measuring the distance between two adjacent coils of the umbilical artery from the outer right surface of the vascular wall to its next twist (aUCI ¼ 1/distance in centimetres). Ultrasonographic image of a hypo-coiled cord (**c**). No coiling is detected in the long axis of the umbilical cord. Image of the placenta with hyper- (**b**) and hypocoiled cords (**d**)

membranes and low Apgar scores at 1 min [26, 27]. Vasa praevia is the commonest known complication [22]. It has been estimated that velamentous insertion of the cord and vasa praevia can coexist in 2–6% of cases [25].

Women with vasa praevia usually present with vaginal bleeding associated with membrane rupture and abnormal foetal heart rate pattern which ranges from decelerations, bradycardia, and a sinusoidal trace to even foetal demise. The mortality from vasa praevia has been estimated to be substantial at a rate of 60% however, if it is diagnosed antenatally, the mortality rate could be reduced to around 3% [25].

Although vasa praevia can be accurately diagnosed using colour Doppler ultrasound at the mid-trimester anomaly scan (Fig. 2) [12, 28]. The Royal College of Obstetricians and Gynaecologists does not recommend routine screening because vasa praevia does not fulfil the required criteria for screening as there is still insufficient information about its natural history and epidemiology [25].

However, some maternity units may find it justifiable to selectively screen high risk group e.g. those with velamentous insertion of the cord, multi-foetal pregnancy and IVF. A recommended screening algorithm has been designed by Jeanty's group [28] who offered colour Doppler ultrasound examination of the cervix at time of second trimester ultrasound scan to those women with any risk factor for vasa praevia.

Lastly, furcate insertion of the cord occurs when the cord loses its Wharton's jelly and branches before insertion into the placenta, leaving the umbilical vessels exposed. Furcate cords may insert into the placental disc or in a velamentous manner. The unprotected cord vessels are at risk of compression, trauma, rupture, and thrombosis [29].

Furcated placentae are found in 0.5–1% of all births. Foetuses with furcate placenta are at risk of preterm delivery may be because this type of the placenta is usually heavier and having more voluminous villi than normal placenta [22].

Nuchal Cord

Nuchal cord (NC) is defined as an umbilical cord passing 360° around the foetal neck. Collins [30] described two types of NC, type A where the cord loop follows an unlocked pattern so it can be opened easily and type B when the cord cannot be undone and ends up as a true knot.

The incidence of NC is reported as 16–30% of all pregnancies [31]. A single loop of cord is present in most of cases but up to nine loops entanglement has been described in literature [32].

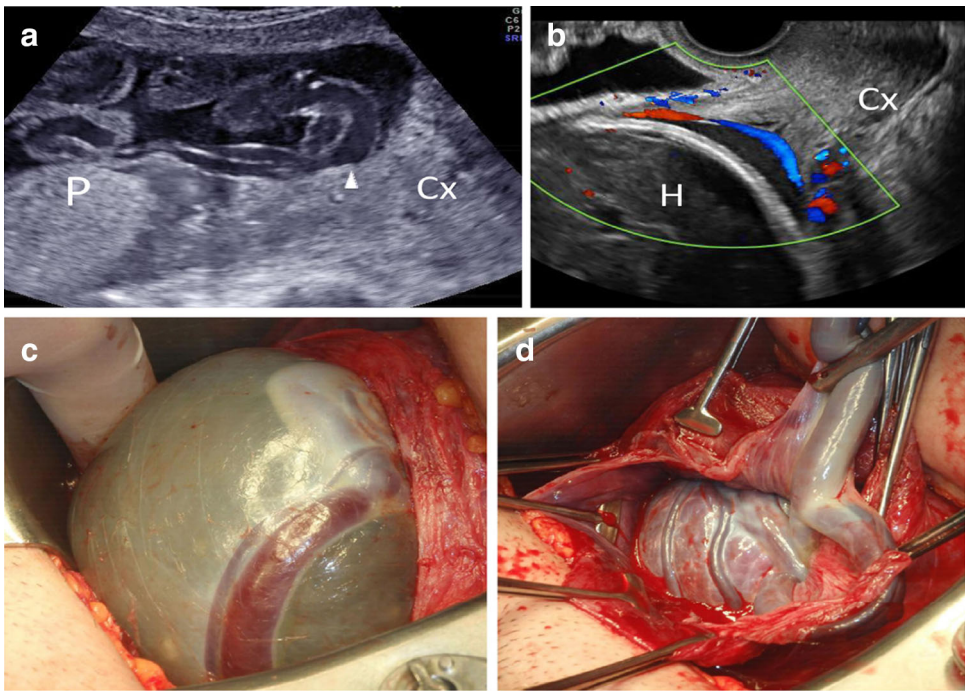

Fig. 2 Ultrasonographic images of vasa praevia. The umbilical cord insertion site (triangle) is located on the internal os (**a**: transabdominal B-mode). The aberrant vessel of vasapraevia is running on the internal os (**b**: transvaginal colour Doppler). P: placenta, H: foetal head, Cx: uterine cervix. Image of vasa praevia during caesarean section (**c**: before rupture of membrane, **d**: after delivery)

In the majority of cases with NC at birth, no complication is observed however, in some cases—particularly those with multiple loops of cord around the neck—there is association with meconium stained liquor, abnormal CTG in labour, increased risk of operative delivery and low Apgar score at 1 min [33].

Because of the low association with poor neonatal outcome, diagnosis of NC is not routine in obstetric practice. Its presence in 3rd trimester doesn't indicate Caesarean delivery [34].

Umbilical Cord Knots

Umbilical cord knots are either true or loose. True knots are observed in 1–2% of all births worldwide and are characterised by variable degrees of increased tension which can potentially compromise blood flow through the cord and increase the risk of abnormal foetal heart rate pattern and interventions in labour so, careful monitoring of pregnancy with true knot of the cord is essential [35]. It has been also estimated that true knot of the cord is associated with fourfold increase in the risk of foetal death [36].

Loose knots may become tight due to foetal movements, or during descent of the baby in labour. But, as long as they remain loose, they are considered of minor importance [35].

Recently, due to the improvement of ultrasound, the diagnosis of true knot cord can be made prenatally. Nevertheless, in the majority of cases, it may not be identified by ultrasound and remains a postnatal finding. The limitations of prenatal diagnosis are mainly due to difficult examination of the entire length of the cord and poor identification of the characteristics of the knot in two dimension scan [35].

Using colour flow Doppler can improve the diagnosis of true knot. López Ramón y Cajal and Ocampo Martíinez [37] described a new characteristic sonographic finding of the true knot which they observed in five cases and diagnoses were confirmed postnatally in all of them. They termed this finding, the 'hanging noose' sign in which a

Fig. 3 This is a true knot of the umbilical cord. Such knots are more likely to occur with abnormally long umbilical cords that may develop with increased foetal movement. Such a knot could constrict the blood vessels and lead to foetal demise. Courtesy of PathologyOutlines.com. https://www.pathologyoutlines.com/topic/placentaknots.html

transverse section of the cord is surrounded by umbilical cord loop (Fig. 3).

Single Umbilical Artery

The normal human umbilical cord contains two arteries and one vein. Single umbilical artery (SUA) is one of the commonest anomalies of the cord. The reported overall incidence varies in literature between 0.2 and 2.0% in singleton pregnancies with the left artery being absent more commonly than the right [38].

It is more common in twin pregnancies where it has been estimated to affect 5% of the cords in at least one of the twins [39].

The pathogenesis of SUA can be explained by either primary agenesis of one artery or more commonly, secondary to atresia of the previously developed artery [40].

Approximately 65–80% of SUAs are isolated i.e. not associated with other congenital anomalies. Nevertheless, Pregnancies with isolated single umbilical artery are at higher risk of pregnancy-induced hypertension (PIH), small for gestational age (SGA), oligohydramnios, neonatal intensive care unit (NICU) admission, and perinatal mortality compared to those pregnancies with normal three vessel cords [40–43].

On the other hand, 20–35% of SUA are associated with other congenital anomalies most commonly cardiovascular and genitourinary [44]. So, identification of SUA in ultrasound should prompt detailed sonographic evaluation and possibly foetal echocardiography to rule out underlying cardiac anomalies [23, 44, 45].

Moreover, it has been estimated that nearly 10% of foetuses with SUA have associated chromosomal abnormalities most commonly trisomy 18 [46].

A study conducted at King's College Hospital in London [46] found that out of 424 cases with isolated SUA, there were 406 euploid foetuses. The remaining 18 pregnancies ended up by foetal loss with no karyotyping however, none of them showed any dysmorphic changes suggestive of chromosomal anomaly.

This study also showed that the risk of chromosomal abnormalities is about 3.7% in cases with SUA and one additional major congenital defect. The risk increases to 50.7% if SUA is combined with multiple defects.

Therefore, it is recommended with SUA that detailed ultrasound is undertaken including foetal echocardiography and if isolated no further action is required, but if associated with one or more structural abnormalities, foetal karyotyping should be offered [46].

Umbilical Cord Tumours

Haemangiomas and teratomas are the only tumours that can arise from the umbilical cord [1]. Although both are rare, haemangioma is the most common tumour of the cord, with about 31 cases reported in the literature [47].

Haemangioma arises from the remnants of embryonic haemangioblast which proliferates in the form of thin-walled capillaries. It can originate from umbilical arteries, umbilical vein or vitelline capillaries [48].

Haemangioma of the cord is often an isolated anomaly, but large lesions may be associated with polyhydramnios, elevated maternal serum alpha-fetoprotein and other foetal abnormalities such as anencephaly and GIT anomalies. Furthermore, foetal death has been reported which may be caused by poor circulation through umbilical vessels, foetal haemorrhage and thrombosis of an umbilical vessel [49].

Teratoma of the cord is extremely rare condition that arises from germ cells and is always benign. Germ cells normally migrate from the yolk sac to the gonadal ridge abnormal or arrested migration may lead to development of teratomas within the cord [1].

Umbilical Cord Cyst

Umbilical cord cysts are either true or pseudo-cysts. True cysts are derived from the embryological remnants of either the allantois or the omphalo-mesenteric duct; they are typically located towards the foetal insertion end of the cord and can vary in size from 4 to 60 mm [50].

Pseudo-cysts are seen more frequently than true cysts and can present anywhere along the cord; they have no epithelial lining and represent localized oedema and liquefaction of Wharton's jelly [50].

The majority of umbilical cord cysts diagnosed in the first trimester are transient and have no adverse effect on pregnancy outcome [51]. However, there is an association between second and third trimester umbilical cord cysts and foetal anomalies.

Therefore, the finding of an isolated umbilical cord cyst should lead to further detailed ultrasound evaluation and if either IUGR or other anomalies are found, karyotyping should be recommended [50].

Ethical Issues

Although every obstetrician is aware of the tremendous importance of the umbilical cord, this simple structure has not received enough scientific attention. Current ultrasound guidelines [52, 53] recommend assessment of the umbilical

cord for its number of vessels only and for placental site of insertion if technically possible.

In fact, most of umbilical cord abnormalities are discovered incidentally during assessment of amniotic fluid or the placenta rather than as a result of targeted examination of the cord itself. The lack of interest in detailed examination of the cord may be attributed to low prevalence of umbilical cord anomalies and uncertainty with regards to their clinical significance, difficult examination of the entire cord length and the time limit.

In this review it has been emphasised that umbilical cord anomalies can sometimes be associated with poor perinatal outcome. Thus, it is important to raise the awareness of screening for some serious conditions such as vasa praevia at least among high risk populations.

Conclusion

Umbilical cord is very important foetal structure that could be affected by various types of abnormalities during intrauterine life. The evidence base of various umbilical cord anomalies needs further development. In addition, local protocols should be continually enforced by emerging research. Vasa praevia is an example of the conditions that can be detected antenatally and successfully managed so foetal morbidity and mortality related to it could be reduced significantly.

References

1. Heifetz SA. The umbilical cord: obstetrically important lesions. Clin Obstet Gynecol. 1996;39(3):571–87.
2. Oyelese Y. Placenta, umbilical cord and amniotic fluid: the not-less important accessories. Clin Obstet Gynecol. 2012;55(1):307–23.
3. Mladen P. Sonographic assessment of the umbilical cord. Donald Sch J Ultrasound Obstet Gynaecol. 2009;3(2):48–57.
4. Balkawade NU, Shinde MA. Study of length of umbilical cord and fetal outcome: a study of 1000 deliveries. J Obstet Gynecol India. 2012;62(5):520–5.
5. Weiner E, Fainstein N, Schreiber L, Sagiv R, Bar J, Kovo M. The association between umbilical cord abnormalities and the development of non-reassuring fetal heart rate leading to emergent cesarean deliveries. J Perinatol. 2015;35(11):919–23.
6. LaMonica GE, Wilson ML, Fullilove AM, Rayburn WE. Minimum cord length that allows spontaneous vaginal delivery. J Reprod Med. 2008;53(3):217–9.
7. de Laat MWM, van Alderen ED, Franx A, Visser GHA, Bots ML, Nikkels PGJ. The umbilical coiling index in complicated pregnancy. Eur J Obstet Gynecol Reprod Biol. 2007;130(1):66–72.
8. Edmonds HW. The spiral twists of the normal umbilical cord in twins and in singletons. Am J Obstet Gynecol. 1954;67:102–20.
9. Lacro RV, Jones KL, Benirschke K. The umbilical cord twist: direction, and relevance. Am J Obstet Gynecol. 1987;157:833–8.
10. Malpas P, Symonds EM. Observations on the structure of the human umbilical cord. Surg Gynecol Obstet. 1966;123:746–50.
11. Strong TH, Jarles DL, Vega JS, Feldman DB. The umbilical coiling index. Am. J Obstet Gynecol. 1994;170:29–32.
12. Hasegawa J. Ultrasound screening for cod abnormalities and delivery management. Placenta. 2018;62:66–78.
13. Mladen P, et al. Assessment of umbilical cord coiling during the routine fetal sonographic anatomic survey in the second trimester. J Ultrasound Med. 2005;24:185–91.
14. Machin GA, Ackerman J, Gilbert-Barness E. Abnormal umbilical cord coiling is associated with adverse perinatal outcomes. Pediatr Dev Pathol. 2000;3:462–71.
15. Morteza T, Reza A. Evaluation of umbilical cord thickness, cross-sectional area, and coiling index as predictors of pregnancy outcome. Indian J Radiol Imaging. 2011;21(3):195–8.
16. Raio L, Ghezzi F, Di Naro E, Franchi M, Magmon E, Muller MD, et al. Prenatal diagnosis of a "lean" umbilical cord: a simple marker for fetus at risk of being small for gestational age at birth. Ultrasound Obstet Gynecol. 1999;3:176–80.
17. Goynumer G, Ozdemir A, Wetherilt L, Durukan B, Yayla M. Umbilical cord thickness in the first and early second trimesters and perinatal outcome. J Perinat Med. 2008;36:523–6.
18. Ghezzi F, Raio L, Günter Duwe D, Cromi A, Karousou E, Dürig P. Sonographic umbilical vessel morphometry and perinatal outcome of foetuses with a lean umbilical cord. J Clin Ultrasound. 2005;33:18–23.
19. Cromi A, et al. Large cross-sectional area of the umbilical cord as a predictor of fetal macrosomia. Ultrasound Obstet Gynecol. 2007;30:861–6.
20. Ghezzi F, Raio L, Di Naro E, Franchi M, Buttarelli M, Schneider H. First-trimester umbilical cord diameter: a novel marker of fetal aneuploidy. Ultrasound Obstet Gynecol. 2002;19:235–9.
21. Mladen P, Perni SC, Stephen C, Chervenak FA. Fetal aneuploidy and umbilical cord thickness measured between 14 and 23 weeks'gestational age. J Ultrasound Med. 2004;23:1177–83.
22. Reddy M, Geetha SP, Nim VK. Variations in placental attachment of umbilical cord. J Anat Soc India. 2012;61(1):1–4.
23. Gary Cunningham F, et al. Placental abnormalities. In: Williams obstetrics. 24th ed. New York: McGraw-Hill Medical; 2014. vol. 6, pp. 116–26.
24. Cîrstoiu Monica M, et al. Velamentous cord insertion—an important obstetrical risk factor. Rom Soc Ultrason Obstet Gynecol. 2016;12:129–34.
25. Royal College of Obstetricians and Gynaecologists. Green-top guideline no. 27: placenta praevia, placenta praevia accreta and vasa praevia: diagnosis and management. London: RCOG; 2011. https://www.rcog.org.uk/en/guidelines-research-services/guidelines/gtg27/.
26. Raisanen S, Georgiadis L, Harju M, Keski-Nisula L, Heinonen S. Risk factors and adverse pregnancy outcomes among births affected by velamentous umbilical cord insertion: a retrospective population-based register study. Eur J Obstet Gynecol Reprod Biol. 2012;165:231–4.
27. Ebbing C, et al. Velamentous or marginal cord insertion and the risk of spontaneous preterm birth, prelabor rupture of the membranes, and anomalous cord length, a population-based study. Acta Obstet Gynecol Scand. 2017;96:78–85.
28. Derbala Y, Grochal F, Jeanty P. Vasa previa. J Prenat Med. 2007;1:2–13.
29. Pinar H, Carpenter M. Placenta and umbilical cord abnormalities seen with stillbirth. Clin Obstet Gynecol. 2010;53(3):656–72.
30. Collins JH. Nuchal cord type A and type B. Am J Obstet Gynecol. 1997;177:94.
31. Akkaya H, Buke B, Pekcan MK, Şahin K, Uysal G, Yegin GF, Avsar AF, Cagli F. Nuchal cord: is it really the silent risk of pregnancy? J Matern Fetal Neonatal Med. 2017;30(14):1730–3.

32. McCaffrey LE, Arbor A. The umblical encircling the neck and its relation to intrapartum complications. Am J Obstet Gynecol. 1927;13:104–8.
33. Larson JD, Rayburn WF, Crosby S, Thurnau GR. Multiple nuchal cord entanglements and intrapartum complications. Am J Obstet Gynecol. 1995;173:1228–33.
34. Pleş L, Beliş V, Rîcu A, Sima R-M. Medico-legal issues of the nuchal cord at birth. Rom J Leg Med. 2016;24:289–93.
35. Pa TKVD, et al. True knot of umbilical cord: a diagnosis and prognostic challenge. Br J Med Med Res. 2014;4(31):5043–52.
36. Abuhamad A. Three-dimensional ultrasound with color Doppler imaging of an umbilical cord true knot. Ultrasound Obstet Gynecol. 2014;43:360.
37. López Ramón y Cajal C, Ocampo Martínez R. Prenatal diagnosis of true knot of the umbilical cord. Ultrasound Obstet Gynecol. 2004;23:99–100.
38. Santillan M, Santillan D, Fleener D, Stegmann B, Zamba G, Hunter S, Yankowitz J. Single umbilical artery: does side matter? Fetal Diagn Ther. 2012;32:201–8.
39. Beal MH. Umbilical cord complications. Medscape. 2015. http://emedicine.medscape.com/article/262470-overview#a3.
40. Kim HJ, Kim J-H, Chay DB, Park JH, Kim M-A. Association of isolated single umbilical artery with perinatal outcomes: systemic review and meta-analysis. Obstet Gynecol Sci. 2017;60(3):266–73.
41. Yajuan X, et al. Association between isolated single umbilical artery and perinatal outcomes: a meta-analysis. Med Sci Monit. 2016;22:1451–9.
42. Horton AL, Barroilhet L, Wolfe HM. Perinatal outcomes in isolated single umbilical artery. Am J Perinatol. 2010;27:321–4.
43. Mailath-Pokorny M, Worda K, Schmid M, Polterauer S, Bettelheim D. Isolated single umbilical artery: evaluating the risk of adverse pregnancy outcome. Eur J Obstet Gynecol Reprod Biol. 2015;184:80–3.
44. Geipel A, Germer U, Welp T, Schwinger E, Gembruch U. Prenatal diagnosis of single umbilical artery: determination of the absent side, associated anomalies, Doppler findings and perinatal outcome. Ultrasound Obstet Gynecol. 2000;15:114–7.
45. Prefumo F, Güven MA, Carvalho JS. Single umbilical artery and congenital heart disease in selected and unselected populations. Ultrasound Obstet Gynecol. 2010;35:552–5.
46. Dagklis T, Defigueiredo D, Staboulidou I, Casagrandi D, Nicolaides KH. Isolated single umbilical artery and fetal karyotype. Ultrasound Obstet Gynecol. 2010;36:291–5.
47. Iyoob SD, Tsai A, Ruchelli ED, Coleman BG, Douglas Wilson R. Large umbilical cord haemangioma, sonographic features with surgical pathologic correlation. J Ultrasound Med. 2006;25:1495–8.
48. Yan J, Zhu Y, Liao H, Su L, Guo Y, Cai J. A case of umbilical cord hemangioma. Rom J Leg Med. 2014;22:177–80.
49. Natalucci G, Wisser J, Weil R, Stallmach T, Bucher HU. Umbilical cord haemangioma. Swiss Society of Neonatology. 2007.
50. Zangen R, Boldes R, Yaffe H, Schwed P, Weiner Z. Umbilical cord cysts in the second and third trimesters: significance and prenatal approach. Ultrasound Obstet Gynecol. 2010;36:296–301.
51. Sepulveda W, Leible S, Ulloa A, Ivankovic M, Schnapp C. Clinical significance of first trimester umbilical cord cysts. J Ultrasound Med. 1999;18:95–9.
52. American Institute of Ultrasound in Medicine. Obstetrical ultrasound examination. AIUM. 2013.
53. International Society of Ultrasound in Obstetrics and Gynaecology. Practice guidelines for performance of the routine mid-trimester fetal ultrasound scan. ISUOG. 2010.