Correlation between the Umbilical Cord Morphology and Birth Weight in Full Term Sudanese Neonates

By

Elghazaly Abdualrahim Elghazaly Abdul Khier

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<td>Prof. Haydar Elhadi babikir</td>
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Date: September 2015
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Date of Examination 3/9/2015
DEDICATION

To Professor: Qurashi Mohammed Ali

The man who believes that we can do something

To my wife for care and love

To my brothers and uncles for their support throughout the study and giving me

More care and support.

To my colleagues
ACKNOWLEDGEMENT

Any large work of this type cannot be completed without the help of many individuals. First foremost my supervisor, Professor: Qurashi Mohammed Ali for his keen interest, guidance, encouragement and constructive criticism throughout the study as father more than a supervisor.

My thanks are due to my Co. supervisor Professor: Haydar Elhadi babikir for the generous guide me, encouragement and help rendered.

I would like to thank all the staff of Omdurman Maternity Hospital of Obstetrics and Gynecology, Physicians, Midwives and Nurses for their help. Also I would like to thank the mothers whom provided me with the information which is needed in the study.

I am grateful to thank the staff of the Faculty of Laboratory Sciences University of Medical Sciences and Technology, especially the Microscope Unit, for kind help and permission to use their facilities.

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Correlation between the Umbilical Cord Morphology and Birth Weight in Full Term Sudanese Neonates

By:

Elghazaly Abdualrahim Elghazaly Abdul Khier

A thesis submitted in fulfillment of the requirement for the degree of Ph.D in Human Anatomy

ABSTRACT

Umbilical cord length, diameter, coiling pattern, placental insertion site and structural components were studied in 1020 full term birth neonates of both sexes, single and twin, of normal vaginal delivery, between February to September 2013, In Omdurman Maternity Hospital in Sudan, with their mother height, weight and body mass index (BMI). Significant correlations were detected between neonatal weight, and the cord length, diameter, coils pattern, insertion site and true knot, but there is no correlation between the neonatal weight with cord cyst, false knot or blood vessels. Also there is strong correlation between cord length with coils, diameter, knot, sex, neonatal height and socioeconomic status of the mother, but not with BMI of the mother. A minimal difference was found in cord length and diameter between male and female and single and twin birth. Male appeared with longer cord and big weight than female. However there is no big difference in the cord length measurement before and after birth. Any cord shows coils, but the degree of coils was varying according to fetal gender, cord length, diameter and mother parity. Most coils were directed to the felt or anticlockwise direction. This could explain that fetus rotate commonly to left side within uterus. In live born the coils number should not exceed 4 to 5 coils per/10cm of the cord length, if it exceed that number it may affect fetal growth or decrease fetal weight. Commonly the cord has eccentric insertion. Frequency of marginal cord insertion was significantly increased in premature birth or when studied postnatal. Single umbilical artery is unrelated to low birth weight, one artery is enough to maintain the blood circulation and fetal weight gain, and were two cases showed nervous system abnormalities, spina bifida associated with hydrocephalus. Birth weight can be detected by measuring cord diameter. The correlation between umbilical cord morphology and birth weight need further studies and much longer periods to clarify more specific correlation especially internal structures.
العلاقة بين الدراسة الشكلية للحبل السرّي في الإنسان ووزن الجنين في السودانين

الغزالي عبدالرحيم الغزالي

رسالته مقدمة لاستيفاء شروط الحصول على درجة الدكتوراه في علم التشريح البشري

ملخص الدراسة

طول ، قطر ، نمط التفاف ، المكونات و موقع ارتباط الحبل السرّي بالمشيمة درست في 1020 مولود كامل النمو في الجنسين، بالولادة الطبيعية المهنية لمواليد احادية و توائم، في الفترة من فبراير إلى سبتمبر 2013، في مستشفى ألولادة أم درمان - السودان، مع دارسة طول، ووزن وكثافة جسم امهاتهم . وجدت الدراسة علاقة هامة بين وزن المولود مع طول ، قطر، نمط التفاف، موقع ارتباط الحبل السرّي بالمشيمة والعقدة الحقيقية، للحبل السرّي، لكن ليس هناك علاقة بين وزن المولود مع وجود الاكياس، العقدة الكاذبة أو ألوية الدموية في الحبل السرّي. أيضا، هناك ارتباط قوي بين طول الحبل مع نمط التفافه، قطره، عقدة، جنس وطول المولود والحالة الاقتصادية للأم ، لكن ليس مع وزن وكثافة جسم الأم. أظهرت الدراسة اختلافاً قليلاً في الطول وقطر الحبل السرّي بين الذكور و الأناث والمولود احادية والتوائم. في الذكور الحبل السرّي أطول واكبر حجماً مقارنة مع الإناث. ليس هناك اختلاف كبير فيقياس طول الحبل قبل أو بعد الولادة. درجة الالتفاف في الحبل تتباين طبقاً لجنس المولود، طول وقطر الحبل وعدد الولادات لدى الأم. وجدت الدراسة ان الالتفافات في الحبل السرّي الملتفة الى اليسار أكثر من الملتفة الى اليمين . هذا يوضح أن الجنين يدوري محوريا داخل الرحم إلى الجانب الايسر. في المواليد البيضاء عدد الالتفافات الحبل السرّي يجب أن لا يتجاوز 4 إلى 5 لفة لكل 10 سنتيمتر من طول الحبل ، إذا زاد عدد الالتفافات الحبل يمكن أن يؤثر في نمو الجنين أو يقل وزنه. يزيد الارتباط الهاشمي للحبل بالمشيمة بشكل ملحوظ في الولادة الغير ناضجة أو عندما يدرس بعد الولادة. وأيضا من الملاحظ أن وجود شريان واحد في الحبل السرّي لا يؤثر في نمو ووزن الجنين أو الوزن عند الولادة ، شريان واحد يكفي لإبقاء توزيع الدم وزيادة الوزن الجنين وأظهرت الدراسة حالتان من الشذوذات الخلقية في الجهاز العصبي مصحوبة بمواد الرأس. وجدت الدراسة أن وزن الجنين عند الولادة يُمكّن أن يُحدد بقياس قطر الحبل. العلاقة بين الدراسة الشكلية للحبل السرّي و الوزن الجنين عند الولادة تحتاج إلى دراسات أخرى ولفترات أطول لتوضيح ارتباطات محددة خصوصاً التراكيب الداخلية للحبل السرّي.
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<td>Single umbilical artery</td>
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INTRODUCTION

The umbilical cord is white color moist tube-like structure that connects fetus and placenta, the cord is sometimes called the baby's supply line because it carries the baby's blood back and forth between the baby and the placenta (Baergen 2007, Chitra et al. 2012). The function of the umbilical cord is to deliver nutrients and oxygen to the baby and remove the baby's waste products, and protect the vessels that travel between the fetus and placenta throughout pregnancy (Wang et al. 2004, Morgan et al. 2006, Barbieri et al. 2011). The cord contains three blood vessels two arteries and one vein, the vein carries oxygen and nutrients from the placenta to the baby, the two arteries transport waste from the baby to the placenta (Barbieri et al. 2011, Keith et al 2011). Cord vessels embedded in gelatinous substance called Wharton's jelly which largely made up of the mucopolysaccharides, insoluble fibers network of different collagen types and some fibroblasts and macrophages (Ghezzi et al. 2001, Mitchell et al. 2003, Kulkarni et al. 2007, Kurita et al. 2009).

The umbilical cord begins to form between four and six weeks of the pregnancy, as the embryonic disc takes a cylindrical shape and becomes progressively longer until reaching the length of 60 to 70 cm (average 50 cm), with a diameter of 1-2 cm and average circumference of 3.6 cm. at the birth (Sepulveda (b) et al. 2003, Marie et al. 2009, Balkawade & Shinde 2012). As the cord gets longer, it generally coils around itself to form a number of helices, either counterclockwise (left), clockwise (right) or random.

A number of the umbilical cord abnormalities occur during the development and cause problems to the fetus and pregnant mother during delivery. Most umbilical cord abnormalities are cord length, about 5% of cords are shorter than 35 cm, and another 5% are longer than 80 cm (Stefos et al. 2003, Sebire 2007). Cord length varies from no cord (achordia) to 300 cm (Marie et al. 2009). Causes of differences in cord length are unknown however long cords are associated with fetal entanglement, true knots, nuchal cord, prolapse and hypertwisting. Cord length had a positive correlation with maternal height, weight, pregnancy weight gain, socioeconomic status, and the fetus being male. Long cord can lead to intrauterine fetal death by compressing the fetal vessels beyond the capacity of the Wharton’s jelly. Short cord is associated with fetal movement
disorders and intrauterine constraint, as well as placental abruption and cord rupture. Also short cords are associated with low Apgar scores. The fetus being smaller than the average for their gestational age, increase risk of stillbirth and associated with fatal problems during their first year of life. A short cord may also cause difficult vaginal delivery of fetus (Sebire 2007, LaMonica et al. 2008). In most cases, a short cord is more worrisome than a long one, but both conditions should be carefully watched to ensure that if any necessary medical step is warranted.

One of the most common umbilical cord abnormalities which should be noted at the delivery is a single umbilical artery (SUA), which occurs in 2.5% of singleton and 5% in multiple pregnancies; it is more common in twin births, fetal demise than in live births (Thummala 1998, Gossett 2002, Gounden 2003 Marie et al. 2009, Santillan et al. 2012). Single umbilical artery was found twice in white than in African newborns, more common in female than male (male-to-female ratio is 0.85:1), and more likely to occur if the mother is over the age of 40 years and has three or more children. Single umbilical artery increases incidence of fetal anomalies by 30% to 60%, SUA has been associated with anomalies in all major organ systems and chromosome abnormalities (Heifetz 1984, Geipel et al. 2000, Mu et al. 2008). Furthermore, there is an association between SUA and low birth weight (<2500g) and early delivery (<37 weeks) (Nyberg et al. 1991, Ghatersamni et al. 2007).

In velamentous cord insertion, the umbilical cord inserts into the membranes, and then travels within the membranes to the placenta; the exposed vessels are not protected by Wharton's jelly and hence are vulnerable to rupture (Wiedaseck 2014). Rupture is especially likely if the vessels are near the cervix, in which case they may rupture in early labor causing a stillbirth (Hasegawa et al. 2006). Abnormal cord insertion (Velamentous insertion) is found to associate with low birth weight, prematurity, and abnormal fetal heart patterns in labor (Feldman et al. 2002, Oyelese et al. 2007).

Umbilical cord cysts are also found in about 3 percent of pregnancies. There are true and false cysts. Studies suggest that both types of cysts are sometimes associated with birth defects, including: chromosomal abnormalities and kidney and abdominal defects (Sepulveda 2006, Marie et al. 2009).
1.2. Problem identification and justification

Umbilical cord is one of the fetal membranes which have common abnormalities during the fetal development. An estimated 30% of pregnancies carried to term have some type of umbilical-placental abnormality (Torpin 2002). This means that every third to fourth delivery has an identifiable umbilical cord abnormality or anomaly. These abnormalities vary, and some are more common than others and may be a source of harm to the developing fetus.

Studying morphological features of the fetal membranes of the human body before and after delivery is important, because they are essential in the fetal development. The abnormality which occurs during their development may affect fetal growth before and after the delivery. The anatomical study of the human umbilical cord morphological features is important, because the umbilical cord plays an essential role in fetal intrauterine survival. It acts as a supply line between the developing fetus and his mother, but it is one of the least studied components of the fetal membranes anatomy during delivery. Many studies were done (Cromi 2005, Axt-Fliedner 2006, Sebire 2007, Sepulveda et al. 2009, Hasegawa 2009, Peres, 2012, Wiedaseck et al. 2014), but most of them were based on sonography examination to assess umbilical morphological features prenatally, and they were usually limited to the evaluation of the number of cord vessels and parameters, such as cord thickness, amount of Wharton’s jelly substance and coiling pattern.

The sonographic assessment of the umbilical cord morphological features within the uterus is technically difficult and takes time for scanning, because: (1) the cord within uterus is not straight, and accurate measurement of cord length requires a straight segment of cord, particularly in more coiled (hypertwisting) cord, (2) during scanning, the whole length of umbilical cord in not routinely seen, (3) the degree of cord coiling pattern through the cord length varies in the cord being evaluated, (4) the sonographic scanning assessment of cord within the uterus takes time and is technically difficult to assess all cord features, (5) most studies have based on antepartum populations. For all of these reasons, this study has been based on postpartum evaluation of umbilical cord morphological features, because the cord, after delivery, is visible and easy to evaluate macroscopically and microscopically, and also can be dissected from end to end. The anatomical postpartum assessment of umbilical cord morphological features may give good results more than sonographic assessment, and may help in detection of some fetal diseases and give clue about neonatal condition after the delivery.
This study includes; umbilical cord length, diameter, number of coiling pattern, placental insertion site and structural components (Wharton’s jelly, arteries and vein), and the correlation between their incidence and birth weight, in full term delivery of Sudanese neonates.
CHAPTER TWO

OBJECTIVES

2.1. General objective

The main aim of this study is to confirm or refute a potential relationship between the umbilical cord morphological features including, (length, diameter, coiling pattern, placental insertion site and structural components) and correlate their incidence and birth weight in full term Sudanese neonates.

2.2. The specific objectives aim to study

1. The gross features of the umbilical cord including, (length, diameter, coiling pattern and placental insertion site).
2. The histological structural components of the umbilical cord, including Wharton’s jelly, arteries and vein.
3. The common umbilical cord abnormalities
4. The common correlation between the umbilical cord morphological features and birth weight.
5. If umbilical cord morphological features give clues about neonatal weight, conditions and birth disorders.
6. The standard weight and correlate with umbilical cord morphology.
3.1. Morphology of the umbilical cord

3.1.1. Length of the umbilical cord

The length of the human umbilical cord varies from no cord (achordia) to 300 cm (Lacro et al. 1987, Berg & Rayburn 1995, Stefos 2003, Marie et al. 2009). About 5% of cords are shorter than 35 cm, and another 5% are longer than 80 cm (Stefos 2003). Causes of differences in cord length are unknown; however, the length of the cord is thought to reflect movement of the fetus inside the uterus. Cord length is dependent on fetal movement, more movement lead to longer cord, the reverse is also true because less intrauterine movement leads to shorter umbilical cords (as attested to by animal experiments where induced fetal muscle paralysis led to shortened umbilical cord length) (Sepulveda et al. 2003). Normally, the human umbilical cord reaches a length of 60-70 cm at term (average 50 cm) (LaMonica et al. 2008, Keith et al. 2011, Balkawade & Shinde 2012). Although the length of the umbilical cord has no intrinsic effect on fetal blood flow, a longer cord is more susceptible to knotting, entanglement around the fetus (especially the neck), and even prolapse out of the uterus during delivery any of which can lead to intrauterine fetal demise (Balkawade & Shinde 2012). Short cords are associated with fetal movement disorders and intrauterine constraint, as well as placental abruption and cord rupture. Although short cord have been blamed for the difficult of vaginal delivery, available data suggest that vaginal delivery can take place with cords as short as 13 cm, which is much shorter than the normal range (LaMonica et al. 2008). Twins and triplets, because of restricted movement, have been shown to have cords on the average shorter than their single counterparts and boys have longer cords than girls (Collins 2002).

3.1.2. Diameter of the umbilical cord

The human umbilical cord average diameter is 1.5 up to 3 cm and average circumference of 3.6 cm at birth. The cords can be large (thick) and exceed an average of 4cm in circumference, especially at the umbilicus (Patel et al. 1989, Sepulveda et al. 2003, Barbieri et al. 2011). The ultrasound average vein diameter is 8mm with an average artery diameter of 4 mm at full term. The average weight is 15 gms/ 10 cm at full term and dependent on male gender, pregnancy
maternal weight and birth weight (Predanic et al. 2005, Togni et al. 2007). The cords can be thin, less than 1cm in circumference and lacks Wharton's jelly. This finding may suggest poor nutrition and lack of glycogen in fetal tissues. Alteration of umbilical cord water and molecular content may also play a role as an independent risk factor for poor outcomes (Predanic et al. 2005, Togni et al. 2006, Kulkarni et al. 2007)

3.1.3. Coils of the umbilical cord

Intrauterine movement, in addition to controlling umbilical cord length, also appears to control cord twisting; cord twisting can be seen as early as the 6th week and is well established by the 9th week of development (Collins 2002, Pathak 2010, Peres 2012). Umbilical cord is helical in nature, with as many as 380 helices, either counterclockwise (left), clockwise (right) or random, but left twisting outnumbers the right by a ratio of approximately 7:1 (or in other words 85% are left, while 15% are right twisted); Since this ratio is similar to the ratio for right to left handedness (approximately 15% of the population is left handed), some authors have suggested that handedness may be the determining factor for umbilical cord twisting (de Laat et al. 2005, 2007, Sebire 2007). What is clear, nevertheless, is that the degree of twisting does relate to intrauterine movement and as with short umbilical cords, hypertwisting can lead to intrauterine fetal demise by compressing the fetal vessels beyond the capacity of the Wharton’s jelly to protect them. Straight cords with few or absent helices have been associated with adverse fetal outcomes (Lacro et al. 1987, Weissman et al. 1994, Heifetz 1996, de Laat et al. 2005, Chitra et al. 2012).

Umbilical cords may have different types of design. Ninety five present are very helical while five present are completely straight cords (Lacro et al. 1987). Not all cords are alike; there are different kinds of cords, curly, straight, thick and thin. Very helical designs (spiraled, coiled, and curled) may predispose the fetus to certain blood flow changes, and very straight designs may be susceptible to compression (Vizza et al. 1996, Ernst et al. 2013). In most babies, the umbilical cord twists to the left, coiling like a phone cord. This twisting allows the cord to lengthen and shorten with the baby's movements (Ezimokhai et al. 2000).
3.1.4. Umbilical cord attachment

The umbilical cord normally connects fetus and placenta. In the fetus the umbilical cord enters the anterior surface of abdomen, at the point which after separation will become the umbilicus or navel. In the placenta umbilical cord normally inserts near the center of the placenta (Vance 2009, Pathak S et al. 2010, Keith et al. 2011) However, in approximately 7% of births the insertion point occurs at the very edge of the placenta (marginal insertion) and in about 1% of birth, the umbilical cord does not insert into the placenta at all, but the fetal vessels ramify through the external membranes before entering the placenta (velamentous insertion) (Harris et al. 2000, Lopriore et al. 2007, Wiedaseck & Monchek 2014)). Another variation is called a furcate cord insertion in which the cord does not connect to the placenta but its branching elements do (Laberke & Deubler 2009). These malformations account for another 0.5% to 1% of all births and are observed more in premature labor, premature birth, fetal stillbirth, and neurologic harm (Ernst et al. 2013).

The umbilical ring is designed to allow for fetal growth without umbilical cord detachment until delivery. The umbilical ring is innervated and these nerves have branches which connect to the vagus trunks and phrenic nerves (Fox & Jacobson 1969, Pearson & Sauter 1969, 1970). There are the connecting branches to the right adrenal gland and may be to the proximal umbilical cord. This neuronal pattern may suggest an umbilical ring to ductous venosous feedback system, which partly regulates blood flow to the fetal cardiovascular system (Fox & Jacobson 1969, Lurie et al. 1990, Kamitomo et al. 1999, Skulstad et al. 2001). Failure of proper umbilical cord development at the fetal attachment can cause stillbirth.

3.1.5. Structures of the umbilical cord

The umbilical cord and its constituent tissues are formed of an outer layer of amnion, Wharton's jelly, two umbilical arteries, and one umbilical vein; all are designed to protect blood flow to the fetus during pregnancy. The outer amnion layer may regulate fluid pressure within the umbilical cord, and the Wharton's jelly likely acts to prevent compression of the vessels. Blood flow is regulated by smooth muscles surrounding the arteries that are intermingled with a collagen based extracellular matrix (ECM) (Kulkarni et al. 2007, Keith et al. 2011; Chitra et al. 2012).
3.1.5.1. Wharton’s jelly of the umbilical cord

Wharton’s jelly is a specialized tissue serving many purposes for the developing fetus. It is a gelatinous substance largely made up of mucopolysaccharides, some fibroblasts and macrophages (Kulkarni et al. 2007, Barbieri et al. 2011). These properties give it elastic and cushion effects, which can tolerate the vibrations, bending, stretching and twisting of the active fetus. In addition, it holds the vessels together, may regulate blood flow, plays a role in providing nutrition to the fetus, stores chemicals for the onset of labor, and protects the supply line. This property serves to protect the critical vascular lifeline between the placenta and fetus. Wharton's jelly, when exposed to temperature changes, collapses structures within the umbilical cord and thus will provide a physiological clamping of the cord, after an average of 5 minutes following birth (Yao et al. 1977, Prabhcharan & Jarjoura 1993, Kulkarni et al. 2007). Cells in Wharton's jelly express several stem cell genes, including telomerase (Chang et al. 2014). They can be extracted, cultured, and induced to differentiate into mature cell types such as neuron, Wharton's jelly is therefore a potential source of adult stem cells (Mitchell et al. 2003, Ma L Feng XY et al. 2005, Salehinejad et al. 2014). The Wharton's is jelly embryologically derived from the extra embryonic mesoderm (Kulkarni et al. 2007).

Umbilical cords, without much Wharton’s jelly are more prone to compression, and complete absence is usually associated with fetal death. If an umbilical cord is twisted or knotted, it is more likely to tighten where there is less resistance, such as an area low in Wharton’s jelly (Kulkarni et al. 2007, Barbieri et al. 2011). It is believed that males have more Wharton’s jelly content than the females and that good nutrition increases the amount. It tends to decrease with gestational age and can disappear when pregnancies go beyond 40 weeks (Kulkarni et al. 2007).

3.1.5.2. Cord vessels

There are usually two umbilical arteries present together with one umbilical vein in the umbilical cord. The vein carries blood and nutrients to the baby from the placenta and the arteries carry blood from the fetus to the placenta. Sometimes, only one umbilical artery is present, in a condition called single umbilical artery (SUA). This condition can indicate possible chromosomal problems, but many babies with single umbilical artery develop fine and are born with no apparent problems (Chow et al. 1998, Ghatersamni et al. 2007, Keith et al. 2011). The
two umbilical arteries wrap around the larger umbilical vein inside the cord. The relationship between the normal vein and two arteries varies, and may imply effects which can alter blood supply to the fetus. Variations include arteries that are together, or separated with each artery lateral to the vein, other variations is arteries wind around the vein while the vein remains central in the cord. This is sometimes referred to as spiraled arteries, but helical is the preferred term the vein can be parallel the arteries in a helical configuration, or can wind around the arteries (Cromi et al. 2005, Chitra et al. 2012).

In the fetus, the umbilical arteries run into the anterior abdominal wall and continue into the internal iliac arteries that supply the hind limbs. The arteries surround the urinary bladder (Keith et al. 2011). Inside the placenta, the umbilical arteries connect with each other at a distance of approximately 5 mm from the cord insertion. Subsequently, they branch into chorionic arteries or intraplacental fetal arteries. The umbilical arteries are the only arteries in the human body, a part from the pulmonary arteries, which carry deoxygenated blood. Within the fetus, the umbilical vein continues towards the transverse fissure of the liver, where it splits into two, one of these branches joins with the hepatic portal vein (connecting to its left branch), which carries blood into the liver. The second branch known as the ductus venosus allows the majority of the incoming blood approximately 80% to bypass the liver and flow via the left hepatic vein into the inferior vena cava, which carries blood towards the heart (Ernst et al. 2013).

The walls of the umbilical arteries are muscular and contain many elastic fibers, which contribute to a rapid constriction and contraction of the umbilical vessels after the cord is tied off. There are two main layers of smooth muscles; an outer layer consisting of circularly arranged smooth muscle cells and an inner layer which shows rather irregularly and loosely arranged cells embedded in abundant ground substance staining metachromatic. The smooth muscle cells of the layers are rather poorly differentiated, contain only a few tiny myofilaments and are thereby unlikely to contribute actively to the process of postnatal closure (Meyer et al. 1978, Gill et al. 1993, Ernst et al. 2013).

Like any vessel in the human adult body, umbilical cord vessels can develop sacs, protrusions, bulges, and varicosities. For example, cord vessels can protrude and thrombose like varicose or hemorrhoidal veins. In addition, the umbilical vein sometimes bunches up on itself, creating the appearance of a false knot or of multiple varicosities; these spaces can acts like quiet pools of
blood that can clot and predispose to a thromboembolism in the fetus. The clot can break free and enter the fetal circulation or can obstruct cord blood flow. The umbilical arteries can develop similar pockets called aneurysms. These bulges in the arterial vessel wall can rupture and lead to fetal hemorrhages in the uterus (Marie et al. 2009, Collins 2014).

3.1.6. Development of the umbilical cord

The umbilical cord begins to form between four and six weeks, as the embryonic disc takes a cylindrical shape. Located at the lower third of the embryo, the proximal portion of the umbilical cord begins to form and develops a sac or herniation (physiological umbilical hernia), which houses the guts or intestines until the tenth week of gestation (Keith et al. 2011). At this time the umbilical cord is short, usually shorter than the head-to-tail (crown-rump) length of the embryo and of proportionately large diameter. It is not able to tolerate rotation about itself or the formed embryo (Torpin 2002, Meyer et al. 1978, Rachakatla et al. 2007). After the tenth weeks, the intestines leave the proximal cord and return to the abdominal cavity, the elongation of the cord begins, and the umbilicus location changes into the middle third of the embryo. The elongation of the umbilical vein and arteries coincides with the development of Wharton’s jelly. The responsibilities of the cord growth are numerous, for example the cord manages its own growth, elongation, expansion, accommodates increasing blood flow, and possibly assists the fetal heart (Rachakatla et al. 2007). Rare instances exist in which no cord develops at all, the fetus being attached directly to the placenta at the umbilicus. In reports in Chinese and French literature studies cite cords as long as 300cm in length (Stallabrass 1960, Naeye et al. 1985, Lacro et al. 1987, Berg et al. 1995, Stefos 2003). Occasionally residual portions of the vitelline and allantoic ducts, and their associated vessels, can still be seen even in term umbilical cords, especially if the fetal end of the cord is examined.

Initially there are four umbilical vessels; two arteries and two veins, but the right umbilical vein undergoes atrophy and disappears; and thus the cord, at birth, contains a pair of umbilical arteries and one (the left) umbilical vein (Rachakatla et al. 2007, Karahuseyinoglu S 2007, Chitra et al. 2012). Since the arteries send blood with waste products from the embryo to the placenta, and the vein sends oxygen and nutrient-enriched blood to the embryo from the placenta, the circulation pattern must respond over time to the constantly changing fetal requirements and demands (Rachakatla et al. 2007). The cord is not directly connected to the
mother's circulatory system, but instead joins the placenta, which transfers materials to and from the mother's blood without allowing direct mixing (Hustin & Schaaps 1987, Hutton & Hassan 2007). It is unusual for a vein to carry oxygenated blood, and for arteries to carry deoxygenated blood, the only other examples being the pulmonary veins and arteries. However, this naming convention reflects the fact that the umbilical vein carries blood towards the fetal's heart, while the umbilical arteries carry blood away. Rare developmental changes which can occur to the embryonic umbilical cord are persistence of the right vitelline vein creating a four-vessel cord with two arteries and two veins, the reverse of this is obliteration of an artery and vein and the development of a two-vessel cord with one artery and one vein. The relationship of the umbilical vein to the umbilical arteries changes with development. These changes can result in cord abnormalities (Collins 2002). Umbilical cord vessels may multiply and branch under stressful conditions. For example, heavy smoking is associated with multiple channels in the umbilical cord, Hypoxia has been determined as the stimulus for opening of early vestigial vessels of the cord, once closed at 10 weeks (Collins 2002).

Over a period of month after birth, the fetal vessels form nonfunctional ligaments. The umbilical vein remains patent for a considerable period and may be used for exchange transfusions of blood during early infancy. The lumen of the umbilical vein usually does not disappear completely; in this case, the round ligament can be cannulated, if necessary. The intra-abdominal part of the umbilical vein eventually becomes the round ligament of liver or ligamentum teres, which passes from the umbilicus to the porta hepatis of the liver. Here it is attached to the left branch of the portal vein. The ductus venosus becomes the ligamentum venosum which passes through the liver from the left branch of the portal vein and attaches to the inferior vena cava. Most of the intra-abdominal parts of the umbilical arteries become the medial umbilical ligaments; the proximal parts of these vessels persist as the superior vesical arteries, which supply the urinary bladder (Mercer et al. 2006, Keith et al. 2011, Ernst et al. 2013).
3.1.7. Umbilical cord abnormalities

A number of abnormalities can affect the umbilical cord during its development, which can cause problems that affect both mother and child. Cord abnormalities can be discovered before delivery using ultrasound. However, they usually are not discovered until after delivery when the cord is examined directly. Many variations of umbilical cord complications exist in which factors such as the time and degree of compression are important. Compression of the umbilical cord obstructs blood flow and oxygen and releases stress factors from endocrine organs which contribute to the immediate danger to the fetus (Baergen 2007). The most obvious unwanted effect of umbilical cord disruption is stillbirth. An estimated 30% of pregnancies carried to term have some type of umbilical-placental abnormality (Torpin 2002). This means that every third to fourth delivery has an identifiable umbilical cord abnormality or anomaly, these abnormalities vary, and some are more common than others and may be a source of harm to the developing fetus. The following are the most frequent cord abnormalities and their possible effects on mother and baby.

3.1.7.1. Abnormality of the umbilical cord length

The length of the umbilical cord varies from no cord (achordia) to 300 cm (Heifetz 1996, Marie et al. 2009); an average length is 50 cm long, about 5% of cords are shorter than 35 cm, and another 5% are longer than 80 cm (Stefos et al. 2003). Causes of differences in cord length are unknown. The cord is believed to elongate until as late as 36 weeks although rapid change occurs until 28 weeks, then slows (Torpin 2002). Cord length plays a role in how a fetus develops, how labor is tolerated, and how delivery occurs. However the cord length is thought to reflect movement of the fetus in utero, correlates to several outcomes and may also influence fetal position (Collins 2002). Cord length had a positive correlation with maternal height, pregravid weight, pregnancy weight gain, socioeconomic status. Male cords are longer than female cords and the first pregnancy having a shorter length than the third; this may imply more room for movement-tension or more blood supply/hormone production/fetal-maternal weight gain. Twin gestations may have fetuses with discordant lengths and shorter lengths than the single birth. In most cases, a short umbilical cord is more worrisome than a long umbilical cord, but both conditions should be carefully watched by the doctor to ensure that any necessary medical steps, such as an emergency cesarean section (Collins 2002, Balkawade & Shinde 2012).
3.1.7.1.1. Short umbilical cord

According to the American Academy of Family Physicians, approximately 6% of babies are born with a short umbilical cord (Collins 2002). The risks to a baby with a short umbilical cord, fewer than 30 cm in length, include having a prolonged labor, experiencing fetal distress and being smaller than the average for their gestational age. Extremely short cords seen in ultrasound may indicate a genetic problem and the doctor should follow up on this kind of observation with further genetic tests. Very short umbilical cords, less than 25 cm, have been associated with neurologic disorders and increase risk of stillbirth. This risk may be as much as six times more likely, especially when other factors like toxemia are involved. Short cords and cigarette smoking tend to result in small babies, called Intrauterine Growth Retardation or (IUGR), (Grange et al. 1987, Krakowiak et al. 2004, Marie et al. 2009). Short cords are associated with fetal movement disorders and intrauterine constraint, as well as placental abruption, inversion of the uterus, cord rupture and cord vessels to tears which can lead to hematomas (Sherer et al. 2010, Keith et al. 2011). Although short cord have been blamed for the inability of some fetuses to be delivered vaginally, because the cord acts like a rope holding the baby back, available data suggest that vaginal delivery can take place with cords as short as 13 cm (LaMonica et al. 2008), which is much shorter than the normal range. Short umbilical cord was found in newborns for whom there was evidence of early intrauterine constraint and in those with gross structural or functional limb defects that limited intrauterine movement. Short cords doubled or tripled the predictive values of low Apgar scores and several other neonatal abnormalities and neurologic abnormalities. Short umbilical cord babies are considered at high risk for having potentially fatal problems during their first year of life, so they should be monitored carefully by both their parents and their pediatrician during that first year (Grange et al. 1987, Krakowiak et al. 2004, Marie et al. 2009).

3.1.7.1.2. Long umbilical cord

Excessively long umbilical cords, longer than 70 cm, are associated with a number of circumstances include entanglement, true knots, and thrombi, which can impact fetal life. A long umbilical cord doesn't generally indicate any birth defects, but can be a problem if the fetus gets tangled in the cord, or develops a tight knot that prevents proper blood and nutrient flow (Collins 2002, Balkawade & Shinde 2012). Length of the cord normally increases with increased
movement of the fetus in the womb and can also be influenced by amniotic fluid volume and anything that restricts fetal movement. It is unknown whether individual cell enlargement or cell division and multiplication cause cord growth. Many different cells such as muscle cells, endothelial cells, fibroblasts, connective cells and amniotic cells, thickness or thinness of vessel walls, composition of Wharton’s jelly, and artery-vein interrelationships may be important findings which explain long cord susceptibility to various events (Collins 2002).

3.1.7.1.3. Absent umbilical cord

If the umbilical cord does not develop, the fetus can develop but can be malformed and the fetus is directly attached to the placenta and usually develops defects. Fetuses without cords have been born by cesarean section. Without an umbilical cord, life is usually not possible (Lockwood et al. 1986, Giacoia 1992).

3.1.7.1.4. Umbilical cord knot

Knots occur most often when the umbilical cord is long enough for the fetus to turn inside the uterus and cord must cross under or over itself, in identical twin pregnancies which share a single amniotic sac, and the baby’s cords can become entangled (Cruikshank & Breech 2003, Keith et al. 2011). About 1 percent of babies are born with one or more knots in the umbilical cord (Cruikshank & Breech 2003, Marie et al. 2009), some knots form during delivery when a baby with a nuchal cord is pulled through the loop and others form during pregnancy when the baby moves around. As long as the knot remains loose, it generally does not harm the baby, but sometimes it can be pulled tight, cutting off the baby's oxygen supply. During labor and delivery, a tightening knot can cause the baby to have heart rate abnormalities that are detected by fetal monitoring (Cruikshank & Breech 2003, Deutsch et al. 2007, Ikechebelu et al. 2014).

Knots may form earlier prior to 32 weeks, since the fetus is so small that it easily moves around in the womb and is a common time of fetal repositioning earlier and have been noted prior to 20 weeks in miscarriage specimens. The earliest knot seen prenatally with ultrasound is in monoaamniotic twins at 19 weeks (Deutsch et al. 2007). Any knots or wrapping at this point are likely to resolve themselves as the baby moves around and unwraps itself (Stempel et al. 2006, Deutsch et al. 2007). Knot complexity depends on the amount of torsion created at the base of the loop. One torsion creates a single knot, two torsions create double knots, and three or
more torsions create complex knots (Collins 1997). True and false knots can form in the umbilical cord during the pregnancy.

3.1.7.1.4.1. True knot

True knots arise from fetal movements and are more likely to develop during early pregnancy. When relatively more amniotic fluid is present and greater fetal movement occurs, most of them are formed during birth. True knots are also associated with advanced maternal age and long umbilical cords. True knots increase the risk of fetal loss, because of compression of the cord vessels when the knot tightens (Ramon et al. 2006, Raisanen et al. 2013, Ikechebelu et al. 2014). It is highly likely that the fetus is entangled with the cord and, when delivered, is pulled through a loop of cord, forming a knot. True knots can completely block the cord, and can be tightened by the fetus during prenatal life. The chance of having a fetus deliver with a true knot of the umbilical cord is on the average 1% to 2% and the chance of fetal demise secondary to a knot blockage is 5% to 10%, and is with the highest rate occurring in monoamnionic twins (Torpin 2002). In fact, fetuses with true umbilical knots are at a four-fold increased risk of intrauterine death. It has been reported that true knots are associated with advanced maternal age, obesity, male fetus and long cord (Raisanen et al. 2013).

3.1.7.1.4.2. False knot

False cord knots or kinks in the umbilical cord vessels, are more common in normal pregnancies and appear due to kinks in the umbilical artery within the cord. It occurs due to local dilatation of the cord vessels and focal accumulation of Wharton's jelly. It is thought to arise as a result from the increased length of the umbilical vein in comparison to the umbilical arteries, and have no known clinical significance (Hertzberg et al. 1988, Ramon et al. 2006, Marie et al. 2009).

3.1.7.1.5. Umbilical cord prolapse

Umbilical cord prolapse occurs when the cord slips into the vagina after the membranes (bag of waters) have ruptured, before the baby descends into the birth canal, because the umbilical cord is heavier than amniotic fluid and therefore sinks (Lin 2006). Cord prolapse occurs in 0.6% of deliveries (Cruikshank & Breech 2003, Marie et al. 2009). The baby can put pressure on the cord as he passes through the cervix and vagina during labor and delivery. Pressure on the cord reduces or cuts off blood flow from the placenta to the baby, decreasing the baby's oxygen
supply. Umbilical cord prolapse can result in stillbirth unless the baby is delivered promptly, usually by cesarean section.

If the umbilical cord presents in front of the fetal presenting part and the membranes rupture, the risk that the cord will prolapse through the cervix into the vagina is significant. The risk is increased with fetal malpresentations, especially when the presenting part does not fill the lower uterine segment, as is the case with incomplete breech presentations, premature infants, and multiparous women (Yla-Outinen et al. 1985, Dildy & Clark 1993, Lin M G2006 ). Causes include abnormal presentation, a long umbilical cord, polyhydramnios, prematurity, and if the woman is delivering twins; the second twins is commonly affected (Oyelese & Smulian 2007). Loops of cord in front of the presenting part can be visualized using color Doppler studies. During the course of labor, fetal bradycardia may indicate compression of a prolapsed cord, which should be ruled out with a vaginal examination. In the presence of intact membranes, the prolapsed cord may resolve spontaneously or may be reduced by the presenting part at the onset of labor. In some cases, manual reduction of the cord has been reported with vaginal delivery and a good fetal result. In the presence of ruptured membranes, a cord prolapse can cause an obstetrical emergency requiring an immediate vaginal delivery or a cesarean delivery at the first sign of fetal distress (Koonings et al. 1990, Prabulos & Philipson 1988, Lin 2006). If a cesarean section can be performed quickly enough, the infant usually survives without harm. Many variations of this event exist in which factors such as time, degree of compression, and age of the fetus play a role. Yet the common effect among these variations is immediate danger to the fetus, because of compression and obstruction of blood flow to and from the fetus. This total obstruction denies the fetus oxygen and blood flow pressure, and it releases stress factors from endocrine organs which contribute to fetal harm (Katz et al. 1988, Usta et al. 1999, Cruikshank & Breech 2003).

3.1.7.1.6. Nuchal cord

The cord may become coiled around various parts of the body of the fetus, usually around the neck (the umbilical cord wrapped around the baby's neck) and rarely causes any problems; Babies with a nuchal cord are generally healthy (Clapp et al. 2003, Sheiner et al. 2006). Nuchal cord is caused by movement of the fetus through a loop of cord. One loop around the neck
occurs in approximately 20 - 25% of cases, and multiple loops occur in up to 5% of pregnancies (Schaffer et al. 2005, Reed et al. 2009).

Nuchal cord has been associated with labor induction and augmentation, prolonged second stage of labor, this may lead to pressure on the cord and sometimes fetal monitoring shows heart rate abnormalities during labor, and the pressure is rarely serious enough to cause death or any lasting problems although occasionally a cesarean delivery may be needed. Nuchal cord can be detected using color Doppler ultrasound, with a sensitivity of over 90%. Fortunately, with modern ultrasound technology and fetal monitoring, doctors and midwives can see if the umbilical cord is wrapped around the neck ahead of time and can prepare for it. Less frequently, the umbilical cord becomes wrapped around other parts of the baby's body, such as a foot or hand; generally don't cause any problems, either prenatally or during birth (Mercer et al. 2005, Mastrobattista et al. 2005, Reed et al. 2009).

3.1.7.2. Abnormality of the umbilical cord coils

Umbilical cords may have different types of design; (95%) are very helical and (5%) are completely straight cords (Lacro et al. 1987, Chitra et al. 2012). Not all cords are alike; there are different kinds of cords, curly, straight, thick and thin. Very helical designs (spiral, coil, and curl) may predispose the fetus to certain blood flow changes. Cord twisting can be seen early at the 6th week and is well established by the 9th week of development (Collins 2012). Umbilical cord is helical in nature, with as many as 380 helices, either counterclockwise (left), clockwise (right) or random, but left twisting outnumbers right by a ratio of approximately 7:1 (or in other words 85% are left, while 15% are right twisted); hypertwisting can lead to intrauterine fetal demise by compressing the fetal vessels beyond the capacity of the Wharton’s jelly. Straight cord with few or absent helices design may be susceptible to compression (Benedetto et al. 1987, Vizza et al. 1996, de Laat et al. 2007, Ernst et al. 2013).

3.1.7.3. Abnormality of the umbilical cord insertion

3.1.7.3.1. Velamentous cord insertion

The umbilical cord normally inserts near the center of the placenta (Keith et al. 2011, Vance 2009). Velamentous insertion occurs when placental tissue grows laterally, leaving the centrally located umbilical cord in an area that becomes atrophic, or when the cord implants in the
trophoblast anterior to the decidua capsularis rather than the trophoblast tissue that is destined to become the placental mass (Lacro et al. 1987, Hasegawa et al. 2006, Wiedaseck & Monchek 2014). In velamentous cord insertion, the umbilical cord inserts into the membranes, and then travels within the membranes to the placenta between the amnion and chorion. The exposed vessels are not protected by Wharton's jelly and hence are vulnerable to rupture. Rupture is especially likely if the vessels are near the cervix, in which case they may rupture in early labor causing a stillbirth. One percent of singletons have velamentous insertion; however, this condition occurs in almost 15% of monochorionic twins and is common in triplets (Heinonen et al. 1996, Feldman et al. 2002, Hasegawa et al. 2006). Velamentous insertion has been diagnosed by ultrasonography with a sensitivity of 67% and specificity of 100% in the second trimester; first trimester diagnosis is also possible (Lopriore et al. 2007). The condition is associated with a lower maternal serum alpha-fetoprotein (AFP) and higher maternal serum human chorionic gonadotropin (hCG) (Marie et al. 2009). Velamentous insertion can cause hemorrhage if the vessels are torn when the membranes are ruptured, most often with a vasa previa. Velamentous insertion of the cord is associated with low birth weight, prematurity, and abnormal fetal heart patterns in labor (Oyelese et al. 2006, Wiedaseck & Monchek 2014).

3.1.7.3.2. Battledore cord insertion

When the placenta develops it sometimes migrates and dissolves from its original site. This sometimes can result in what appears to be a relocation of the placenta. The placenta tissue dissolves, leaving a membrane (the amnion) remaining which can then be the connection (insertion) site of the umbilical cord. This results in the umbilical cord placental end looking like it is connected to the edge of the placenta called a marginal or Battledore insertion and a membranous insertion called a Velamentous insertion (Hasegawa et al. 2006). The risk of cord vessel rupture is increased with an abnormal cord insertion. If the membranous insertion is over the cervical opening, the risk of tearing and fetal blood loss is great. If a marginal insertion is against the sacrum, the risk of compression and fetal circulation disruption is great as the fetus descends into the pelvis. This relationship of vessel location to fetal location has caused sudden fetal distress (Marie et al. 2009).
3.1.7.3.3. Furcate cord insertion

In the furcate cord insertion the umbilical cord does not connect to the placenta but its branching elements do; however, no membranous insertion exists. These malformations account for another 0.5% to 1% of all births and are observed more in premature labor, premature birth, fetal stillbirth, and neurologic harm (Laberke & Deubler 2009).

3.1.7.4. Abnormality of the umbilical cord structures

3.1.7.4.1 Single umbilical artery (SUA)

Normally, an umbilical cord has three vessels, one vein and two arteries. In a pregnancy with a single umbilical artery, one of the two umbilical cord arteries is missing, leaving only one vein and one artery. A single umbilical artery can lead to an increased risk of birth defects, but these are usually associated with other signs as well (Mu et al. 2008, Keith et al. 2011).

A single umbilical artery (SUA) occurs in 0.5% to 2.5% of singleton and 5% in multiple pregnancies; it is more common in multiple or twins births and in fetal demise than in live births (Thummala et al. 1998, Gossett 2002, Ghatresamani et al. 2007). This is sometimes referred to as a two vessel cord. The loss of one umbilical artery likely occur secondary to thrombotic atrophy of a previously normal artery. Less likely, the loss may result from primary agenesis of the artery (Retik & Murdock 1978 Ghatresamani et al. 2007). The left umbilical artery is more commonly absent. The clinical significance of an SUA is not completely understood, and there are many different reports regarding outcomes of fetuses with this finding. Single umbilical arteries are found twice as often in white women than in African, American or Japanese women, also more common when the baby is a girl (Ghatresamani et al. 2007). The male-to-female ratio is 0.85:1. It is more likely to occur if the mother is over the age of 40 years and has three or more children (Fujikura 2003). Development of a single umbilical artery cord may be associated with maternal smoking, drug exposure, placental abnormalities and maternal diabetes. The incidence can be overestimated with gross examination of the cord, especially if the portion close to the placenta is examined, because the arteries may fuse close to the placenta (Fujikura 2003). Single umbilical arteries have been reported to increase incidence of fetal anomalies by 30% to 60%. Single umbilical artery has been associated with anomalies in all major organ systems for example the cardiovascular (in 15-20% of such cases), gastrointestinal, and central nervous systems (Marie et al. 2009). The most common congenital abnormality usually involves the kidneys. In addition, SUA is associated with an increased risk of chromosome abnormalities
such as trisomy 13, trisomy 18 and triploidy (Peckham et al. 1965). Aside from these problems, between 15% and 20% of infants with SUA may suffer from intrauterine growth retardation. Single umbilical artery also has an increased miscarriage rate of 22% associated with it, likely due to the increased abnormalities. Furthermore, there is an association between SUA and low birth weight (<2500g) and early delivery (<37 weeks) (Nyberg et al. 1991, Mu et al. 2008, Dane et al. 2009). A woman whose baby is diagnosed with single umbilical artery during a routine ultrasound may be offered certain prenatal tests to diagnose or rule out birth defects. The tests may include a detailed ultrasound, amniocentesis (to check for chromosomal abnormalities) and in some cases, echocardiography. The provider also may recommend that the baby have an ultrasound after birth (Dane et al. 2009).

An umbilical cord with more than two arteries or more than one vein is called a multivessel cord. A multivessel cord is rare and has been reported in conjoined twins (Heifetz 1984, Harris et al. 2000). Abnormalities of the umbilical vein are rare. Normally, the right umbilical vein atrophies at 6 weeks of the gestation, leaving a single left umbilical vein. Persistence of the right umbilical vein occurs in approximately 1 in 400 pregnancies (Peckham et al. 1965, Collins 2014). This finding is usually identified ultrasonographically in the fetus, but not specifically in the umbilical cord, and can be associated with many congenital malformations.

3.1.7.4.2. Umbilical cord cyst

Cord cysts can be defined outpockets in the cord as true or false cysts, and they can occur at any location along the cord. They are irregular in shape and are located between the vessels and they are found in about 3% of pregnancies (Chen 1995, Ratan et al. 2007, Zangen et al. 2010). There are two types of cysts true and false one (Bonilla et al. 2010).

True cysts are small remnants of the allantois (allantoid cysts) or the umbilical vesicle, which have an epithelial lining. They occur at the fetal end of the cord, and usually resolve during the first trimester. They can be associated with hydronephrosis, patent urachus, omphalocele, and Meckel diverticulum (Bunch et al. 2006, Ratan et al. 2007). False cysts can be as large as 6 cm and represent liquefaction of Wharton jelly; they do not have an epithelial lining and are most commonly found at the fetal end of the cord. 20% of cord cysts are associated with structural or chromosomal anomalies (Kilicdag et al. 2004, Bonilla F et al. 2010).
Studies suggest that both types of cysts are sometimes associated with birth defects, including chromosomal abnormalities and kidney and abdominal defects (Chen et al. 1995). Cysts can be visualized most easily with color doppler studies during the first trimester, when the umbilical vessels are small. When a cord cyst is found during an ultrasound, the provider may recommend additional tests, such as amniocentesis and a detailed ultrasound, to diagnose or rule out birth defects. During fetal anatomy scans, the abdominal wall near the cord insertion is the most likely location to detect a cyst. In patients with large cysts, cesarean delivery undertaken as soon as fetal lung maturity is achieved may help to avoid fetal damage from cyst rupture during labor (Chen et al. 1995, Zangen R et al. 2010)

3.1.7.4.3. Vasa previa

Is an obstetric complication defined as fetal vessels crossing or running in close proximity to the internal cervical os, or occur when one or more blood vessels from the umbilical cord or placenta cross the cervix underneath the baby (Oyelese et al. 2007). The blood vessels unprotected by the Wharton's jelly in the umbilical cord or the tissue in the placenta, from either a velamentous insertion of the umbilical cord or join an accessory (succenturiate) placental lobe to the main disk of the placenta. Sometimes these vessels tear off when the cervix dilates or the membranes rupture. This can result in life-threatening bleeding in the baby. Even if the blood vessels do not tear, the baby may suffer from lack of oxygen due to pressure. Vasa previa occurs in 1 in 200-300 deliveries (Oyelese et al. 2007). The cause of vasa previa is unknown; and it may be associated with low-lying placenta, placenta with accessory lobes, and with multiple pregnancies. However, when vasa previa is diagnosed by ultrasound earlier in pregnancy, fetal deaths generally can be prevented by delivering the baby by cesarean section at about 35 weeks of gestation (Lee et al. 2000, Bhide & Thilaganthan 2004, Gagnon et al. 2009).

The risk of fetal exsanguinations is significant if the vessels are torn when the membranes rupture, with an associated 50-75% fetal mortality rate. If compressed during labor, the vessels can cause fetal heart decelerations. Compression of the vessels during labor can also cause the vessels to thrombose (Yasmine et al. 2007). A pregnant woman may be at increased risk for vasa previa if she has a velamentous insertion of the cord or has placenta previa or certain other placental abnormalities or is expecting more than one baby. Vasa previa is seen more commonly with velamentous insertion of the umbilical cord, accessory placental lobes
(succenturiate or bilobate placenta), and multiple gestation. This is rarely confirmed before delivery but may be suspected when antenatal sonogram with color-flow doppler reveals a vessel crossing the membranes over the internal cervical os (Lee et al. 2000, Wiedaseck 2014). The diagnosis is usually confirmed after delivery on examination of the placenta and fetal membranes. Most often the fetus is already dead when the diagnosis is made; because of the blood loss (Oyelese et al. 2007).

3.1.7.4.4. Cord stricture

Cord stricture is constriction or occlusion of the cord. This condition is found in 19% of fetal demises (Peng et al. 2006). Familial recurrence of umbilical cord strictures has been described (French et al. 2005). The etiology of umbilical cord stricture is unknown. There is a deficiency in Wharton jelly in the umbilical cord in the area of stricture; however this could be a postmortem change. This condition cannot be diagnosed prenatally. Most infants with cord stricture are stillborn (Tan et al. 2010).

3.1.7.4.5. Hematoma of the Umbilical Cord

A hematoma of the umbilical cord is due to bleeding into the substance of the umbilical cord. It can be spontaneous, traumatic self-induced, or secondary to an umbilical cord defect. The usual risk of cord hematomas occurs in about 1/1,000 deliveries. Hematomas can be due to the umbilical artery or umbilical vein injury and seems to be more frequently noticed on the fetal end than on the placental end (Makhoul et al. 2005, Marie et al. 2009). The chance of death to the fetus is as high as 50% and as low as 14%. The cause of hematoma development is unknown but it may be due to wearing of the vessel walls, and then bleeding into the substance of the cord. Compression of the cord vessels leads to clogging and then death of the fetus (Feldberg et al. 1986, Makhoul et al. 2005, Gualandri et al. 2008).

The most common time of hematoma formation is also unknown. Numerous descriptions focus on hematomas which originate from the umbilical skin vessels penetrating the Wharton’s jelly from the umbilicus. They may rupture from fetal manipulations, which include pulling on the umbilical insertion or fetal grasping. Fetuses have been observed sucking and pulling on everything in the uterine amniotic cavity (Summerville et al. 1987, Gualandri et al. 2008).
3.2. Physiology of the umbilical cord

The umbilical cord appears to have organ-like properties. These properties are prone to disturbance under certain conditions which can affect the fetus. Just as a heart can fail pumping, or the liver and kidney can fail filtering the body’s chemistry and waste products, the umbilical cord can fail in its role of being a supply line (Torpin 2002). Primarily, it serves as a blood source for the fetus that provides the fetus the oxygen it needs to live (Torpin 2002). The umbilical cord also serves as a source of nutrients, including calories, proteins and fats, as well as vitamins and nutrients. The umbilical cord transfers waste products and deoxygenated blood away from the fetus to the maternal circulation, where it can be processed and excreted (Ferguson & Dodson 2009). The umbilical cord has three functions for the developing fetus. It supplies oxygen, delivers nutrients, and helps to withdraw blood rich in carbon dioxide and depleted in nutrients. Blood from the umbilical cord can also be used to treat a variety of diseases, much like bone marrow (Rachakatla et al. 2007).

Umbilical cord blood vessel is without branches. This is unique compared to the large blood vessels of the adult body, the aorta and vena cava. Its properties, therefore, are different in some respects and alike in others (Torpin 2002, Ferguson & Dodson 2009). The umbilical cord has two-way traffic; the arteries carry blood pumped by the heart away from the fetus and the vein returns blood to the fetus from the placenta. The fetal heart cannot expand or work harder because it is surrounded by a fluid-filled lung, like pushing against a water bed. The fetus has to work against a larger column of fluid and tissue resistance at the placental end. This assist pump may be designed to help the fetus over difficult growth proportions which may exist at 20 weeks, 24 weeks, 28 weeks, and 32 weeks -times that are known for premature labor to appear (Collins 2014). The extra stress on the fetus may require that the cord be designed correctly so that it can have properties of an assist mechanism or pump. This requires that the arteries surround the vein in the proper architecture. The umbilical vein goes all the way to the fetus's liver, where it splits into two, one part of the vein supplies blood to the hepatic portal vein, which supplies blood to the liver. The other branch, which is known as the ductus venosus, supplies 80% of the blood to the human body, allowing oxygen and other vital nutrients to circulate throughout the fetus (Keith et al. 2011). It is unusual for a vein to carry oxygenated blood, and for arteries to carry deoxygenated blood, the only other examples being the pulmonary veins and arteries, connecting the lungs to the heart. Regulation of blood flow, vessel constriction at birth, and blood loss
prevention may be the roles of these vessel-active substances, some of these substances originate in the placenta (Ferguson & Dodson 2009). In large mammals, the cord must constrict from the placenta to the fetus for the fetus to avoid anemia. In the human, similar mechanisms may be available chemically. In absence of external interventions, the umbilical cord occludes physiologically shortly after birth, explained both by a swelling and collapse of Wharton's jelly in response to a reduction in temperature and by vasoconstriction of the blood vessels by smooth muscle contraction. In effect, a natural clamp is created, halting the flow of blood. If left to proceed naturally this physiological clamping will take as little as five minutes and up to 20 minutes (Young et al. 2008). Closure of the umbilical artery by vasoconstriction consists of multiple constrictions which increase in number and degree with time (Meyer et al. 1978). The vasoconstrictive occlusion appears to be mainly mediated by 5-hydroxytryptamine and thromboxane A2 (Quan et al. 2003). Researchers have identified nerve endings near the umbilical insertion of the cord in the Wharton’s jelly. These nerve endings may play a role in communicating with fetal valves called shunts relative to blood volume wave properties entering the fetal circulation through the umbilical vein at the level of the liver and heart.
CHAPTER FOUR

MATERIALS AND METHODS

4.1. Study area

This study carried in Omdurman Maternity Hospital. It’s a main referral Maternity Hospital in Sudan, with a high incidence rate of deliveries; it receives different cases of normal and abnormal deliveries from different areas and tribes.

4.2. Study design

This is a descriptive prospective cross sectional hospital-based study in which samples will be collect throughout the study period.

4.3. Study population

The study samples include;

- Inclusion criteria; full term neonates of both sexes of normal vaginal delivery at the period of the study.
- Exclusion criteria; still birth, caesarean section and abnormal vaginal deliveries, because the environment around the researcher is not convenient as the operation, both put the doctors and patients relative under stress. This will not allow the researcher to do the measurements need at ease.

4.4. Study period

This study carried at the period between February to September 2013.

4.5. The sample size

The sample will include 1020 neonates with their umbilical cord of both sexes, during the time of data collection.

4.6. Data collection tools:

Data was collected using the following tools; observation and parameters (measuring, weighing).

4.7. Statistical analysis

Data will be enter to the software computer programs and analyze using statistical package for social Science (SPSS) version 16. Frequencies, percentage, mean, standard deviation, Chi-Squire and correlation
are taken to identify the association between variables, and confidence interval of a P-value equal 0.05 or less as consider statistically significant.

4.8. Ethical considerations

Verbal consent was taken from pregnant mothers and written approval was obtained from hospital administrator.

4.9. Methods

Immediately after delivery, the umbilical cord cut about 5 centimeters from the baby abdominal wall (fetal part) by scissor. The rest of the cord from the cut end to the placental insertion (placental part) is measure in centimeters, using flexible plastic meter. The five centimeters added to the rest of the cord. Diameter umbilical cord is measure by Vernier Calipers, the measurement applied to three different regions, and then the average measurement is taken. The fetal surface of the placenta observed for cord insertion, the cord insert whether central, eccentric and marginal. Coil is taken as one complete 360-degree spiral course of the umbilical vessels, and the numbers of entire cord coils are counted. For coils direction, placental end of the cord is selected, because the coils were seen visible. Base on their patterns, coils are classified into; type I, type II and type III. Type II is classifying into A and B. The umbilical cord knots, cord cysts also studied. The neonatal weight is measure using Siltsc electronic baby weighing scale BS1, and then height of the neonate measure from the vertex down to the heel by a flexible plastic meter. The following maternal factors are taken; mother height and weight using weighing scale ZT-220 with (serial number: 233, Weights: 220Kilo), and their body mass index (BMI) is calculate. Mother age, age of menarche, duration of marriage, parity, socioeconomic classes of the mother and diet during their pregnancy are also taking.

For gross appearances of the umbilical cord blood vessels some cords dissected longitudinally while other regionally (window dissection), using anatomical dissection method and tools. The blood vessels deliver from surrounding tissues and studied

For general histology sections, segments of the umbilical cord tissues; approximately one to two centimeters thick is obtain. Tissue entirely fixed in 10% neutral buffered formalin and placed in a plastic container of suitable size with tight fitting lid. The tissues storage at room temperature, and dehydrated with alcohol, cleaned in chloroform and embedded in paraffin wax. Sections is cut at 5 μm thick using leica rotary microtome (Leica Germany), and stained with Hematoxylin and Eosin (H&E) stains for routine cord histological structures (Culling, 1974).
Special stains Masson’s Trichrome, Van Gieson and Verhoff’s stains also used to study the connective tissues fibers within the umbilical cord (Culling 1974, Bancroft & Stevens 1990).
CHAPTER FIVE
RESULTS AND DISCUSSION

5.1. RESULTS

5.1.1. Neonates

The study was carried out among 1020 full term neonates of normal vaginal deliveries with their umbilical cords specimens. Out of these 584 (57.3%) were male and 436 (42.7%) were female babies, (Fig. 1), and 980 (96%) were single and 20(4%) were twins babies, (Fig. 2). All neonates included in this study were looked healthy.

The weight of the single birth ranged from 1200 to 5000 gram with mean (3.1806 ± .45242 std-deviation) in male and from 2000 to 4100 gram with mean (3.1257 ± .29401 std-deviation) in female. The weight of the twin birth ranged from 1900 to 3200 gram with (mean 2.6250 ± .49785 std-deviation) in male and from 1300 to 3000 gram with mean (2.2833 ± .67532 std-deviation) in female, (Table 1).

The height of the single birth ranged from 40 to 60 cm. with mean (50.1825 ± 2.60560 std-deviation) in male and from 43 to 55 cm. with mean (49.6557± 1.95923 std-deviations) in female. The height of twins birth ranged from 43 to 50 cm with (mean 46.2500 ± 2.65922 std-deviations) in male and from 42 to 50 cm with mean (45.8333 ± 2.85509 std-deviation) in female, (Table 2).

(Figure 1): Shows the numbers and percentage of neonatal gender of the 1020 Sudanese neonates

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>584 (57.3%)</td>
<td>436 (42.7%)</td>
</tr>
</tbody>
</table>

40
(Table 1): shows neonatal weight in grams in the single and twin birth.

<table>
<thead>
<tr>
<th>Gender of the neonate</th>
<th>Birth outcome</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std-deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Single</td>
<td>1200</td>
<td>5000</td>
<td>3.806</td>
<td>.45242</td>
</tr>
<tr>
<td></td>
<td>Twin</td>
<td>1900</td>
<td>3200</td>
<td>2.625</td>
<td>.49785</td>
</tr>
<tr>
<td>Female</td>
<td>Single</td>
<td>2000</td>
<td>4100</td>
<td>3.1257</td>
<td>.29401</td>
</tr>
<tr>
<td></td>
<td>Twin</td>
<td>1300</td>
<td>3000</td>
<td>2.2833</td>
<td>.67532</td>
</tr>
</tbody>
</table>

Total (1020) neonates

(Figure 2): Shows numbers and percentage of the 1020 Sudanese neonates

(Table 2): shows neonatal height in cm. in the single and twin birth.

<table>
<thead>
<tr>
<th>gender of the neonate</th>
<th>Birth outcome</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std-deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Single</td>
<td>40</td>
<td>60</td>
<td>50.8125</td>
<td>2.60560</td>
</tr>
<tr>
<td></td>
<td>Twin</td>
<td>43</td>
<td>50</td>
<td>46.2500</td>
<td>2.65922</td>
</tr>
<tr>
<td>Female</td>
<td>Single</td>
<td>43</td>
<td>55</td>
<td>49.6557</td>
<td>1.95923</td>
</tr>
<tr>
<td></td>
<td>Twin</td>
<td>42</td>
<td>50</td>
<td>45.8333</td>
<td>2.85509</td>
</tr>
</tbody>
</table>

Total (1020) neonates
5.1.2. Mother

The mother age ranged between 16 to 45 years with mean (27.1500 ± 6.16854 std-deviation), their menarche started at age of 13 up to 15 years with mean (13.7060 ± 6.4806 std-deviation), in most of them as regular, with average blood amount and katamina of 4 to 28 days. The marriage duration ranged from 1 to 28 years with mean (6.5420 ± 5.57021 std-deviations), (Table 3), the mother parity ranged from one to ten children with mean (2.8500± 2.03363 std-deviation). Most of mothers of good diet during their pregnancy, (Fig. 3), with middle socioeconomic class, (Fig. 4), and their body mass index (BIM) ranged from 17.30 to 46.75 with mean (29.2990± 4.96811std-deviation), (Table 3).

(Table 3): shows age, menarche, duration of marriage, number of pregnancy, parity and BMI, in Sudanese mothers

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std-deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of mother in year</td>
<td>16</td>
<td>45</td>
<td>27.1500</td>
<td>6.168540</td>
</tr>
<tr>
<td>Age of menarche in year</td>
<td>13</td>
<td>15</td>
<td>13.7060</td>
<td>6.4806</td>
</tr>
<tr>
<td>Duration of marriage in year</td>
<td>1</td>
<td>28</td>
<td>6.5420</td>
<td>5.57021</td>
</tr>
<tr>
<td>Number of pregnancy</td>
<td>1</td>
<td>10</td>
<td>3.0080</td>
<td>2.1553</td>
</tr>
<tr>
<td>Number of deliveries (parity)</td>
<td>1</td>
<td>10</td>
<td>2.8500</td>
<td>2.3363</td>
</tr>
<tr>
<td>Body mass index (BMI)</td>
<td>17.30</td>
<td>46.75</td>
<td>29.2990</td>
<td>4.96811</td>
</tr>
</tbody>
</table>

(Figure 3): shows numbers and percentage of the mother diet during the pregnancy.
5.1.3. Umbilical cord
5.1.3.1. Attachment

Grossly the attachment of umbilical cord to the fetal placental surface was observed which is shown in (Fig. 5). Eccentric insertion in which the cord inserted near the centre of the placenta was about 850 (83.3%). Central insertion in which the cord inserted on the centre of the placenta was about 134 (13.2%). Marginal insertion in which the cord inserted on the placental edge was about 36 (3.5%), (Fig. 6).
(Figure 6): shows the umbilical cord insertion site with placenta. A. Central insertion, B. Eccentric insertion and C. Marginal insertion.

5.1.3.2. Umbilical cord knots and cysts

The umbilical cord knot appeared in 126 (12.4%) specimens. Out of these 114(11.2%) were false knots and 12(1.2%) were true knots, (Fig. 7 and 8). Eight (66.7%) out of the true knots occurred near to the fetal end, 3 (25%) occurred at middle and 1(8.3 %) occurred near the placental end of the cord, and all of which appeared single, (Fig.9). Out of the true knots 8(66.7 %) coiled to left (anticlockwise direction) and 4(33.3%) coiled to right (clockwise direction), (Fig.10 and11). The ratio of the left to right true knot coiling direction was approximately 2:1.

The false knots appeared of variable size, numbers, location and shape. The dissected false knot showed central vein surrounded by long tortuous arteries, and when cut transversally showed multiple blood vessels most of which arteries, (Fig. 12). The umbilical cord cysts were seen in 42 (4.1%) specimens, out of 1020 cords sample with variable size and shapes, (Table 4), (Fig. 13).
(Figure 7): Shows the numbers and percentage of the umbilical cord knots, in 1020 Sudanese neonates.

(Figure 8): shows types of umbilical cord knots.
A. true knot, B. false knot and C. bilateral knots.
(Figure 9): Shows numbers and percentage of the umbilical cord true knot location, in 1020 Sudanese neonates.

(Figure 10): Shows the numbers and percentage of the umbilical cord true knot coiling direction, in 1020 Sudanese neonates.

(Figure 11): shows side of the umbilical cord true knot coil direction. A. true knot coiled to left and B. true knot coiled to right

(PE= placental end of the umbilical cord, FE= fetal end of the umbilical cord)
(Figure 12): A. shows the umbilical cord false knot, before and after the dissection. B. and C. show cross section of the cord at level of the false knot (UA= umbilical artery, UV= umbilical vein and W= Wharton jelly)

(Table 4): shows the frequency and percentage of the umbilical cord cyst in Sudanese Neonates,

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cord without false cyst</td>
<td>978</td>
<td>95.9%</td>
</tr>
<tr>
<td>Cord with false cyst</td>
<td>42</td>
<td>4.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1020</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
(Figure 13): shows umbilical cord cysts. (Arrow shows the cysts)

5.1.3.3. Umbilical cord coils and pattern

The number of umbilical cord coils in single birth babies ranged from 4 to 45 coils with mean $(13.2222 \pm 7.96597$ std- deviation) in males and from 4 to 36 coils with mean $(12.2358 \pm 7.47579$ std- deviation) in females. In the twins birth babies the coils ranged from 6 to 18 coils with mean $(13.0000 \pm 4.89898$ std- deviation) in males and from 6 to 32 coils with mean $(15.1668 \pm 10.13395$ std- deviations) in females, (Table 5). Out of all the umbilical cords specimens 759 (74.4%) were coiled to left (anticlockwise direction) and 261(25.6%) were coiled to right (clockwise direction), from placental end of the cord, (Fig. 14 and 15). The left twisting outcomes number to right by a ratio of approximately 3:1 or 74.4% to left and 25.6% to right. Basis of their coiling number, the cords were grouped into groups, A (less than ten coils), group B (between 10 - 40 coils) and group C (more than 40 coils), (Table 6), (Fig.16).

(Table 5): shows number of the umbilical cord coils in single and twin, Sudanese neonates

<table>
<thead>
<tr>
<th>Gender of the neonate</th>
<th>Birth outcome</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std-deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Single</td>
<td>4</td>
<td>45</td>
<td>13.2222</td>
<td>7.96597</td>
</tr>
<tr>
<td></td>
<td>Twin</td>
<td>6</td>
<td>18</td>
<td>13.0000</td>
<td>4.89898</td>
</tr>
<tr>
<td>Female</td>
<td>Single</td>
<td>4</td>
<td>36</td>
<td>12.2358</td>
<td>7.47579</td>
</tr>
<tr>
<td></td>
<td>Twin</td>
<td>6</td>
<td>32</td>
<td>15.1667</td>
<td>10.13395</td>
</tr>
</tbody>
</table>

Total (1020) neonates
(Figure 14): Shows the numbers and percentage of the umbilical cord coil direction, among 1020 Sudanese neonates

- 261 (25.6%): To the right
- 759 (74.4%): To the left

(Figure 15): shows side of the umbilical cord coils direction
A. Cord with left coils, B. cord with right coils

(FE= fetal end of umbilical cord, PE= placental end of umbilical cord, RA= remnant of the amniotic membrane attaché to placental end of the cord)

(Table 6): shows frequency and percentage of the umbilical cord coil number, in single and twin Sudanese neonates,
<table>
<thead>
<tr>
<th>Group</th>
<th>No of coils</th>
<th>Variable</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 10</td>
<td>Hypocoiled cord</td>
<td>232</td>
<td>22.7%</td>
</tr>
<tr>
<td>B</td>
<td>10-40</td>
<td>Normocoiled cord</td>
<td>775</td>
<td>76%</td>
</tr>
<tr>
<td>C</td>
<td>&gt; 40</td>
<td>Hypercoiled cord</td>
<td>13</td>
<td>1.3%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>1020</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Figure 16**: shows the umbilical cord coils.

A. hypocoiled cord, B. Hypercoiled cord, (Arrow shows coils)

### 5.1.3.4. Umbilical cord length

The length of the umbilical cord in single birth babies ranged from 24 to 90 cm. with mean (47.4167±11.48761 std-deviation) in males, and from 20 to 86 cm. with mean (44.7547±11.29347 std-deviation) in females, and in twins birth babies the cord length ranged from 32 to 42 cm. with mean (35.6500±4.02670 std-deviation) in males, and ranged from 30 to 48 cm. with mean (36.6667±6.78680 std-deviation) in females, (Table 7).
(Table 7): shows umbilical cord length in (cm), for the single and twin Sudanese neonates

<table>
<thead>
<tr>
<th>Gender of the neonate</th>
<th>Birth outcome</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std-deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Single</td>
<td>24</td>
<td>90</td>
<td>47.4167</td>
<td>11.48761</td>
</tr>
<tr>
<td></td>
<td>twin</td>
<td>32</td>
<td>48</td>
<td>35.7500</td>
<td>4.02670</td>
</tr>
<tr>
<td>Female</td>
<td>single</td>
<td>20</td>
<td>86</td>
<td>44.7547</td>
<td>11.29347</td>
</tr>
<tr>
<td></td>
<td>twin</td>
<td>30</td>
<td>42</td>
<td>36.6667</td>
<td>6.78680</td>
</tr>
</tbody>
</table>

Total (1020) neonates

5.1.3.5. Umbilical cord diameter

The diameter of the umbilical cord in single birth babies ranged from 0.5 to 2.5 cm. with means (1.1582 ± .24093 std-deviation) in males, and from 0.5 to 1.6 cm. with mean (1.0939± .16011 std-deviation) in females. In twins babies the cord diameter ranged from 0.8 to 1.2 cm. with mean (.9±.18516 std-deviation) in males and from 0.7 to 1.2 cm with mean (.9 ± .17056 std-deviation) in females, (Table 8), (Fig 17).

(Table 8): shows umbilical cord diameter in single and twin Sudanese neonates

<table>
<thead>
<tr>
<th>gender of the neonate</th>
<th>Birth outcomes</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std-deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Single</td>
<td>0.5</td>
<td>2.5</td>
<td>1.1582</td>
<td>0.24093</td>
</tr>
<tr>
<td></td>
<td>Twin</td>
<td>0.8</td>
<td>1.2</td>
<td>0.9000</td>
<td>0.18516</td>
</tr>
<tr>
<td>Female</td>
<td>single</td>
<td>0.5</td>
<td>1.6</td>
<td>1.0939</td>
<td>0.16011</td>
</tr>
<tr>
<td></td>
<td>Twin</td>
<td>0.7</td>
<td>1.2</td>
<td>0.9000</td>
<td>0.17056</td>
</tr>
</tbody>
</table>

Total (1020) neonates
(Figure 17): shows diameter of the umbilical cord

A. Cord with small diameter, B. Cord with medium diameter and C. Cord with large diameter
5.1.3.6. Umbilical cord blood vessels

Out of 1020 umbilical cords specimens, 110(99%) cords has three blood vessels two arteries and one vein, and 10(1.0%) has two blood vessels, one artery one vein (SUA). (Fig. 18 and 19). The single umbilical artery was found in single birth babies, out of them 6 were males and 4 females, the ratio of male-to-female with SUA is 3:2. The weight of the babies with SUA ranged from 3.300 to 3.500 gram in males and from 3.000 t0 3100 gram in females and their cord diameter ranged from 1.2 to 1.5 cm. Two babies showed congenital abnormalities, spina bifida associated with hydrocephalus. The age of mother of SUA babies ranged from 29 to 38 years with parity ranged from 2 - 5 children.

The dissected cord specimens showed the relationship between the arteries and vein is varying. In type I, the arteries and vein were course together in a parallel, vein centrally with the arteries peripherally, in cross section showed to run in a column manner (Fig A. 20). In type II A, the vein is a run predominantly straight with arteries coiled around it, and in B, arteries and vein course together in a helical fashion in a one-to-one relationship, in cross section showed to run in a triangular manner (Fig B. 21). The umbilical vein was found bigger, thin wall than arteries and surrounded by a special sheath, (Fig. 22).

(Figure 18): Shows the numbers and percentage of the umbilical cord blood vessels, in 1020 Sudanese neonates.
(Figure 19): A cross sections showing number of the umbilical cord blood vessels
A. cord with three blood vessels, two arteries and one vein, B. cord with two blood vessels one artery and one vein, (1 = umbilical vein, 2 = umbilical artery)

(Figure 20): A. Cross section of the umbilical cord showing the blood vessels. B. dissected cord  (1 = umbilical vein, 2 = umbilical artery)
(Figure 21): A. window dissection showing relationship between cord blood vessels in a coiled cord. B. A cross section of the cord showing blood vessels lying in triangular manner (1= umbilical vein, 2= umbilical artery)

(Figure 22): A. longitudinal dissection showing cord vessels. B. window dissection showing cord vessels, (the vein covered with sheath) (1= umbilical vein, 2= umbilical artery, 3= outer covering of the umbilical cord and 4= sheath around the umbilical vein)
5.1.3.7. Histological features of the umbilical cord

The umbilical arteries were found distinctly smaller in size than the vein, and being circular, oval, or dumb-bell in shape. Indicative of tortuosity or helical twisting, the lumen of the umbilical arteries appeared irregular in shape. The umbilical vein was large with a thinner tunica media and few smooth muscles cells than arteries (Fig. 23). Verhoff’s stain reacts with connective tissue fibers of the umbilical cord. The elastic fibers appeared pink or back colored areas in the cord; vary in thickness, being more in arteries than vein (Fig. 24). Tunica intima consists of endothelium cells, with less prominent internal elastic membrane in both arteries and vein. Van Gieson stain reacts with connective fibers and smooth muscle cells in the tunica media of vessel. The connective tissue fibers appeared blue red, while the smooth muscle cells appeared yellow. The tunica media consisted predominantly of smooth muscle cells, being thicker in artery than vein. The smooth muscle cells in the tunica media arranged into longitudinally orientated with a small groups of circular (Fig.25). The spaces between the smooth muscles cells vary in width and in place with discontinuous or fragmented segment of elastic fibers of variable length and thickness, as in mature arteries. Masson’s trichrome stain reacts with the connective tissue fibers within the umbilical cord. The connective fibers appeared as waving blue to black colored areas scattered within the cord, highly condensed and concentrated close to the vein than arteries, forming sheath like structure (Fig 24, 25 and 26). Adventitia or vasa vasorum were not clearly visible in either arteries or veins.

(Figure 23): shows normal histological features of umbilical cord. (H and E stains, lens 60X)
1. lumen of the blood vessels, 2. blood cells, 3. tunica media, 4. Tissue of Wharton’s jelly - arrow showing cells and fibers as condensation around blood vessels. UA= umbilical artery, UV= umbilical veins
Figure 24: shows normal histological features of the umbilical cord (connective tissues fibers) (Verhoeff’s stain, lens 40X)
1. lumen of the blood vessels - arrow shows intima
2. tunica media - pink colored in 2 showing elastic fibers within the tunica media
3. collagenus fibers condensed around cord blood vessel

Figure 25: shows normal histological features of human umbilical cord ((H and E stains, lens 40X) A. Umbilical vein, B. umbilical artery
1. Circular muscle in wall of cord blood vessel, 2. Longitudinal muscle in wall of cord blood vessel and 3. cells of Wharton’s jelly condense around cord blood vessel (Arrow showing tunica intima)
(Figure 26): shows normal histological features of human umbilical cord (Van Gieson stain, using lens 40X).

A. umbilical artery, B. umbilical vein
   1- lumen of the blood vessels- arrow showing tunica intima
   2- blood cells
   3- tunica media
   4- cells of Wharton’s, jelly condensed around cord blood vessels
Correlations (Table 9): shows correlations of neonatal weight with umbilical cord length, diameter, number of coils, insertion site, knots, cysts and blood vessels of Sudanese neonates

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Variable</th>
<th>Person Chi-square</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonatal Weight</td>
<td>umbilical cord length</td>
<td>0.219</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>Umbilical cord diameter</td>
<td>0.744</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>number of cord coils</td>
<td>0.112</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>Umbilical cord insertion site</td>
<td>0.087</td>
<td>0.005*</td>
</tr>
<tr>
<td></td>
<td>True cord knot</td>
<td>0.303</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>False cord knot</td>
<td>0.048</td>
<td>0.127**</td>
</tr>
<tr>
<td></td>
<td>False cord cyst</td>
<td>0.150</td>
<td>0.577**</td>
</tr>
<tr>
<td></td>
<td>cord blood vessel</td>
<td>0.028</td>
<td>0.366**</td>
</tr>
</tbody>
</table>

Total 1020 neonate

- * means significant correlation
- ** means non significant correlation

(Table 10): shows correlations of human umbilical cord length with neonatal height, number of cord coils, diameter of, cord knot, cord cyst and sex of neonate of Sudanese neonates

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Variable</th>
<th>Person Chi-square</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Umbilical cord length</td>
<td>Height of neonate</td>
<td>0.191</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>Number of cord coils</td>
<td>0.503</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>Diameter of the cord</td>
<td>0.221</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>Umbilical cord knot</td>
<td>0.102</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>Umbilical cord cyst</td>
<td>0.023</td>
<td>0.787**</td>
</tr>
<tr>
<td></td>
<td>Gender of neonate</td>
<td>0.118</td>
<td>0.000*</td>
</tr>
</tbody>
</table>

Total 1020 neonate

- * means significant correlation
- ** means non significant correlation

(Table 11): shows correlations of neonatal weight and umbilical cord length with, socioeconomic class of the mother and body mass index (BMI) of the mother of Sudanese neonate and their mothers.

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Variable</th>
<th>Person Chi-square</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonatal weight</td>
<td>socioeconomic class of the mother</td>
<td>0.569</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>BMI of the mother</td>
<td>0.078</td>
<td>0.012*</td>
</tr>
<tr>
<td>Cord length</td>
<td>socioeconomic class of the mother</td>
<td>0.100</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>BMI of the mother</td>
<td>0.075</td>
<td>0.016**</td>
</tr>
</tbody>
</table>

Total - 1020 neonate and 1000 mother

- * means significant correlation
- ** means non significant correlation
5.2. DISCUSSION

5.2.1. Umbilical cord external features

5.2.1.1. Cord Length

There are several reports of studies on the correlations of the length of human umbilical cord with various factors. Tomoko et al. in (1991), Marie et al. (2009) and Balkawade & Shinde (2012), they reported that, the length of the human umbilical cord ranged from 60 to 70 cm with average of 50 cm. In the majority of previous studies, average cord length arranged from 50 to 60 cm. In the present study the cord length was arranging from 20 to 90 cm. with an average of 55 cm, with minimum difference between males to females and single to twin birth. The result in present study was conforming to those of other previous studies. There is no big difference in the cord length measurement before and after birth, comparing the two methods (ultrasound and manual measurements).

In (1958) Javert, found that the length of the cord was usually the same as the standing height of the fetus at all stages of pregnancy. This study, is in according to the finding of Malpas (1964), a British obstetrician studied cord length in the (1960s), he found the average length of the umbilical cord is about 61 cm. Rare instances exist in which cord not develop at all, and the fetus being attached directly to the placenta at the umbilicus, but in (1992) Giacoia examined a 20-year-old pregnant woman by ultrasound and found a fetus with a large ventral abdominal wall defect diagnosed as a fetal omphalocele. The neonate was delivered by cesarean; the abdominal viscera including liver, stomach, spleen, pancreas, intestine, and uterus were contained in an extraembryonic sac directly attached to the placenta without an umbilical cord. In the present study all neonates were born with a cord. However, absent cord is associated with stillbirth or cesarean section, and normal vaginal delivery needs a cord.

In (1996) the Heifetz, reported in Chinese and Japanese populations, a cord length reaching 300 cm length. The finding of this study and that of Malpas (1964) and Javert (1996) were in agreement and confirmed most of the previous studies. However, the majority of studies did not report cord length reaching the length which mention by Heifetz (1996).
In (1960), Walker & Pye, who studied non-African populations, concluded that cord length was related to the sex, but not to the mother parity, height, weight duration of pregnancy, parity age, weight and height of the baby. And in (1964) Dippel mentioned that there was no relation between the length of cord and the weight of either fetus or its placenta. Also in (2012), Balkawade & Shinde who studied cord length and fetal outcome described that the cord length did not relate to weight, length and sex of the baby, but Collins in (2002) reported that cord length had a positive correlation with maternal height, pregnancy weight gain, more parity, socioeconomic status and male gender. The present study found significant correlation between the cord length and the neonatal weight, height, sex, socioeconomic status, P-V< 0.001, and there was no significant correlation between cord length and cyst, P-V 0.787, and BMI of the mother P-V 0.016, as in the Collins (study 2002). Big fetal weight, subsequent pregnancies and male gender associate with cord length. This is may be true because most long cord in this work was seen in multi-parity, male babies. However, a significant linear correlation between cord length and fetal weight was observed, which differs from the findings of Walker & Pye (1960), but corresponds with those of Malpas (1964) and Steve (1991) who study cord in African population. Soernes & Bakke in (1986) reported that cord length in twin was shorter than single birth. They suggested that this difference may be caused by restriction of the fetal movement and the weak tensile force of the cord in twin pregnancy. This theory was originally proposed in (1982) by Moessinger et al. from experiments on pregnant rats in which artificial restriction of fetal movement resulting in shortening of the cord in rats were done. If the length of the cord is influenced only by the activity of the fetus in the uterine cavity, the length of the cord and the ratio of it is length to the body weight of infants should be less in multiple than in single pregnancies. This study also found differences in cord length between single and twin births; this confirms with result of Soernes & Bakke (1986). This difference may refer to differences in birth weight, height between single to twins neonates. Thus, it can be posfilaled that the fetal activity in uterus may have a more important influence than fetal weight on the length of umbilical cord. Because the fetal activity, increase cord tensile force, by which the cord elongates.

Cord length plays a role in how a fetus develops, how labor is tolerated, and how delivery occurs. In (2002) Collins, described according to the American Academy of family Physicians, approximately 6% of babies were born with a short umbilical cord. Stefos et al in (2003) also reported that about 5% of cords are shorter than 35 cm, and about 5% of cords are longer than 80
cm. The present study found about 14% cords were shorter than 35cm, and about 1% was longer than 80 cm; however the differences in the results may be due to difference in techniques used for measuring the cord length. Most of the previous studies measured cord length within uterus. Measurement of cord length after birth is easy and gives accurate length than postnatal study.

Cord length correlates to several outcomes. Cord too short or too long predisposes the fetus to intrauterine dangers. Short cord, mean that cord has length less than 32cm, this length was determined in (1910) by Joseph an obstetrician, who reported that a 32cm was the minimal length necessary for a term fetus to deliver. But in (2008) LaMonica et al, reported that the vaginal delivery can take place with cords as short as 13 cm, which is much shorter than the normal range mentioned by Joseph (1910). The present study showed normal delivery with cord length of about 20cm. however 20cm of the cord length is suitable for fetus to be delivered vaginally in case of twin birth, but cords of less than 20 cm are making problems during pregnancy and delivery. Thus, the finding of a short umbilical cord may indicate diminished fetal movement from either early intrauterine constraint or fetal limb dysfunction.

5.2.1.2. Umbilical cord knot

Incidence of true knot of the umbilical cord is not only very low, but it is often diagnosed antenatally or postnatal, but postnatal detection is more common than antenatal. When the true knot remains tight, it may impede the circulation of the fetus and may result in fetal death in utero especially during labor. In the majority of the cases, true knots of the umbilical cord occur without any clinical significance. However, in some rare cases, an association between umbilical cord knots and intrauterine fetal death was found. A numbers of factors have been described by Hershkovitz et al. in (2001) and Ikechebelu in (2014); to increase the incidence of umbilical cord true knot due to advanced maternal age, multiparity, male fetus and long cord. These factors are similar to the finding of this work. Furthermore the present study found significant correlation between the true knot and cord length P-V 0.001 and true knot and low birth weight P-V 0.001. Because most babies with true knotted cord were born with low birth weight, less than 2000kg. This enhances the results of Ramon, et al. in (2006), who reported similar observation in his study. If the true knot remains very tight it will eventually cause collapse of the cord vessels, this will reduce blood flow to the baby and fetal weight gain will reduce. The present study found the majority of the umbilical cords with true knots have great thickness of Wharton’s jelly at the site
of knot and loose knot; therefore they are protected against occlusion. The tightening knot can occlude fetal circulation resulting in an intrauterine demise. Therefore, the Wharton’s jelly which surrounds the fetal blood vessels has potential of withstanding significant tensional and compression force. Occasionally, adequate Wharton’s jelly may not develop in all segments of the cord. If this occurs, the fetal vessels are no longer protected from tensional force and they are prone to occlusion if twisted leading to fetal demise in utero. In (2000) Sornes, described that true knot can occur anywhere through cord length. Furthermore the present study found that most of the true knots were occurring near to the fetal end of the umbilical cord, and coiled to the left side (anticlockwise direction), because this part moves with fetus. This could explain why the fetus rotates mainly on the left side of uterus, even during pregnancy examination most fetal back are commonly found located on the left side of the uterus. Off all types, the true knots is remains the most serious condition.

Hertzberg et al in (1988) and, Ramon et al in (2006), studied cord knots and reported that false cord knots were occurring due to increased length of the umbilical vein in comparison to the arteries, but when the knots were dissected in the present study, it was found mainly is consist of long tortuous arteries and a central straight vein. This finding is disagreeing with the results of Hertzberg et al in (1988) and, Ramon et al in (2006). The result showed that false knot are occur due to increased length of the umbilical arteries, because normally the arteries are longer than the veins and run spirally or in a tortuous way in their nature, but when the tortuosity increases the false knot creates. The false knot has no known clinical significance, as mentioned by Hertzberg et al in (1988) and, Ramon et al in (2006), but if it becomes multi-knotted it may interrupt blood flow. The study did not find any correlation between the false knot and the fetal weight P-V 0.127.

5.2.1.3. Umbilical cord false cyst

The presence of umbilical cord cyst was studied by many authors. Sepulveda in (2006) studied cord cyst by postnatal sonographcally and reported that, the true cysts are less common, and if present in second and third trimesters, are found associated with an omphalocoele or patent urachus. The false cyst is usually smaller and occurs anywhere along the cord course. Similar observations are also noted by Zangen et al.in (2010). The present study found that the false cysts were multiple and commonly occur in the middle of the cord than peripheral. Chen et al. in
(1995) and Keith et al. (2011), reported that the false were found in about 3% of the umbilical cord, in the present study was about 4.1%. There was no big difference between results in the present study and the results of Chen et al. in (1995) and Keith et al. (2011).

Zangen et al in (2010), who studied the cord cysts in second and third trimesters, reported that the incidence of cord cyst may increase the incidence of congenital anomalies, but in (2013) Hannaford et al, in his study described that patients with umbilical cord cysts were found to have a lower body mass index than those with normal umbilical cord. In this study, as in other publications, no significant correlation was found between the presence of cord cyst postnatal and cord length P-V 0.787 and fetal outcomes P-V 0.577, but it may increase the cord diameter. However detection of the cord cyst prenatally may give significant results than postnatal.

5.2.1.4. Diameter of the umbilical cord

Presence of a thin cord during pregnancy places the fetus at risk of restricted growth and birth weight, classified as small for gestational age. This appears to be a consequence of a reduction in the area of Wharton’s jelly or small cord diameter. The cord diameter is depending on the amount of Wharton’s jelly. Most of previous reports relate cord diameter to the amount of its Wharton’s jelly, and correlated between cord diameter, area of Wharton’s jelly and fetal loss, premature birth and inadequate fetal growth, (Goodlin 1987 and Predanic et al. 2005). In (1994), Weissman et al. studied umbilical cord diameter and its blood vessels, and he calculated the area of Wharton’s jelly at different gestational age and described that, there was increase in cord diameter due to increase in amount of Wharton’s jelly till week 34 then it stabilized. also Sepulveda et al in (2003), and Barbieri et al, (2011), reported that there was an increase in the amount of Wharton’s jelly as a function of gestational age until 32 weeks, after which it remained practically stable until the end of the pregnancy, and described average cord diameter was 1.5 up to 3 cm, at birth. In the present study cord diameter ranging between 0.5 to 2.5 cm with of average 1.5 cm, being big in males and single than in females and twin birth. Moreover this finding confirms the most of pervious findings of Sepulveda et al. (2003) and Barbieri et al. (2011), because it is believed that males have more Wharton’s jelly content than do females. The cord diameter in the present study was found not to exceed 2.5 cm, if cord diameter exceeds 2.5 cm.
In (2007) Togni et al, found that there is a weak correlation between mount of Wharton’s jelly and fetal weight. However, in (2011) Barbieri et al. (2011), shows a direct relationship between gestational age and mount of the Wharton’s jelly of the umbilical cord. The present study also showed significant correlation between umbilical cord diameter and neonatal weight, P-V 0.000. Cords with big diameters were associated with high birth weight. These finding were in agreement with the finding of Sepulveda et al, in (2003), who found that big cord are associated with high birth weight and in contrast to the small ones. Because the big cords have large blood vessels caring large amount of blood leading to an increased fetal weight gain.

It is demonstrated from this work that, there is a significant correlation between cord diameter and neonatal weight. Each 0.1 mm of cord diameter equals 300 grams of neonatal weight, or (multiple cord diameters in mm. × 3000 grams). This fact helps or allows determining fetal weight by measuring umbilical cord diameter, of the normocoiled cord, because the hypercoiled on reduced the blood flow in which the fetal weight will be slow or than normal.

5.2.1.5. Coils of the umbilical cord

There are several researches done about cord design. Collins in (2000) and de Laat et al in (2005), studied cord coiling and reported that, the helical or twisting appearance of the umbilical cord is likely to be due to movement of the fetus within the uterus or helical course of the umbilical vessels, because the arteries are longer than the veins. They added that, the umbilical arteries run in tortuous course within the Wharton’s jelly without branching and restricted anatomical structures or neighboring organs. They also demonstrated that, the intense of twisting can cause urachal and vessel obstruction if they exceed the ability of the cord to absorb. Very helical designs, (spiral, coiled, and curled), may predispose the fetus to certain blood flow changes, and very straight designs may susceptible to compress.

Edmonds in (1954) and Malpas & Symonds in (1966), studied cord coils characteristics at early stage of development, and reported that, embryo develops 6-8 coils from 6-10 weeks when at that time it forms a physiologic umbilical hernia. The coils grow by increasing the turn in between each vein to artery, and as the umbilical cord lengthens the coils get further apart. They reported that the average length cord has 8 to 11 coils, but de Laat et al, in (2005), described 380 coils in his study. In the present study the maximum cord coils was about 45 coils. The difference in cord coils number in the present study and the studies of Malpas & Symonds (1966)
and de Laat (2005), may be referred to differences of the technique used. More coils described by de Laat(2005), may predispose the fetus to certain blood flow changes. The present study found that the coils numbers were varies, depending to the fetal gender, parity of the mother, from cord to another and from area to another through cord length. Males have more coils than females and single has more coils than twin birth, the difference referring to the difference in their cord length and diameter.

Collins in (2002) estimated that coils occur in 10% of deliveries. He found 1 twist/ 9 cm of cord length or less, and the de Laat et al. in (2007), reported that coils occur in 6.14% of deliveries he found a number of completed coil per centimeter, but Erust et al. in (2013), described that, cord have >3 coils/10cm. The present work found number of complete coil per two centimeter or (4 to 5 coils)/ 10 cm of cord length, the present study confirm the work of Erust et al. in (2013). The studies which described coil per centimeter or less did their work prenatally. If a number of completed coils occurred per centimeter, torsion exists, leading to hypercoiled cord, cause blood vessels constriction or obstruction in which the blood flow will impaired and fetal growth also.

The previous studies of Collins in (2002) and de Laat et al. in (2007), were clearly showed the correlation between hypocoiled and hypercoiled cord and poor fetal outcomes, but in (2013) Erust et al, found that the number of cord coils did not correlate with the fetal outcomes. The present study found significant correlation between the cord coils with the cord length P-V 0.000 and with fetal weight P-V 0 .000. The study found that long cords are more coiled than the short ones, because long cords give free mobility for fetus within the uterus in which the cord will gain more coils. More coils in cord may be predispose the fetus to certain blood flow changes and less coils may be susceptible to the cord compression; however in both cases the blood flow of the fetus may affect and fetal weight also.

Among previous studies, Lacro et al. in (1987), found the left coils direction is more common than the right, similar result were found in the studies of de Laat et al (2005), Pathak et al. in (2010) and Ernst et al. in (2013). The present study also found similar result, left coils direction more common than the right. de Laat et al in (2005), found the ratio of left to right twisting was approximately 7:1, in the present study outcomes ratio of left to right twisting was approximately 3:2. This indicates that the fetus may be rotates to the left side more than the right. Ernst et al. in
(2013), found significant correlation between the right coil direction with fetal vessels obstruction and fetal outcomes in compared to left coil, but the present study failed to find any correlation between cord coils direction and fetal outcomes.

According to the numbers of the cord coils, the study found a few cords of groups A (hypocoiled) and group C (hypercoiled), but the majority of the cords of group B (normocoiled). Hypercoiling becomes pathologic when the coiling involves the vein. Because the vein is more likely susceptible to compression, torsion and kinking than arteries.

5.2.1.6. Umbilical cord attachment

Normally the umbilical cord inserts to the fetal surface of the placenta near the center. Abnormal placental cord attachment can affect fetal growth and weight. Failure of cord attachment will cause fetal death. Numerous authors have addressed the significance of abnormal umbilical cord insertion, of them Harris et al. (2000), Vance (2009), Luo & Redline (2013) and Brouillet et al. (2014). They described that the umbilical cord commonly has eccentric insertion. Similar observation also were mentioned by Pathak et al. in (2010) who studied the placental shape, position and cord insertion in term deliveries, described that the eccentric cord insertion was more common than central. A similar result was found in the present study.

In (1978) Woods studied cord insertion site and birth weight and reported that there was no relation between birth weight and whether the cord was inserted centrally, eccentrically or marginally, but in (2005) Loos et al. who studied birth weight and cord insertion, reported that infants with peripheral cord insertion had weight less than infants with central cord insertion. Also in (2014) Brouillet et al, studied cord insertion site on optimal individual birth weight demonstrated that the infants born with peripheral insertion were growth restricted and the neonates with centrally inserted cord were significantly heavier. The present study demonstrated that the cord insertion correlates with fetal weight P-V 0 .005. This is confirming the work of Loos et al. (2005) and Brouillet et al. (2014) whom reported similar observation. The present study found central and eccentric cord insertion having good radiating branching vessels over the fetal surface of placenta than marginal insertion, this will increase blood flow and fetal weight gain. Marginal cord insertion increases the risk of cord vessels rupture, in which the blood will reduce and decrease fetal weight.
Harris et al. (2000), found that about 7%, of cords has marginal insertion and Luo & Redline in (2013), described about 8.4% of cords has marginal insertion. The present study found about 3, 5% of cords marginal insertion. This difference may refer to difference in methods of the studies, Harris et al. (2000) and Luo & Redline in (2013), studied cord insertion ultrasograghically postnatal, while the present study uses visual observation postnatal. The frequency of marginal cord insertion was significantly increased in premature birth or when studied postnatal.

5.2.2.1. Internal structures of umbilical cord

Normally the cord has three vessels. The absence of one umbilical artery is defined as a single umbilical artery (SUA). The exact cause of SUA is unknown, but Bourke et al. in (1993), suggested that it occurs due to primary agenesis or secondary atrophy of one artery in the early stages of embryonic life. Also in (2007), Ghatersamni reported that atrophy is probably the most frequent mechanism for SUA formation. Abuhamad et al. (1995), found that the umbilical artery more commonly absence on the left side; a similar finding was described by Ghatersamni et al in (2007), but in contrast to results of Blazer et al. in (1997) and Fukada et al. in (1998), did not find such difference. The present work failed to determine the side of missing artery, because Abuhamad et al. (1995) and Ghatersamni et al in 2007 they did their works prenatally ultrasograghically and they able to scan fetal abdominal wall, while the present work done postnatally.

Detection of a SUA can be done by several methods before birth by ultrasound or after birth following examination of the placenta. In (1993) Bourke et al. and in (2000) Geipel et al. studied cord blood vessels prenatally, found that the incidence of SUA occurs in about 1% of deliveries; and more common in females than in males babies. In the present study the incidence of SUA was about 1% of deliveries, this is consistent with the available data from examination of the umbilical cord before delivery.

A number of studies have reported that the presence of SUA may be related to a variety of congenital anomalies of the major organ systems as well as to chromosomal defects and low birth weight, of them, Nyberg et al. in (1991), Gornall et al. in (2003), Mu et al. in (2008) and Dane et al. in (2009). The reported anomaly associated with incidence of SUA greatly differs and may be influenced by, race, geographical and socioeconomic factors. The present study showed two cases of nervous system abnormalities; spina bifida associated with hydrocephalus.
In (2003) Gornall et al. and (2008) in Mu et al. found that presence of a SUA correlated with the low birth weight, but the present study found that presence of a SUA unrelated to low birth weight, P-V 0.366. The weight of the neonates of a SUA in the present study ranged from 3000 - 3500 kg, presence of one artery in the cord is enough to maintain the blood circulation and fetal weight gain. One artery is enough for the baby to be born healthy, but in rare cases it can be a signal for a higher risk of certain birth defects. In fact few babies born with a SUA showed birth defects. Umbilical cord with four vessel is rare, and been reported by Heifetz (1984), in conjoined twins, the present study didn’t found cord with four blood vessel either in single or twins birth. The present study found a SUA was more common in males than females babies and was associated with multiparity and advanced maternal age. Similar finding was noted by Fujikura in (2003) and Santillan et al. in (2012), but Bourke et al. (1993), Geipel et al. (2000) and Marie, et al. (2009) found that the incidence of a SUA is more common in females than in males.

The relationship between the vein and arteries within the cord varies. Commonly the vein runs centrally with arteries in the periphery in three vessels cord, or the vein and artery course together in parallel fashion in two vessels cord. Moreover they don’t run close each other like the rest of the blood vessels in the body; they are separated by a wide tissues structure and located in soft mucous of Wharton’s jelly without branches elements. The present study found that the dominant tissues of the human umbilical cord vessels wall were smooth muscle with thin layer of cells lining the vessel opening. A similar finding was observed by Ernst et al in (2013). They found that, the design of the smooth muscle cells is inner layer runs with the vessel lengthwise, while the outer layer runs in circle ways. Contrary to the findings of Ernst et al in (2013), the present study found that, inner layer runs in circle ways while the outer muscular layer runs with the vessel lengthwise. The arrangement of smooth muscles in wall of cord vessels in this study similar to arrangement the muscles in wall of esophagus, these arrangement will allow the cord to shorten and elongate during fetal movements within uterus. In this study adventitia was not clearly seen either in wall of arteries or vein, a similar observation found by Meyer et al. in (1978) and Gill & Jarjoura in (1993), but the present study showed a highly condensed tissue around the cord vessels. However these tissues could be maintenance the vessels wall especially the vein, because the vein runs straight and under tensile forces more than the arteries and the helical nature of arteries adapt the tensile force of the neonate.
CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

Throughout human history, stillbirths and neonatal outcome after delivery has been associated with umbilical cord findings. Cord abnormalities may put the baby in higher risk of certain diseases or low birth weight. The etiology of the umbilical cord abnormalities are not clear diagnosis. Although the fetal mortality associated with umbilical cord abnormalities is very high, identification of the fetus at risk has remained a difficult problem. In this study it is concluded that

1. Neonatal weight and height more in males than females.
2. Birth weight correlates with cord length, diameter, numbers of coils, true knots, and cord insertion site and socioeconomic of the mother, but there was no correlation between birth weight and false knots, blood vessels or BIM of the mother.
3. Cord length correlate with neonatal weight, height, gender and socioeconomic status of the mother, but not with cord cyst and BMI of the mother
4. The average length of the umbilical cord in Sudanese neonates about 55 cm, being long in males and single birth. There is no big difference in the cord length measurement before and after birth, comparing the two methods (ultrasound and manual measurements). 20cm of the cord length is suitable for fetus to be delivered vaginally.
5. Average cord diameter in Sudanese neonates about 1.5 cm, being big in males and single birth. The measurement of cord diameter can help for detection of neonatal weight, 0.1mm of the cord diameter equal 3000grams of the birth weight.
6. Maximum umbilical cord coils in Sudanese neonates about 45 coils, being, more in males and single birth.
7. In Sudanese neonates the eccentric umbilical cord insertion to placenta is more common than central and marginal.
8. The false knots of the umbilical cord are more common than true knots. False knot occurs due to increased length of the umbilical vein in comparison to arteries, and has no known clinical significance.
9. Most of the cord true knots located near to the fetal end of the umbilical cord, and they were commonly coiled to the left side (anticlockwise direction)
10. The incidence of a SUA in Sudanese neonate about 1% more common in males, its incidence associated with multiparity and advanced maternal age. One artery is enough for the baby to be born healthy.

11. The dominant tissues of the umbilical cord vessels is smooth muscle without clear adventitial layer either in wall of arteries or vein, but the wall of vessels around by dense tissue structures.
6.2. RECOMMENDATIONS

The fetal membranes have a very important role in the fetal development. It’s very important to know the detailed anatomy and any associated congenital anomalies that may affect the neonatal outcome. As the umbilical cord is one of the fetal membranes, it has great significances.

It is recommend that:

1. The doctors and midwifes should give consideration about umbilical cord in the labor room, it should be carefully examined immediately after the delivery from end to end, and they should know all cord morphological features and its clinical significance during and after the birth.

2. The umbilical cord congenital abnormalities should be given care after delivery, because they may give clues about the neonatal status.

3. Studying the cord congenital abnormalities at the labor room, help for diagnoses of some neonatal diseases.

4. Umbilical cord diameter can be used as one of the measurement of neonatal weighing at delivery.

5. There is a further need for routine continuous studies to look for more correlations correlates between the umbilical cord morphological features and neonatal outcome.
REFERENCES


APPENDICES

Gezira University
Postgraduate Studies
Faculty of Medicine and Health Sciences

Questions submitted for fulfillment of the requirement of Ph.D in Human anatomy

Correlation between the Umbilical Cord Morphology and Birth Weight
in Full Term Sudanese Neonates

- case number __________

A-Mother:
1- Age of the mother _______ years.
2- Residence ____________________________
3 -Tribe ____________________________
4-Menarche at _______ years
5- Katamina -regular _______ -irregular _______ - amount _______ -associated with colts _______
   -Pain _______ abnormal vaginal discharge _______ intermenstural bleeding _______
   -Use of contraceptives _______ - how long _______ years
6 -Duration of marriage _______ years
7- Diet of the mother during pregnancy: - good diet _______ - poor diet _______
8- Number of pregnancies Gravida _______ - No of deliveries Para _______
9- Term of delivery- _______ full term delivery - per term _______
10- Socioeconomic class: - high income _______ -medium income _______ - low income _______
11- Social habits of the mother: - alcoholic _______ - smoker _______ - snuffer _______
   - Other ........................................................................................................
12- Chronic diseases of the mother: -diabetes _______ - hypertension _______ - renal _______ - asthma _______
   - Others………………………………….- Any chronic medication.........................
13- Weight of the mother _______ kg.
14- Height of the mother _______ cm.
15- Complications during the pregnancy (bleeding): in 1st trimester _______ -2nd trimester _______ - in3rd
    trimester ______
### B-Neonate:

16- Sex of the neonate:  
- Male ☐  - Female ☐

17- Number of neonates:  
- single ☐  - twins ☐  - triplets ☐  - Quadruplets ☐

18- Weight of the neonate ☐ kg.  
- Height of the neonate ☐ cm.

### C-umbilical cord

- **Gross features.**

19- Length of umbilical cord ☐ cm.

20- Diameter of the umbilical cord ☐ cm.

21- Number of umbilical cord coiling ☐ coils

22- Direction of coiling:  
- to right ☐  - to the left ☐

23- Umbilical cord attachment:  
- central ☐  - near to the center ☐  - marginal ☐

24- Umbilical cord knots:  
- absent ☐

- present ☐  - if present - true ☐  - or false ☐

25- Umbilical cord cysts:  
- absent ☐

- present ☐  - if present – true ☐  - or false ☐

26- Number of the cord vessels:  
- No. of arteries ☐  - No. of veins ☐

27- Placenta abnormalities.

- **Histology.**

28- Diameter of the umbilical cord ☐ cm.

29- Diameter of the umbilical cord vessels:  
- diameter of the arteries ☐ cm  
- diameter of the vein ☐ cm

30- Mount of the Wharton’s jelly

- Other comments.................................................................................................................................