



# Twins, Complications and Vaginal Delivery: Vaginal vs. Cesarean Section Deliveries and Opportunities for Improvement

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Twins, Complications and Vaginal Delivery:  
Vaginal vs. Cesarean Section Deliveries and Opportunities for Improvement

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A Thesis in the Field of Bioengineering & Nanotechnology  
for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

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## Abstract

With the rise in twins born each year, there is an increased concern with how to ensure twin delivery is conducted safely for both mother and infants (CDC, 1998, 2015, 2017). A gestation that has multiple fetuses can lead to complications throughout the gestation and during delivery for both the mother and the babies (Choi, 2010). The complications during delivery of multiples often lead doctors to choose the route of cesarean section (Office of Communications NIH, 2017). This study evaluated the safety of cesarean delivery of twins in comparison to vaginal delivery. The goal was to assess the complications, identify key factors in successful delivery and compile recommendations that promote safe vaginal delivery of twins. If medical professionals and mothers follow a set of guidelines, administer medication when necessary, and apply technology in greater frequency, they may have healthier pregnancies and there may be potential to change the practice to be more confident in vaginal delivery of twins. By better understanding twin pregnancies and deliveries, parents can make more informed decisions and medical professionals can find novel ways to manage it. In this thesis, studies were reviewed to assess the safety of vaginal delivery as compared to cesarean delivery. Studies were also reviewed to analyze the effect of lifestyle changes, technology use and medication administration on pregnancy and delivery outcomes. The findings were that technology and lifestyle maintenance may prevent some complications. Findings did not confirm that all medications are effective at preventing complications in all twin cases.

## Frontispiece



(Huhman, 2020)

### Author's Biographical Sketch

Born in Italy of Cape Verdean parents and raised in the United States. I am a melting pot of culture and knowledge. I grew up in Providence, RI and attended various public schools in RI. After grade school, I attended the University of Rhode Island and graduated with a Bachelor of Science in Biological Sciences and a minor in Psychology. My ambition growing up was to go into medicine as I found obstetrics very interesting. My passion is to study fetal development and delivery. My hope is that I can contribute knowledge that will make delivery of all babies safe and memorable for all women.

## Dedication

This thesis is dedicated to my daughter Penelope. May you grow to be a healthy, intelligent, and happy woman. May the obstetrical advancements of today benefit you in your lifetime.

## Acknowledgments

This thesis was possible because of the many people who supported me. To my mother Maria for working hard to give us what we needed growing up and today. To Francesca for always pushing me to be better. To my boyfriend Junior for supporting me through the good days and the bad. To my sister Alessandra for the long and deep conversations that helped me get through the hard days. To my best friend Annie for always providing a helpful hand and a nudge here and there. Lastly, to Dr. Bhatia for guiding me through this thesis process.



## Table of Contents

Frontispiece.....	iv
Author’s Biographical Sketch.....	v
Dedication .....	vi
Acknowledgments.....	vii
List of Tables .....	x
List of Figures .....	xi
Chapter I. Introduction.....	1
Complications .....	10
Route of Delivery.....	16
Chapter II. Materials and Methods .....	27
Technology .....	28
Lifestyle .....	29
Medication .....	31
Vaginal vs. Cesarean.....	31
Chapter III. Results .....	33
Technology .....	33
Lifestyle .....	35
Weight Gain.....	35
Exercise.....	38
Nutrition.....	39

Medication .....	41
Vaginal vs. Cesarean.....	43
Delivery of Twins .....	45
Studies on Pregnancy Outcomes.....	46
Chapter IV. Conclusion .....	54
Appendix 1. Glossary.....	62
References .....	63

## List of Tables

<b>Table 1:</b>	Types of twins.....	3
<b>Table 2:</b>	Types of major anomalies out of 10,000 cases .....	13
<b>Table 3:</b>	Congenital anomaly cases: multiple vs. singleton pregnancies .....	13
<b>Table 4:</b>	Multiple pregnancy monitoring methods.....	33
<b>Table 5:</b>	Weight gain in pregnancy according to BMI.....	37
<b>Table 6:</b>	Twin daily diet requirements .....	40
<b>Table 7:</b>	Characteristics of participants in the progesterone study .....	43
<b>Table 8:</b>	Participant variables for the prenatal care and education study.....	47
<b>Table 9:</b>	Demographic and clinical parameters.....	51
<b>Table 10:</b>	Mode of delivery in the vaginal delivery-intention group.....	51
<b>Table 11:</b>	Neonatal outcome: cesarean vs. vaginal .....	52
<b>Table 12:</b>	Management of twin pregnancy & delivery summary .....	54

## List of Figures

<b>Figure 1:</b>	Total U.S. Births from 1980-2017 .....	6
<b>Figure 2:</b>	Total Triplet/+ Births from 1980-2017 .....	6
<b>Figure 3:</b>	Total Twin Births from 1980-2017 .....	7
<b>Figure 4:</b>	Total Number of Singleton, Twin, Triplet + Births, 1980-2018 .....	8
<b>Figure 5:</b>	Gestational Age vs. Plurality .....	10
<b>Figure 6:</b>	Birthweight vs. Plurality .....	12
<b>Figure 7:</b>	Route of Delivery- Vaginal vs. Cesarean .....	18
<b>Figure 8:</b>	Cephalopelvic proportions at the pelvic inlet .....	20
<b>Figure 9:</b>	Timeline of human evolution and obstetrically relevant traits .....	21
<b>Figure 10:</b>	Pregnancy Weight Gain- Twins vs. Singletons .....	38
<b>Figure 11:</b>	Pregnancy Outcomes .....	48
<b>Figure 12:</b>	Neonatal Interventions .....	49
<b>Figure 13:</b>	Neonatal Diagnoses .....	50
<b>Figure 14:</b>	Outcomes vs. route of delivery and fetal position .....	53

## Chapter I.

### Introduction

In recent decades, it seems that multiple gestational pregnancies are on the rise. Cesarean delivery has also been on the rise in recent years. Both occurrences have created great concern due to the obstetrical complications that are associated with them. Multiples are considered twins, triplets or higher order multiple gestation pregnancies (Martin et al., 2018). Recent findings suggest that the prevalence of multiple births is on the rise, mainly due to assisted reproduction (Doyle, 1996). Many professionals are troubled with this finding and have been pushing to refine guidelines (Kulkarni et al, 2013). The complexities of maintaining a healthy twin pregnancy and safe vaginal delivery rely on various influences. In this study lifestyle choices, technology use and medication administration are evaluated to see if there are ways to improve the safety.

Understanding the definition of twins and categorizing them is the first step in breaking down the complexities of twin pregnancy and delivery. According to the CDC, the definition of multiples is a gestation that involves more than one infant, i.e. twins, triplets, etc. (Martin & Park, 1999). Multiple gestational pregnancies and births typically occur less frequently than singleton pregnancies (CDC 1998, 2015, 2017). Multiple gestational pregnancies can also be, at times, very different as compared to singleton pregnancies from conception to delivery (Martin, 2013). The following sections will review the types of twins, evaluate statistics on all births and discuss some of the differences between multiple gestational pregnancies and that of singleton pregnancies.

Twins are complicated in many ways, so when creating protocols for prenatal care and labor, every variable must be analyzed. Understanding the fundamentals is the first step, which is knowing how to differentiate between the type of twins. This will dictate what protocol a practitioner will most likely follow. See **Table 1** below for a basic explanation of the types of twins (Leiter et al, 2000). All blue highlighted sac orientations are examples of monozygotic twins, and all green are dizygotic twins (Leiter et al, 2000). Determining the type of twins is important for many reasons such as: twin to twin transfusion syndrome (TTS), which is of concern due to the size difference between the two fetuses, twin congenital malformations in one fetus amongst the set of twins, and death of one of the fetuses amongst the set of twins (Di Renzo et al, 2001). The death of one of the fetuses as well as chord entanglement are some of the concerns with monochorionic twins, as they can be fatal for the other fetus (Di Renzo et al, 2001). The combination of sac and fetal presentation is important to understand when looking to manage the pregnancy and delivery.

**Table 1:** Types of twins

Sac Orientation		Monozygotic Twins	Dizygotic Twins
		<ul style="list-style-type: none"><li>• One egg, one sperm</li><li>• Always the same gender</li><li>• Fertilized egg divides between 2 and 17 days after fertilization</li></ul>	<ul style="list-style-type: none"><li>• Two eggs, two sperm</li><li>• 50% are different genders</li></ul>
1 placenta	fused placenta	<b>Dichorionic-Diamniotic</b> division within 3 days of fertilization 30% of monozygotic twins	
2 chorions			
2 amnions			
1 placenta	most common	<b>Monochorionic/Diamniotic</b> division 4-8 days after fertilization 68% of monozygotic twins	
1 chorion			
2 amnions			
1 placenta	rare & most at risk for complications	<b>Monochorionic/Monoamniotic</b> division 8-13.5 days after fertilization ***division after 13.5 days may result in incomplete genetic material division and in conjoined twins 1-2% of monozygotic twins	
1 chorion			
1 amnion			
2 placentas			
2 chorions			
2 amnions			

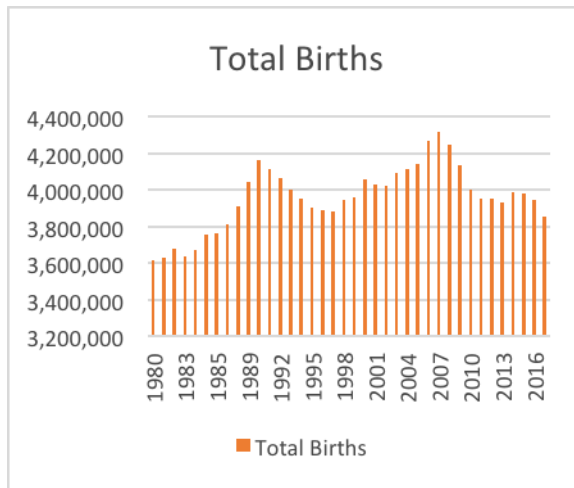
There are generally two main types of twins, monozygotic and dizygotic (Leiter et al, 2000). **Table 1** shows how monozygotic twins result when one egg is fertilized with one sperm and then at some point in the growth process it divides to create two separate fetuses (Leiter et al, 2000). Whereas dizygotic twins originate from two separate eggs fertilized by two separate sperm cells (Leiter et al, 2000). Dizygotic twins can be of either sac presentation: each fetus has its own separate placenta, chorion and amnion, or each fetus can have its own chorion and amnion and share one placenta (Leiter et al, 2000). There are three types of monozygotic twins that are based on the chorionicity and

amnioticity, which occur at different moments of the growth process (Leiter et al., 2000). Dichorionic-diamniotic refers to two fetuses each in its own amnion and chorion (Leiter et al., 2000). Monochorionic-diamniotic refers to two fetuses within their own amnion but sharing one chorion (Leiter et al., 2000). The last is monochorionic-monoamniotic which refers to both fetuses sharing the same amniotic sac and within the same chorionic sac (Leiter et al., 2000). Knowing the type of twin, may present complication flags to look out for in the pregnancy and during delivery.

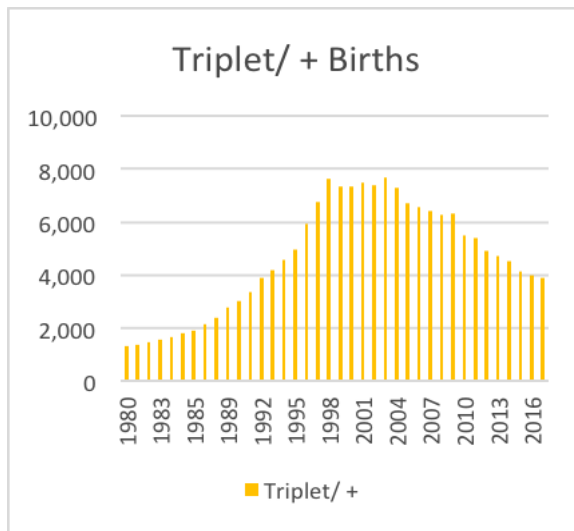
Monochorionic-monoamniotic twins are the rarest and the most at risk of complications (Leiter et al., 2000). This is key in early diagnosing, because physicians should place even closer observation on pregnancies carrying monochorionic-monoamniotic twins. In order to differentiate monoamniotic twins from the other types there are a few factors that must be checked off: the amniotic membrane must be fully intact with no division, there should only be one placenta, both fetuses must be the same gender, the amniotic fluid present should be of sufficient amount, and both of the fetuses should be able to move within the uterus without impediment (Di Renzo et al., 2001). Once the twin type has been identified, it is advisable that experienced staff or centers take over the prenatal care and delivery, or at the least work jointly with experienced practitioners (Di Renzo et al., 2001). Secondary or tertiary centers may be better equipped to handle twin complications during pregnancy (Di Renzo et al., 2001). Practitioner experience will be discussed further in subsequent sections. But first a review of U.S. birth statistics provides some context regarding twin births in comparison to singleton and higher order multiples.



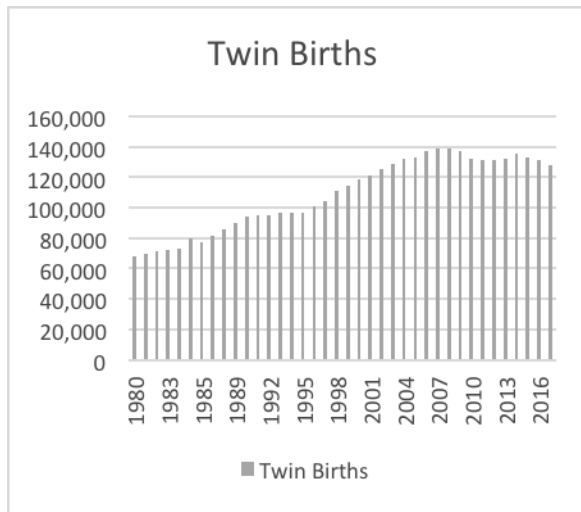
Generally, statistical analysis of births in the U.S. in recent years have shown an increase (CDC 1998, 2015, 2017). There is some fluctuation between 1980 and 2017, but overall, the rate of births has increased from approximately 3.6 million to 3.8 million (**Figure 1**) (CDC 1998, 2015, 2017). The occurrence of triplet and higher order births have also increased in the U.S (see **Figure 2**) (CDC 1998, 2015, 2017). Tripling from 1,337 in 1980 to 3,917 in 2017 (CDC 1998, 2015, 2017). It is interesting to note, that triplet/ + births increased significantly from 1980 to 1998, (see **Figure 2**) (CDC 1998, 2015, 2017). Then the annual birth numbers of triplets/+ gradually decreased (CDC 1998, 2015, 2017). Twin birth numbers followed a completely different path (see **Figure 3**) (CDC 1998, 2015, 2017). Twin births have gradually risen from 1980 to 2017, with the later years slowly dropping (CDC 1998, 2015, 2017). This steady drop appears to show some resistance as compared to triplet and higher order multiples (CDC 1998, 2015, 2017). There seems to be something significantly different about twin births in comparison to triplet and higher order births, as well as singleton births (CDC 1998, 2015, 2017).



**Figure 1:** Total U.S. Births from 1980-2017

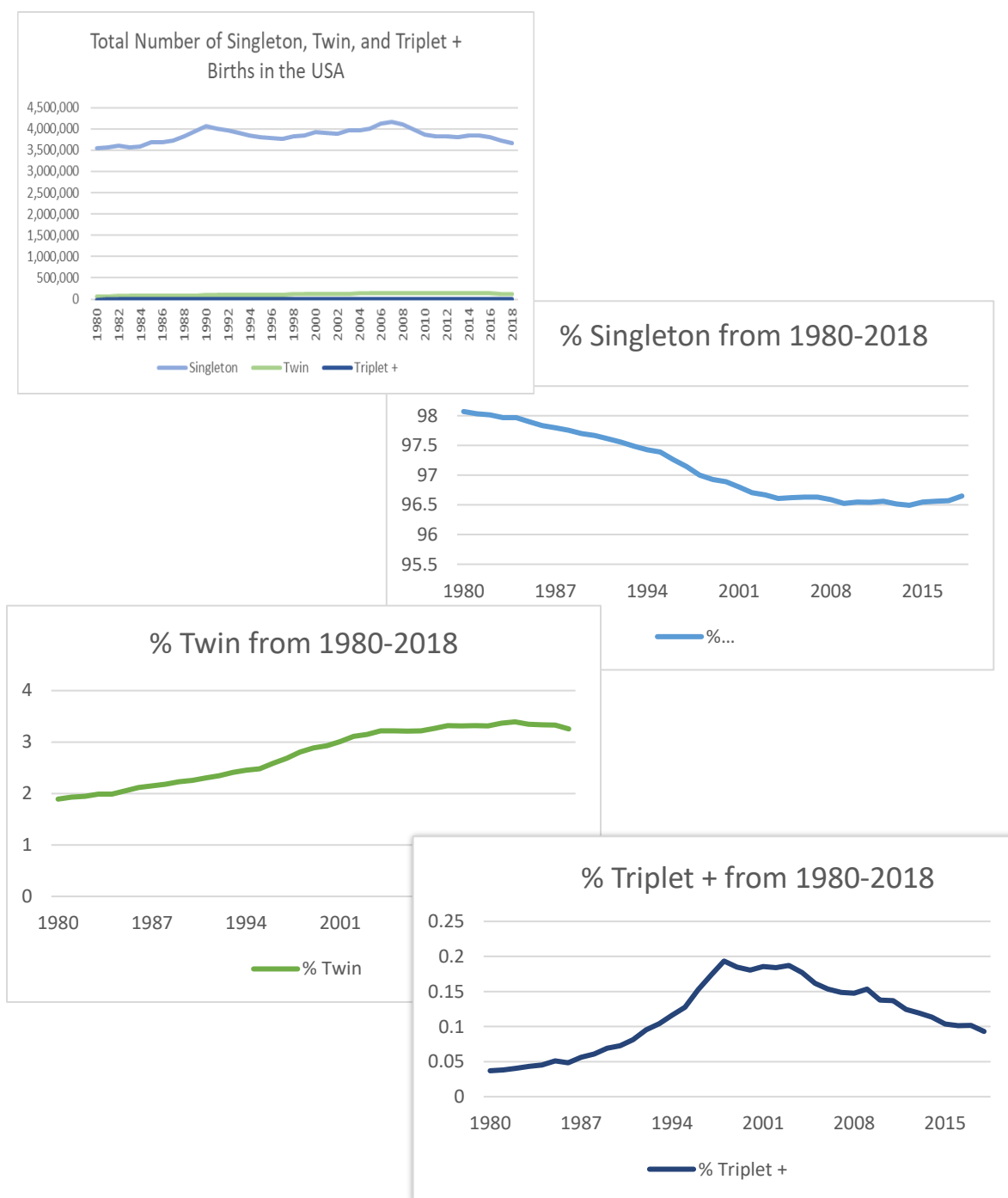


**Figure 2:** Total Triplet/+ Births from 1980-2017



**Figure 3:** Total Twin Births from 1980-2017

Taking a closer look at Figure 1, 2, and 3 will show the progression of births. Placed together it is hard to see how singleton births, triplet + and twin births all compare to total births. **Figure 4** displays this comparison in greater detail among births in the USA (CDC, 2012, 2019). In the first figure, **Figure 4A**, one can see the overall comparison, and then **Figure 4B, C, and D** break down **Figure 4A** to provide a closer look at the trend (CDC, 2012, 2019). Between 1980 and 2018, the average total number of births per year in the USA was 3,953,123 (CDC, 2012, 2019). Within this average of births per year, 97.12% were singleton births, 2.77% were twin births and 0.12% were triplet and higher order births (CDC, 2012, 2019). These numbers can be misleading. It seems that multiple births are not significant enough and it is difficult to see the trend. More in later sections will be discussed regarding the importance of studying multiple births, especially twins. But simply looking at the details in **Figure 4**, births of multiples in the past 39 years show that there is something significant about twin births.



**Figure 4:** Total Number of Singleton, Twin, Triplet + Births, 1980-2018

*Figure 4A: Total number of births in the USA broken down by singleton, twin, triplet and higher order multiples. The following three graphs are a zoomed-in image of Figure 4A. Figure 4B: Percent of singleton births in the USA. Figure 4C: Percent of twin births in the USA. Figure 4D: Percent of Triplet + births in the USA.*

It seems clear that multiple gestational pregnancies are on the rise and they may continue to rise with the increased use of assisted fertilization procedures and medications. Some believe this increase in assisted pregnancy technology is the direct cause (MedlinePlus, 2018). Medications such as clomiphene, induce ovulation and may induce the release of multiple ova (MedlinePlus, 2018). Medline also notes that there is an increased chance of having twins when taking clomiphene (MedlinePlus, 2018). Clomiphene is one of a few medications that induce ovulation, but medication is not the only form of assisted reproduction.

In vitro fertilization (IVF) is another form of assisted reproduction technology (ART) that may also be adding to the increase in multiples incidence (Doyle, 1996). IVF involves retaining several ova, fertilizing, and developing them in the lab and then transferring them to the mother's uterus (Progyny, 2018). Previously, IVF involved transferring multiple embryos into the mother in hopes that at least one would implant (Progyny, 2018). Recent advancement in medicine has allowed women and medical professionals to have more confidence in the transfer of only one embryo (Progyny, 2018). These improvements continue to make the IVF process more efficient over time.

The quality of IVF has come a long way since its introduction in the 1970s (Zhu, 2009). In a study conducted by Kulkarni et al. (2013), researchers show that IVF may have led to an increase in multiples based on the prevalence of multiples when IVF was first medically introduced. Then the number of multiples declined around 1998, which Kulkarni et al. (2013) believes correlates with the introduction of IVF clinical guidelines. These guidelines were tailored to focus toward lowering the number of multiple births obtained through IVF (Kulkarni et al., 2013). There seems to be no way to know how

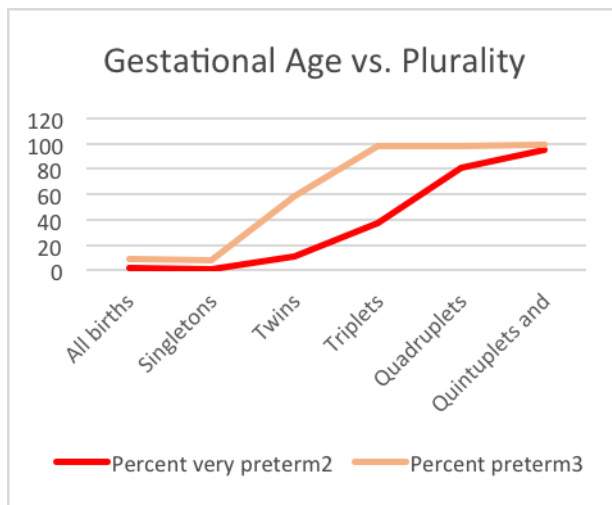
many live births will result from the transfer. For women who choose multiple embryo transfer, it is also probable that more than one embryo will implant due to egg splitting, leading to multiples (Ikemoto et al., 2018). With this said, there is a growing debate on whether multiple embryo transfer is ideal. Many fear that it may be detrimental to the health of both the mother and the babies (Doyle, 1996). Unfortunately, preventing conception of twins entirely is not an option, particularly when they are conceived naturally. It might be more valuable to apply the research energy instead toward improving IVF protocols and improving the procedures when delivering multiples, specifically twins?

### Complications

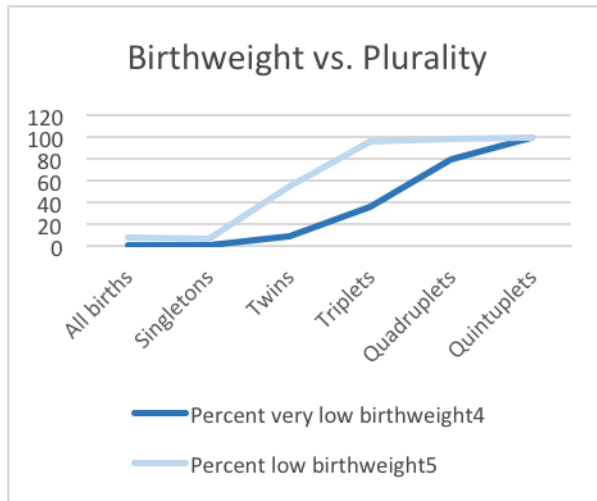
Multiples pregnancy is different from singleton pregnancy (one infant) in many ways, especially involving the complications (Choi, 2010). Some women are fortunate to have a normal multiples gestation and vaginal delivery, but for many, this is not possible. Complications include preterm births, mortality, low birth weight, hemorrhaging, medical abnormalities for both mother and infants (Choi, 2010). Other complications include cervical incompetence, polyhydramnios, growth discrepancy and growth retardation of one of the fetuses, intrauterine fetal death, preeclampsia, and gestational diabetes (Di Renzo et al., 2001). There are many more complications that are not listed here.

As the number of infants increase, so does the incidence of preterm and low birth weight. (see **Figure 5 and 6**) (CDC, 1998, 2015, 2017). This is a concern because preterm babies are at greater risk of health problems, improper development, and mortality (Martin & Osterman, 2018). Preterm birth is a major problem with twin pregnancies, 50% of twin's deliver before 37 weeks and 9% deliver before 32 weeks

(Schuit et al., 2014). It is interesting to note that up to 27 weeks, both multiple gestational fetuses and singleton fetuses all display around the same amount of weight gain (Martin, 2013). It is not until after this gestational period that multiples tend to slow down in the amount of weight gain in comparison to singleton fetuses (Martin, 2013). It is believed that the womb expansion abilities are the cause, it is limited in how much it can expand to accommodate the quantity of fetus's present (Martin, 2013).



**Figure 5:** Gestational Age vs. Plurality



**Figure 6:** Birthweight vs. Plurality

Pregnancy involving multiples may also be different compared to singleton pregnancies involving congenital anomalies. According to the World Health Organization, congenital anomalies are birth defects and disorders (WHO, 2016). Congenital anomalies occur in both cases of multiples and singletons (Glinianaia, et al. 2008). The more prevalent anomalies found in twin births in a study by Glinianaia et al. are genitourinary system anomalies, cardiovascular anomalies, central nervous system anomalies, musculoskeletal anomalies, and chromosomal anomalies (2008). See **Table 2** for statistics on some common congenital anomalies observed in the Glinianaia study (Glinianaia, et al. 2008).



**Table 2:** Types of major anomalies out of 10,000 cases

Types of major anomalies out of 10,000	Twins ( <i>n</i> )	Singletons ( <i>n</i> )
Central nervous system	24	326
Cardiovascular	51	1146
Chromosomal	20	649
Genito-urinary system	25	427
Musculoskeletal system	19	292
Other anomalies	31	677
Twin-specific anomalies	11	—

In a study by Boyle et al., complications in multiples were classified into three categories: all congenital anomalies, non-chromosomal anomalies, and chromosomal anomalies (2013). **Table 3** shows a comparison between multiples vs. singletons in the percentages of congenital anomalies within each type from 1984 to 2007 within 14 European countries (Boyle et al., 2013). Non-chromosomal anomalies refer to cases that resulted in no genetic disorders, whereas chromosomal anomalies refer to the cases where multiples were born with genetic disorders (Boyle et al., 2013).

**Table 3:** Congenital anomaly cases: multiple vs. singleton pregnancies

% Multiple births vs. % Singleton births						
Year-groups	All congenital anomaly cases		Non-chromosomal anomalies		Chromosomal anomalies	
1984-87	2.41	2.28	2.16	2.03	0.25	0.25
1988-91	3.19	2.65	2.91	2.31	0.27	0.33
1992-95	3.67	2.79	3.34	2.41	0.33	0.38
1996-99	3.28	2.68	2.99	2.33	0.29	0.34
2000-03	3.74	2.83	3.54	2.5	0.2	0.33
2004-07	3.55	2.66	3.26	2.27	0.29	0.39
Total	3.49	2.7	3.23	2.35	0.26	0.35

Although the Boyle et al. study did not decipher between twins and other higher order multiples, it is interesting to note that the study reviewed 148,359 births with congenital anomalies and 3.83% of these births were cases involving multiples (2013). The breakdown showed that in multiple births they found that non-chromosomal congenital anomalies represented 3.23%, whereas chromosomal anomalies cases represented 0.26% (Boyle et al., 2013). Another interesting note that was discussed in the Boyle et al. study was that it is unknown whether the complications occurred because they were twins, due to ART procedures, or if it was related to underlying problems with the parents (Boyle et al., 2013). If the complications were ART related, then Boyle et al. believes that transferring one embryo could result in similar findings (Boyle et al., 2013). Same goes to problems within the parents, if a mother has a condition that causes her to seek ART, maybe it will not make a difference whether she has one child or twins (Boyle et al., 2013). Either way the probability of having complications will still be present and can simply distribute to each fetus (Boyle et al., 2013).

Although, chromosomal anomalies do not appear to occur more in twins than singletons, there are some anomalies that do occur more in twins (Di Renzo et al., 2001). Twin pregnancies have double the chance of having fetal malformations as compared to singletons; monozygotic twins have double the chance compared to dizygotic twins (Di Renzo et al., 2001). These malformations include conjoined twins, acardiacus and fetus-in-fetu (Di Renzo et al., 2001). There are also positional and vascular complications. Positional defects occur because of limited space and these include clubfoot and congenital dislocation of the hip (Di Renzo et al., 2001). Anomalies that occur because of vascular complications after fetal death of one twin include “congenital skin defects,

microcephaly, hydrancephaly, porencephaly, multicystic encephalomalacia, hydrocephalus, intestinal atresia, and limb amputation” (Di Renzo et al., 2001). These are just a fraction of possible anomalies, but there are more complications.

Another complication that comes up in pregnancies is Down Syndrome. It is interesting to note though that in one study cases of Down Syndrome were reported to be fewer in twins than in singletons (Glinianaia, et al. 2008). Overall, Down Syndrome prevalence is the same for singleton and twin pregnancies, but the rate of Down Syndrome still ends up occurring more often in twin pregnancies, 1:1.28 chance (Di Renzo et al., 2001). Each fetus has an independent chance of being born with Down Syndrome (Di Renzo et al., 2001). In dizygotic twins (two eggs are fertilized), mothers have two [independent] chances of [either one or both] having Down Syndrome (Di Renzo et al., 2001). In monozygotic twins (one fertilized egg that splits into two), both fetuses will have Down Syndrome (Di Renzo et al., 2001).

As it seems, twin pregnancies are very complex and often lead to complications. If assisted reproduction has led to an increase in multiples, then why do women continue to seek these procedures? Many women who seek assisted conception often do so because of infertility problems (Mayo Clinic Staff, 2017). One example involves women with Polycystic Ovaries Syndrome (PCOS) (Mayo Clinic Staff, 2017). Women with PCOS suffer from hormonal disruptions that often lead to infertility (Mayo Clinic Staff, 2017). Those who can conceive naturally or through ART, are already at a higher risk of developing gestational diabetes and/or preeclampsia in comparison to healthy women (Mayo Clinic Staff, 2017). Conditions like PCOS if not controlled, lead to a greater probability of deliveries ending in cesarean section (Office of Communications NIH,

2017). IVF is also common in older women who often have had trouble conceiving naturally for years (Carroll & Yeomans, 2006). But with older age comes an increased risk of complications and a natural increased rate of multiples (Carroll & Yeomans, 2006). So it may be inevitable that twins will be conceived with or without the assistance of ART. Vaginal delivery in these situations tend to be associated with risks for the mother and baby's health, as a result many of these deliveries are through cesarean-section (Office of Communications NIH, 2017). But cesarean section in itself comes with its own complications.

### Route of Delivery

Cesarean section as discussed in the previous section is often the route taken when delivering twins or complicated pregnancies. Cesarean section (C-section) is a surgical procedure in which the baby is delivered through an incision in the mother's lower abdomen (MedlinePlus, 2015). If the mother was unable to maintain a healthy pregnancy, then chances are she may not be able to deliver vaginally (MedlinePlus, 2015). As this may be highly risky for the mother and baby's health (MedlinePlus, 2015). There is more to a c-section than discussed thus far.

Cesarean section deliveries have been conducted for centuries and once had such low survival rates for the mother – physician conducted c-sections were 2/20 (Horgan & Farine, 2015). Around 1875 analgesia was invented, which drastically improved the survival rates of c-sections (Horgan & Farine, 2015). Maternal survival rates continued to increase once blood transfusions and antibiotics were introduced around the 1940s (Horgan & Farine, 2015). In addition to these techniques, Gregory, K. et al. cited 85% of mothers were dying due to c-section procedures in the 19<sup>th</sup> century (2012). This was

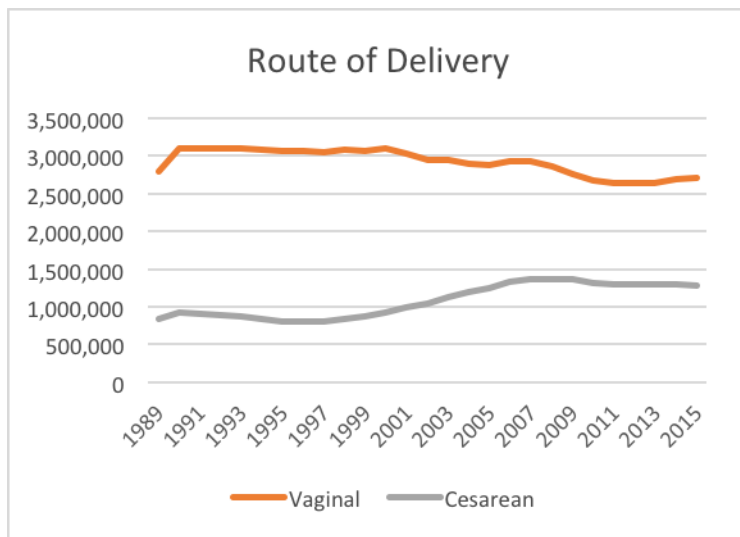
before improvements in a cohort of techniques: aseptic technique, suture materials, and the change to low transverse uterine incision (Gregory et al., 2012).

Cesarean delivery is a costly procedure that is being conducted even more in recent years as discussed in the following sections. The delivery of multiples often requires cesarean section procedures (Doyle, 1996). Multiples deliveries are often complicated, and these babies typically stay in the intensive care units until they are stabilized (Choi, 2010). This can be costly, and then to add on C-section costs, may be financially drowning to the family. With the increase in the incidence of multiples being born, cesarean section procedures are most likely going to also rise. Even though, this may be financially pleasing for hospitals and the insurance companies, it is not necessarily the best option for the families. In some instances, doctors may deliver twins vaginally, but as the number of babies increase, the probability of requiring C-section becomes more definite (Doyle, 1996). Triplets and higher order births are almost always delivered through C-section (Doyle, 1996). In some countries, cesarean sections are highly preferred even in singleton delivery (Zakerihamidi, 2015). According to Castlight, cesarean sections cost roughly a few thousand dollars more than vaginal delivery (Mangan, 2016). In the end, the hospitals and insurance companies are benefiting, while families are recovering physically and financially for an extended period.

Unfortunately, cost for cesarean deliveries is not the only problem, complications and recovery times are also concerning with cesarean. C-section complications include infection, hemorrhaging, and blood clots, to name a few (MedlinePlus, 2015). Families may not be aware that recovery is often longer for the mother and puts her at risk of future complications with birthing (MedlinePlus, 2015). C-section procedures require

longer stays in the hospital and often require the use of anesthesia (Mayo Clinic Staff, 2018). It may be more valuable to replace the c-section route with vaginal birth amongst twin pregnancies at the least.

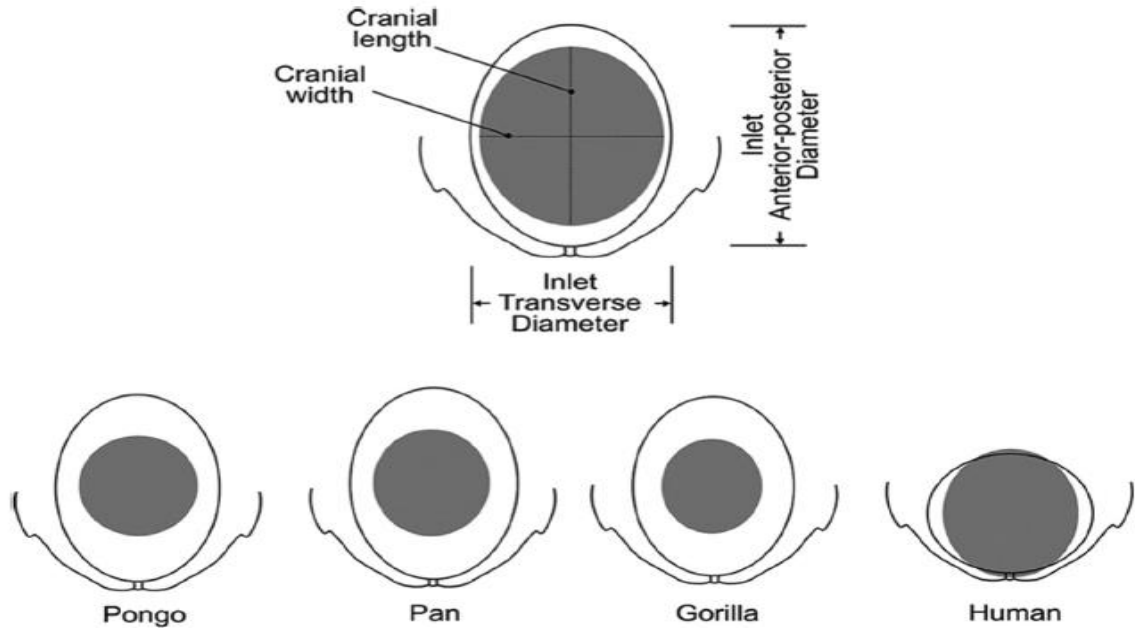
Vaginal delivery may have been the common route for delivery of all infants at one point in time, but data from recent years show that this is changing (CDC, 1998, 2015, 2017). Vaginal deliveries are not occurring as often; instead cesarean deliveries are being conducted in greater proportions in recent years (CDC, 1998, 2015, 2017). There is potential to change the norm back to vaginal delivery, the natural form of delivery. If certain factors can be enhanced such as timing and position, coupled with the use of medications and technology, then there is potential for improvement.



**Figure 7:** Route of Delivery- Vaginal vs. Cesarean

Route of delivery statistics from 1989 to 2015 show that cesarean section deliveries are slowly rising (see **Figure 7**), while vaginal deliveries are on the decline (CDC, 2015). In 1989, there were 2.8 million vaginal deliveries (CDC, 2015). But then it decreased to 2.7 million in 2015 (CDC, 2015). In comparison, cesarean deliveries totaled 0.8 million in 1989 and then 1.2 in 2015 (CDC, 2015). Looking at twins and higher order multiples, the statistics are difficult to acquire and are not as definitive. The reason being is that each infant has its own separate probability of delivery route. For example, the first twin might be vaginally delivered, while the second twin might have been delivered through cesarean (CDC, 2015). Based on this it may be assumed that triplets and higher order deliveries would show even more variability. Obtaining this data would most likely require more detailed research to uncover the actual numbers and to compare all the factors. In general, more cesarean deliveries are being documented, which may correlate with the increase of multiples (CDC, 2015).

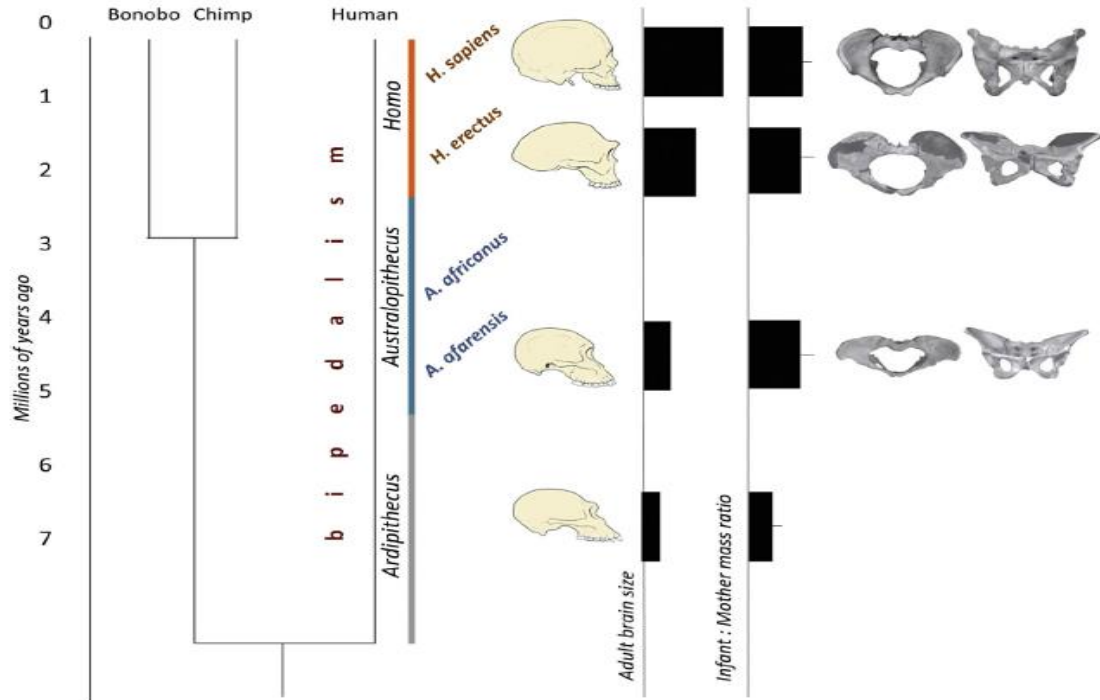
As discussed in previous paragraphs, cesarean deliveries are occurring more. It is possible that evolution may help explain how we arrived at this fact. When reviewing the human pelvis and comparing it to the fetal head, it is easy to see why humans have such complicated deliveries. The human fetal head is often larger than the size of the human pelvis, especially when compared to other animals (Pavlicev et al., 2020). **Figure 8** shows the comparison of the human fetal head against the human fetal pelvis and compares it to other closely related animals- the gorilla, the pan and the pongo (Pavlicev et al., 2020). This misalignment of the fetal head and the pelvis often causes complications during delivery, higher rates of cephalopelvic disproportion (CPD) and obstructed labor (Pavlicev et al., 2020).



**Figure 8:** Cephalopelvic proportions at the pelvic inlet

If having larger heads is such a problem, than how did humans survive and continue to reproduce, passing on the genes to create these large heads? Sherwood L. Washburn believed that humans came to this dilemma through a push and pull between bipedalism, brain size and the evolution of the pelvis (Pavlicev et al., 2020). See **Figure 9** for an evolutionary timeline of the human pelvis (Pavlicev et al., 2020). He believed that as humans evolved into walking with two legs to free up the hands for tool use, thereby selecting for a larger brain, the pelvis evolved to accommodate this new form of motion (Pavlicev et al., 2020). A wide pelvis is beneficial for carrying and delivering a fetus, but a narrow pelvis makes walking with two legs more efficient (Pavlicev et al., 2020). The evolution of the pelvis was not only different between primates, but also between human genders.





**Figure 9:** Timeline of human evolution and obstetrically relevant traits

When comparing pelvises amongst the human genders, a clear difference is also seen (Pavlicev et al., 2020). Females have wider pelvises, particularly around the pelvis opening, in comparison to males (Pavlicev et al., 2020). This variability in pelvis shape does not translate to efficiency when walking and running, as may be expected (Pavlicev et al., 2020). Females keep up with higher speeds through pelvic rotation manipulations into strides (Pavlicev et al., 2020). There is also a push and pull with having wide or narrow birth. Narrow birth canals allow for more support for a growing fetus during pregnancy (Pavlicev et al., 2020). More support could be necessary when carrying twins. But the narrow canals create complications with delivering the large human fetus head (Pavlicev et al., 2020). Whereas wide birth canals are less efficient in supporting the growing fetus as well but are perfect for delivering the large fetal head (Pavlicev et al.,

2020). When comparing human fetal differences to that of primates, fetal heads are significantly larger, taking up 90% of the mothers' pelvis in comparison to less than 60% in other primates (Horgan & Farine, 2015). The large human head size accommodates for the larger brain, something that evolved as a trade off with restricted mobility and almost always assisted delivery (Horgan & Farine, 2015). So, humans require assistance in delivering babies, but how does this lead to cesarean and why do humans have a hard time with delivering multiples?

As discussed in previous sections, vaginal delivery of multiples is not simple and may often not be safe for women delivering multiples. But other animals that are smaller than humans deliver multiple babies per pregnancy. What is the problem, why do humans have such a difficult time delivering multiples? Evolutionary science may help explain this, it could give insight to how humans are different and possibly provide solutions. Guinea pigs for example, deliver anywhere between one and six pups within each pregnancy (Lake Shore Pet Hospital, 2020) How do they do this? One possible way is that guinea pigs have the ability to separate/expand the pubic symphysis from 11 mm to 23 mm to accommodate the size of the neonate head (Pavlicev et al., 2020). This action is accomplished through the release of estrogen and relaxin and development of a ligament in between the joint (Pavlicev et al., 2020). The human pelvis in comparison typically separates 3 mm (Pavlicev et al., 2020). This separation of the pubic symphysis is a common occurrence in other animals such as bats, deer, and mice (Pavlicev et al., 2020). How did humans survive and reproduce with what appears to be a flaw? It is possible that many of the species that can create this wide gap are successful because they are able to minimize the pressure on the pelvis due to their small size or by living in the water

(Pavlicev et al., 2020). Living in the water is not an option for mothers carrying twins, instead improving prenatal care and balancing the factors that influence the route of delivery could lead to success.

Delivering twins is a complex procedure that relies on several factors (Blickstein & Keith, 2006). Even if the mother has a healthy pregnancy, she may still be faced with complications during the delivery process (Blickstein & Keith, 2006). One problem could be the alignment of the two babies during delivery (Blickstein & Keith, 2006). Breeched, for example is the state in which a baby is positioned feet down, where the feet are delivered first (The Bump, 2018). In twins, one baby can be head down while the other is breeched (The Bump, 2018). A similar term for head down is also cephalic (The Cleveland Clinic, 2020). There are various levels of breech and head down (Blickstein & Keith, 2006). It is not straight forward and so the procedure cannot be treated in such a simple manner. In a case where one baby is breeched, she would most likely be delivered by cesarean section if she cannot be realigned (Blickstein & Keith, 2006). Position is one factor, but there are others that affect the outcome of delivery.

Timing of delivery is a very crucial factor to consider when delivering twins. Often delivering the babies as quickly as possible is the route that many doctors take for various health reasons (Blickstein & Keith, 2006). But there are situations in which twins may be delivered months apart (Blickstein & Keith, 2006). There is a case in which one twin was born premature and the second was born full term (Blickstein & Keith, 2006). It was possible because each baby was in his own sac (Blickstein & Keith, 2006). Mothers carrying twins who are in separate sacs could possibly deliver each baby at different intervals. It could allow the mother time to recuperate. It could also allow the medical

team time to readjust. When delivering multiples, the hospital provides each baby with her own set of staff members (Blickstein & Keith, 2006). This time lapse could allow the second team time to setup or subtract the need for a second set of staff member's altogether. Which would save both the hospital and therefore the parents some money. Allowing this time lapse is one way to allow vaginal delivery, but there are other ways.

Ultrasound use can be coupled with lifestyle changes to improve the health of the mother, thereby increasing the likelihood of a safe vaginal delivery. Diet and exercise regimens can be setup by the medical practices as soon as mothers learn of their pregnancy. Medication administration may be introduced into these regimens to improve the pregnancies and prevent health problems in the future. Metformin, for example, is often used as one solution in controlling insulin levels in women with PCOS during pregnancy (Feig & Moses, 2011). The combination of medication use, diet, exercise, and technology may be the solution to safe vaginal delivery of twins. Other aspects of safe twin pregnancies and deliveries are education and physician experience.

Whether parents are deciding if they should transfer multiple embryos through IVF or if they naturally become pregnant with multiples, they must be made fully aware of what twin pregnancies and deliveries entail. Parents should know that complications that arise during pregnancies are three to five times more likely to occur amongst multiples as compared to singletons (Di Renzo et al., 2001). Protocols to inform parents of the possible economical and psychological pressures of twin pregnancies and deliveries, should be fully evaluated and measures should be put in place to prepare the parents (Di Renzo et al., 2001). Maternal age should be a factor that is also fully evaluated. Age can lead to twin pregnancies and complicate twin pregnancies (Di Renzo

et al., 2001). In addition to twin education for the parents, physician training is also paramount. All this research is pointless if practitioners are not being trained on the latest and best practice, and/or they are not interested in learning how to make vaginal delivery of twins safer.

Practitioner experience and attitudes toward vaginal delivery influence delivery outcomes (Easter et al., 2017). The more practitioners become comfortable with the practice and repeatedly rehearse to improve their technique, the greater the chance of opting for vaginal delivery when possible. The Easter et al. study reviewed practitioner attitudes toward vaginal delivery of twins (2017). It was found that only 31% of the surveyors who were familiar with the Barrett study decided to modify their practice taking into account the new findings (Easter et al., 2017). The Barret study analyzed a series of twin pregnancies and the route of planned delivery- cesarean vs. vaginal (2013). Their conclusion was that in twin pregnancies between 32 weeks and 38 weeks 6 days, no change in the risks were observed amongst the planned route of delivery where the first twin was in cephalic position (Barrett et al., 2013).

The Easter et al. study showed that experience might have an impact in choosing vaginal over c-section (2017). In this study it was observed that practitioners that preferred breech labor had an increased rate of specialized training in maternal-fetal medicine, had more experience working in settings with higher rates of twin deliveries- more than 30 twin deliveries per year, and these practitioners had a higher chance of working in academic facilities (Easter et al., 2017). This study also showed that 45.8% of the practitioners surveyed were open to more training and enthusiastic about having more training specifically with breech delivery and strategies with delivering the second twin

(Easter et al., 2017). These practitioners who were accepting of more training were more likely to seek assistance from other practitioners and encouraged various styles of training (Easter et al., 2017). Training such as simulation training, hands on training, and classroom training (Easter et al., 2017). If continual physician training is encouraged, then some of the safety issues may be corrected regarding the delivery of twins.

Twin pregnancies and deliveries are at risk of complications. But many of these complications can be prevented or managed. Prenatal care must be improved to better prepare mothers and physicians as well as help to prevent further complications. At delivery, it is important that the following occurs: experienced staff are present, anesthesiologist are present as well as pediatricians, an operating room is on standby for emergency cesarean section, and fetal monitoring is conducted for each fetus (Di Renzo et al., 2001). Lifestyle, technology, and medication may improve pregnancy and help to increase the probability of safer vaginal delivery of twins.

## Chapter II.

### Materials and Methods

This study of multiples was based on literature review. Within this study a comparison of the safety of vaginal laboring versus cesarean delivery was assessed. The complications that often arise during twin pregnancy and delivery was reviewed. As well as the components that allow for a safe gestation and delivery. The goal was to evaluate the safety of vaginal delivery versus cesarean section delivery, identify the factors that result in a safe vaginal delivery of twins and compile guidelines that lead to safe vaginal delivery of twins.

This research was a deeper look into the factors that influence healthy twin pregnancy and delivery, as discussed in the introduction. Healthy lifestyle habits were evaluated along with routine technology use and medication administration. Studies on lifestyle habits were reviewed to see how much nutrition and exercise make a difference on the success of safe twin pregnancy and delivery. A review of the effect a mothers' health has on the pregnancy and delivery was conducted. Studies on current medication administration was reviewed in search for success rates. Technology use during pregnancy and delivery studies was also reviewed in hopes of finding opportunities for improvement or more frequent use. Literature was obtained through database searches such as HOLLIS within the Harvard library website, using key words in relation to twins, nutrition, technology, pregnancies, and deliveries. Public sites such as the Center for

Disease Control was reviewed for statistics in the United States. Studies compiled focused on relevant research of twin pregnancy and delivery.

In this study various literature was reviewed which includes scientific articles, textbooks, websites, books, and national databases. The results are presented in four different sections: Technology, Lifestyle, Medication, and Vaginal vs. Cesarean outcomes. The following is a list of literature organized by these four sections.

### Technology

Information about how technology benefits twin pregnancy and delivery was gathered from the following literature:

- Vaginal Delivery of Twins, Mary Anne Carroll & Yeomans, E. 2006

Vaginal Delivery of Twins is an article that reviews delivery of twins and its complexities. This article was chosen because it provided a detailed review of important factors to evaluate and manage such as type of twin pregnancy, position of twins and requirements during labor. Various technology use was discussed within this article.

- The Ten Commandments in Multiple Pregnancies, G.C. Di Renzo, et al. 2001

Multiple pregnancies are indeed complex, this article was beneficial and pin-pointing specific details in managing twin pregnancies. The writers discussed various types of technology that is used to monitor twin pregnancies and deliveries therefore also ensuring safe deliveries.

- Multiple Gestation: Labor and Delivery, Keith & Johnson 2008

This article was reviewed to provide further discussion on managing labor and delivery of twins.



- IVF and the Twin Trend: Educating Patients about the Risks, Progyny 2018

When researching why there has been an increase in twin pregnancies and why this increase appears to continue, it was noted that IVF played a key role. Many twin pregnancies appear to be due to IVF treatments. This article discussed the risks that many parents should be made aware of before they engage in this complex journey, if they have the choice. Awareness and preparedness are valuable components to safe vaginal delivery of twins.

### Lifestyle

The lifestyle section looked at how nutrition and exercise benefit twin pregnancy and delivery. The following literature was reviewed to gather this information:

- Optimal Nutrition for Improved Twin Pregnancy Outcome, William Goodnight & Newman 2009

After reviewing various articles on twin pregnancy, it was noted that nutrition during twin pregnancy is extremely important. This article by William Goodnight & Newman discussed the importance of nutrition and provided the details to what ideal nutrition is for a mother carrying twins.

- Weight Gain During Pregnancy, Centers for Disease Control and Prevention 2019

The CDC website was searched and this article on weight gain appeared to be particularly informative. It helps to identify standards that are currently communicated to mothers with twins.

- Specialized prenatal care and maternal and infant outcomes in twin pregnancy, Barbara Luke et al. 2003

Throughout this thesis, the comparison of twin pregnancy to singleton pregnancy has been expressed repeatedly. This study conducted by Luke et al. reviews the importance of prenatal care even more so in twin pregnancies because of the complexity of twin pregnancy needs.

- Improving Multiple Pregnancy Outcomes with Nutritional Interventions, Barbara Luke 2004

Barbara Luke also wrote another article on nutritional interventions in multiple pregnancies that was important in showing how efficient interventions can be effective in the outcome of twin pregnancies. This provided some statistics to show how proper management of twin pregnancies may lead to better outcomes as far as pregnancy and delivery goes.

- Provider advice on physical activity and nutrition in twin pregnancies: a cross-sectional electronic survey, Kara M. Whitaker et al. 2019

Physical activity is a controversial topic in twin pregnancy, especially during the last months of pregnancy. The concern is due to complications that some believe may arise because of physical activity. This article was reviewed to identify the ideal amount of physical activity and nutrition necessary in twin pregnancies.

- Everything You Need to Know to Have a Healthy Twin Pregnancy, Gila Leiter et al. 2000

This book by Dr. Gila Leiter et al. is a novel written to provide mothers carrying twins a full review of important factors to consider and manage throughout pregnancy. It was helpful in providing details such as medication used for pregnancy symptoms,

discussions on experienced medical staff needed and how to mentally prepare for a twin pregnancy. This book also briefly touched up on exercise in twin pregnancies.

- Excessive Weight Gain in Term Twin Pregnancies, Fox et al. 2011

This article by Fox et al. was significant when reviewing weight gain throughout pregnancy as it looked at excessive weight gain and whether it actually causes harm to the mother.

### Medication

Information about how medication benefits twin pregnancy and delivery was gathered from the following literature:

- Vaginal Delivery of Twins, Mary Anne Carroll & Yeomans, 2006
- Effectiveness of progestogens to improve perinatal outcome in twin pregnancies: an individual participant data meta-analysis, E. Schuit et al. 2014

Progesterone has been shown to be effective in preventing preterm labor. This article by E. Shuit et al. compared a list of studies on progesterone use in twin pregnancies and conducted a meta-analysis to determine the actual effectiveness of progesterone in twin pregnancies.

### Vaginal vs. Cesarean

Information about Vaginal delivery vs Cesarean delivery outcomes was gathered from the following literature:

- Multiple Pregnancy, Epidemiology, Gestation & Perinatal Outcome. 2nd edition, Isaac Blickstein & Keith, L. 2006

This textbook provided several details about twin pregnancy, twin delivery cases and positioning of twins. It provided insight to twin pregnancy, being that it is a textbook, it might have been studied by various soon to be physicians looking to deliver twins.

- The Ten Commandments in Multiple Pregnancies, G.C. Di Renzo, et al. 2001
- Specialized prenatal care and maternal and infant outcomes in twin pregnancy, Barbara Luke et al. 2003
- Mode of delivery of twin gestation with very low birthweight: is vaginal delivery safe? Eran Barzilay et al. 2015

The Barzilay et al. study was reviewed in hopes of evaluating how the mode of delivery reflected on the outcome of twin pregnancy. Twins are often born low birthweight as mentioned in previous sections. This study specifically covered low birthweight and the outcome of delivering them vaginally.

### Chapter III.

#### Results

##### Technology

The use of ultrasound during prenatal appointments benefits the pregnancy for many reasons. These reasons include early assessments of fetal weight and membrane development, as well as abnormalities (Carroll & Yeomans, 2006). It is interesting to note that a fetus that is within 1500 g is typically able to be delivered vaginally (Carroll & Yeomans, 2006). Some believe ultrasound use could be vital in determining the fetal weight (Carroll & Yeomans, 2006). In prenatal care, there are various types of ultrasound and monitoring devices, each used for different purposes (Di Renzo et al., 2001). **Table 4** below provides details on the types of monitoring methods and what healthcare workers can identify (Di Renzo et al., 2001).

**Table 4:** Multiple pregnancy monitoring methods

Multiple pregnancy monitoring methods	Used to identify or monitor:
Transvaginal sonography (TVS)	Chorionicity
TVS evaluation of the cervix	Risk of preterm delivery
Amniocentesis	Aneuploidies and malformations
Ultrasound morphological examination	Malformations
Ultrasound biometric examination	Discordant twins or intrauterine growth retardation (IUGR)
Doppler velocimetry or ultrasound biophysical profile or NST or fetal behavior	Fetal health

Monitoring growth progress is important especially in twins. As mentioned in previous sections, twin pregnancies at times, are similar to singleton pregnancies. In situations that compare fetal growth, similar tests for growth progression that are used in singleton pregnancies, can also be used in twin pregnancies up to 28 weeks of gestation (Di Renzo et al., 2001). But after 28 weeks of gestation growth curves that are unique to twin gestations should be used instead (Di Renzo et al., 2001). Growth monitoring is important because 12-47% of twin pregnancies display growth discordance, sometimes sooner than 28 weeks of gestation (Di Renzo et al., 2001). Red flags are indicated if weight discordance is 25% or greater and AC difference is greater than 20 mm (Di Renzo et al., 2001). Monitoring growth progression throughout pregnancy can point out any growth differences that may lead to complications later on in pregnancy and delivery.

Ultrasounds are also being used before and during labor to monitor the status of a fetus, her health, and her position (Carroll & Yeomans, 2006). Ultrasounds are helpful during labor to ensure babies and their umbilical cords are not entangled (Keith & Johnson, 2008). If adjusting the position of the babies is necessary for safe delivery as in the case of a baby that is breeched or positioned otherwise, then the use of anesthesia together with ultrasound use could increase the success rate of vaginal delivery (Keith & Johnson, 2008).

Monitoring of multiples in the womb is important but also complex. In the case of twins, two external fetal monitors can be used to track each fetus instead of just one, with an emphasis on placement accuracy (Di Renzo et al., 2001). Another option is to first use scalp electrodes; placed on the first twin until delivery, then the second twin can be monitored by electronic or sonographic monitoring (Di Renzo et al., 2001). An intra-

amniotic catheter can be used to read both fetal heart rate simultaneously, while two external transducers can read uterine contractions (Di Renzo et al., 2001). Newer monitoring devices can print the fetal heart rates for each fetus on the same tracing while still allowing a channel for uterine contractions (Di Renzo et al., 2001).

## Lifestyle

Multiple pregnancies contrast against singleton pregnancies when it comes to body changes and gestational lifestyle differences. Pregnancy symptoms, such as nausea and heartburn may be worse in multiples as compared to singletons (Leiter et al., 2000). Pregnancy hormones tend to be the culprit when it comes to morning sickness, and women carrying multiples have an increase in pregnancy hormones (Leiter et al., 2000). Emotions may also cause nausea and vomiting during pregnancy (Leiter et al., 2000). Gila Leiter and Rachel Kranz suggest eating small portions frequently throughout the day, hydrating, acupressure, hypnosis, ginger products, hard candies, ice pops, lemon rinses, and crackers to help combat these symptoms naturally (Leiter et al., 2000). This a brief review of changes caused by hormone influence. Weight changes is another difference between multiple pregnancies and that of singletons.

## Weight Gain

Weight gain in twin pregnancies is significant as may be expected when carrying two fetuses as well as the various sacs that they reside in. The following are components that also contribute to this weight gain. This weight that is accumulating during pregnancy accounts for extra blood volume, placenta, and other materials (Leiter et al., 2000). Twin moms have a 50-70% increased blood volume only 20 weeks into the

pregnancy (Goodnight & Newman, 2009). This blood volume has only a 25% increase in erythrocytes, it also has diluted hemoglobin, albumin, and water-soluble vitamins (Goodnight & Newman, 2009). In addition to these changes, twin mothers experience an increase in plasma volume, basal metabolic rate and resistance to carbohydrate metabolism (Goodnight & Newman, 2009). Twin mothers experience a 10% increase in resting energy expenditures as compared to singleton moms, which can result in the need to intake 40% more calories (Goodnight & Newman, 2009). The increased volume and metabolic changes are expected and acceptable within means.

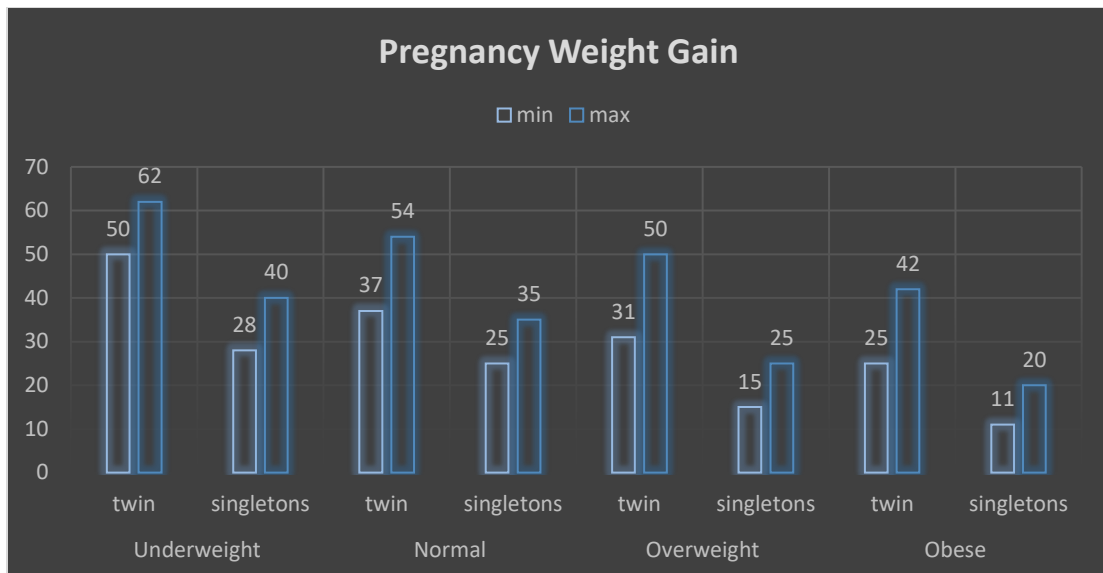
Pregnancy weight gain is important to balance within singleton pregnancies but even more so in twin pregnancy (Leiter et al., 2000). Early weight gain is most ideal, preferably 24-30 pounds by week 24 of pregnancy and 50 pounds by week 37 of pregnancy (Leiter et al., 2000). The Luk et al. (2003) study recommends weight gain earlier in the pregnancy and less towards the end of the pregnancy. **Table 5** below displays more detail about how much weight should be gained by 20 weeks, 28 weeks and 36-38 weeks of pregnancy (Luk et al., 2003). It is important to balance this weight gain appropriately, as too much weight gain may lead to complications during pregnancy and during delivery (Leiter et al., 2000). The amount of weight a mother should gain during the course of the pregnancy is based off of her pre-pregnancy weight (Leiter et al., 2000). Underweight women must gain more weight during the pregnancy than normal weight women, and overweight should gain less than normal weight women (Leiter et al., 2000).



**Table 5:** Weight gain in pregnancy according to BMI

<b>Weight Gain Goals (pounds)</b>	<b>Underweight</b>	<b>Normal weight</b>	<b>Overweight</b>	<b>Obese</b>
<b>at 20 weeks</b>	25-35	20-30	20-25	15-20
<b>at 28 weeks</b>	37-49	30-44	28-37	21-30
<b>at 36-38 weeks</b>	50-62	40-54	38-47	29-38

Pregnancy weight gain should be more than that of singleton pregnancies, but the key is figuring out the ideal range (CDC, 2019). **Figure 10** below provides a comparison of ideal weight gain between singleton pregnancies and twin pregnancies (CDC, 2019). Guidelines for total weight gain through the course of pregnancy for mothers carrying twins is based on the mother's BMI (Fox et al., 2011). A BMI of 37-54 lbs. for normal weight, 14-23 lbs. for overweight, and 25-42 lbs. for obese women is what is recommended by the Institute of Medicine (IOM) (Fox et al., 2011). The IOM suggests this weight gain for twin pregnancies with the goal of improving pregnancy outcomes and decreasing cases of low birth weight babies (Fox et al., 2011). One study sought out to challenge this and found that excessive weight gain improved pregnancy, with larger babies and fewer cases of low birth weight (Fox et al., 2011). The study also showed that this weight gain did not negatively affect the chances of complications such as gestational diabetes and hypertension (Fox et al., 2011).



**Figure 10:** Pregnancy Weight Gain- Twins vs. Singletons

### Exercise

As may be expected, exercising during pregnancy is beneficial for many reasons. Exercise improves pregnancy and delivery, but only if done in moderation and done at a rate aligned with the pre-pregnancy routines (Leiter et al., 2000). A mother of twins should workout based on what she was already doing before getting pregnant, nothing more (Leiter et al., 2000) and with modifications added as the pregnancy continues (Leiter et al., 2000). Exceptions include mothers at risk for preterm labor, consistent bleeding in the first trimester, high blood pressure problems and fetal growth restrictions (Leiter et al., 2000). Swimming is often the most effective as it is less strenuous on the uterus, it maintains good blood flow and a stable body temperature (Leiter et al., 2000). It is also helpful by increasing urine output and decreasing swelling (Leiter et al., 2000). As noted in previous sections, twin pregnancies are often complex and according to the American College of Obstetricians and Gynecologists (ACOG) these pregnancies still

require some level of physical activity (Whitaker et al., 2019). Recommendations from ACOG are that women partake in aerobic exercise 20-30 minutes a day and 150 minutes a week (Whitaker et al., 2019). In addition to aerobic exercise, it is also important to include strength training (Whitaker et al., 2019). Balancing activity levels is complex and should be discussed in greater detail with the overseeing physician. This is important in accommodating to each patient's unique need.

Stress, working too much and standing too much can put the mother at risk of complications also (Leiter et al., 2000). But bed rest is a controversial topic, especially for multiples. Standing for long periods can focus a lot of weight on the pelvis as the uterus sinks into it and restricts blood flow from the legs to the heart, which can lead to uterine contractions and preterm labor (Leiter et al., 2000). In the case of multiples this is of concern, in the past it has led physicians to insist on prophylactic bed rest in the hospital (Leiter et al., 2000). There are times when physicians still prescribe bed rest, but recent studies have shined light on the risks of bed rest (Leiter et al., 2000). Often bed rest can lead to deep venous thrombophlebitis and weak muscle tone which can then lead to exhaustion during labor (Leiter et al., 2000). Exercise during twin gestations may be tricky, but nutrition is even more complex and more influential.

## Nutrition

Nutrition is another important factor during pregnancy because it ensures the growing fetus has the fundamental components to thrive. As Luke states, "Pregnancy is a state of accelerated starvation, resulting in lower fasting glucose levels and an exaggeration of the insulin response to eating" (2004). According to Goodnight & Newman, diet requirements differ for twin pregnancies (2009). Protein, calorie intake, fat

and calcium along with other vitamins should be increased (Leiter et al., 2000). Ideally, protein intake should be 4-4oz per day, calories should be increased by 300 per day, and calcium 1200 mg per day (Leiter et al., 2000). Folic Acid intake of 0.4-0.8 mg is normally consumed in singleton pregnancies, in multiples this should be increased by 1 mg per fetus (Leiter et al., 2000). Intake of 5 mg of Zinc each day may lower the chance of infection and premature rupture of the fetal membranes (Leiter et al., 2000). During the pregnancy, mothers carrying twins should consume the recommended calories, protein, carbohydrates, and fats according to their pre-pregnancy BMI (Goodnight & Newman, 2009). **Table 6** shows these details (Goodnight & Newman, 2009).

**Table 6:** Twin daily diet requirements

<b>Twin daily diet requirements</b>	<b>Underweight</b>	<b>Normal weight</b>	<b>Overweight</b>	<b>Obese</b>
<b>Calories</b>	4000	3000-3500	3250	2700-3000
<b>Protein</b>	200	175	163	150
<b>Carbohydrate</b>	400	350	325	300
<b>Fat</b>	178	156	144	133

Iron supplements are also very important because of the increased blood volume that leads to diluted red blood cells (Leiter et al., 2000). Mothers carrying multiples are two and half more likely to experience anemia complications (Leiter et al., 2000). Hemorrhaging during pregnancy and delivery is also an increased risk for multiple mothers (Leiter et al., 2000). It is important to take supplements that contain purely iron and with no other components that may reduce the absorption of iron (Leiter et al., 2000). Limiting caffeine intake and not taking iron at the same time as other supplements, as well as with dairy products or certain foods with fiber may also increase absorption

(Leiter et al., 2000). These are the basic nutritional and supplemental components to evaluate in twin pregnancies.

### Medication

When natural remedies are not enough, medications can help in a variety of ways throughout pregnancy and delivery. As discussed in the previous section, hormone related pregnancy symptoms are significant in twin pregnancies. Medications that may help combat these issues, may be Emetrol (phosphorated carbohydrate solution), Vitamin B6 (pyridoxine), Zantac, Benadryl (diphenhydramine) and Unisome (doxylamine succinate) (Leiter et al., 2000). These should first be discussed with the overseeing physician before trying (Leiter et al., 2000). In addition to pregnancy symptoms, medications can be used throughout pregnancy and delivery for other purposes.

The use of various medications during the delivery of twins may play an important safety factor. The use of medications such as oxytocin, epidural anesthesia and other medications are beneficial during the delivery of multiples (Carroll & Yeomans, 2006). Oxytocin is used to induce labor, though often with twins, this may be unnecessary (Carroll & Yeomans, 2006). The over-extension of the uterus as well as other pressures due to the lack of space often lead to natural induction (Carroll & Yeomans, 2006). But in some situations, such as in patients with preeclampsia, where the mother and baby's safety are at risk, oxytocin may be used to induce labor (Carroll & Yeomans, 2006). Women carrying multiples often have health complications such as extra pressure on the abdomen and an overly extended uterus (Carroll & Yeomans, 2006). Both of which make the use of anesthesia alarming (Carroll & Yeomans, 2006). If administered to the mother while she is in an ideal position, then there is less of a concern

(Carroll & Yeomans, 2006). The use of an epidural injection has shown to extend the interval between the first twin and the second twin (Carroll & Yeomans, 2006). It has also been shown to increase the total time duration of delivery for both twins (Carroll & Yeomans, 2006). The control of blood loss is another problem during delivery, unfortunately anesthesia can increase this blood loss (Carroll & Yeomans, 2006). There are alternative medications, such as nitroglycerin, that may be safer (Carroll & Yeomans, 2006). Used together with ephedrine, nitroglycerin may relax the muscles without lowering the blood pressure to dangerous levels (Carroll & Yeomans, 2006). Still there are other factors that may help vaginal delivery flow more smoothly.

Preterm births are one of the complications that is common in twin pregnancies as discussed in previous sections. The following are medications that may help. Tocolytics are medications that are often used to prevent preterm labor (drugs.com). These drugs may delay labor for 48 hours allowing for intervention protocols to take place (drugs.com). There are many kinds of tocolytics, but some of the commonly used types in multiple pregnancies are Indomethacin, terbutaline, magnesium sulfate and ritodrine (Di Renzo et al., 2001).

Antenatal progestogens are medications that are used to reduce the risk of preterm delivery or administered to mothers with a short cervix (Schuit et al., 2014). This is often administered in singleton pregnancies, but more studies are looking into using this therapy for twin pregnancies (Schuit et al., 2014). Schuit et al. conducted an Individual participant data meta-analysis (IPDMA) to review studies that evaluated the use of two types of progestogen therapies on twin pregnancies to prevent prematurity (2014). The two types of progestogens were intramuscular 17-hydroxyprogesterone caproate (17Pc)

and vaginal progesterone (Schuit et al., 2014). 17Pc was administered weekly at doses that ranged from 250 mg to 500 mg (Schuit et al., 2014). Vaginal progesterone was administered daily between 90 mg to 400 mg in either pessary form, gel form, as suppositories or capsules (Schuit et al., 2014). **Table 7** below shows the details of some relevant variables that were observed throughout the studies (Schuit et al., 2014). The conclusions that were made from this review are: concentration of 17Pc did not lower gestational age at delivery, vaginal progesterone might be beneficial to women with a short cervix carrying twins, progesterone did not decrease early delivery based on chorionicity (Schuit et al., 2014).

**Table 7:** Characteristics of participants in the progesterone study

Characteristics of participants	17Pc	17Pc Control	Vaginal Progesterone	V.P. Control
Mean Maternal age, yrs	31.6	31.4	32.2	32.2
Mean BMI, kg/m <sup>2</sup>	25.8	25.7	24.6	24.6
Mean Gestational age at randomization, weeks	19	19	20.1	20.6
Mean Cervical length at randomization, cm	2.3	2.5	3.8	3.7
Mean Cervical length before 24 weeks of gestation, cm	4.1	4.2	3.9	3.8
Nulliparous, %	48	48	60	60
Assisted conception %	50	42	62	59
Monochorionic twin %	14	14	11	15
Previous preterm delivery %	8	10	3	3

#### Vaginal vs. Cesarean

Once through the pregnancy, safely delivering multiples is another complex process. One common problem is premature labor and how to prevent it. Ways to prevent preterm labor are to first diagnose the concern as early as possible, then to direct the

mother to bed rest, perform cervical cerclage if necessary, administer medication such as progesterone, administer tocolytics and to monitor the uterine activity regularly (Di Renzo et al., 2001). Cervical cerclage are procedures in which the mother's cervix is either sewn closed or synthetic tape is applied to seal the cervix to prevent early labor (Mayo Clinic Staff, 2020). These prevention strategies are not always effective though (Di Renzo et al., 2001). Bed rest for example, is meant to reduce the pressure on the mothers' cervix and increase the blood flow to the uterus (Di Renzo et al., 2001). As of yet, there are no studies that have been able to definitively prove these strategies successful in reducing complications like preterm delivery, mortality, or increased birth weight in twin pregnancies (Di Renzo et al., 2001). It is important to note that tocolytics have been shown to cause complications such as pulmonary edema in 3-9% of women and more than 20% were of multiple pregnancies (Di Renzo et al., 2001).

Another concern is anemia, as there is a 40% increased chance of it occurring in multiple pregnancies (Di Renzo et al., 2001). For this reason, it is even more important in multiple pregnancies that iron and folic acid be taken regularly (Di Renzo et al., 2001). Correcting the problem early in pregnancy could prevent problems during delivery as far as blood loss (Di Renzo et al., 2001). Treatment for TTS is done by serial therapeutic amniocentesis which minimizes hyradramnios and iodomethacin to minimize fluid from accumulating again (Di Renzo et al., 2001). The following paragraph provides further information about TTS.

Identifying TTS early is important in preventing subsequent issues. There are several indications of TTS: 1-monochorionic pregnancies, 2-same gender fetus who weigh different amounts, 3-olygohydraminos (smaller fetus) and polyhydraminos (larger



fetus), and 4-hemoglobin levels greater than 5 mg/dl after cordocentesis between the two fetuses (Di Renzo et al., 2001). There are different types of TTS some more common than others (Di Renzo et al., 2001). Twin reversed arterial perfusion (TRAP) is one that is a rare occurrence in monochorionic twins, in which at least 50% of the smaller fetus dies or they are delivered preterm (Di Renzo et al., 2001Renzo). Another type of TTS is the stuck twin, in which one of the fetuses is in an oligohydramniotic sac that is against the uterine wall (Di Renzo et al., 2001).

### Delivery of Twins

When the time comes to deliver the twins, timing of delivery and fetal position are important safety factors that must be evaluated. Delivering the babies at different intervals is possible in certain situations as mentioned in the background section. If before 28 weeks of gestation labor of the twins ends after only one of the fetuses is born, there is the option of securing the mother in a way to allow her to carry out the second twin to full term (Di Renzo et al., 2001). In order to accomplish this, three steps are necessary, first clamp and ligate the umbilical cord as high in the cervix as is possible than follow-up with cervical cerclage (Di Renzo et al., 2001). Second, administration of corticosteroids, antibiotics, and tocolytics are given. Lastly, blood cultures and vaginal swabs are taken to check for pathogens and finally the fetus is regularly monitored (Di Renzo et al., 2001).

Knowing the position of the fetuses is important in safely delivering twins vaginally (Blickstein & Keith, 2006). If both are positioned head-down, then they are often delivered vaginally (Blickstein & Keith, 2006). But there are many variations of alignment of the babies (Blickstein & Keith, 2006). In general, if the second baby is in

some variation of butt down, then vaginal delivery may have risks (Carroll & Yeomans, 2006). External Cephalic Version (ECV) is a procedure that can be used to turn the baby for safer delivery (Carroll & Yeomans, 2006). ECV is a difficult procedure, but it has been shown to be successful in 72% of deliveries (Carroll & Yeomans, 2006). ECV is often successful when used along with various monitoring technology such as ultrasound and heart rate monitors (Carroll & Yeomans, 2006).

Delivering twins that are not both vertex facing is tricky, but there are options. If the first twin is vertex, but the second twin is breeched then the options for delivery can go either way (Di Renzo et al., 2001). Vaginal delivery entails external cephalic version or internal podalic version guided by ultrasound (Di Renzo et al., 2001). It is important to note that breech delivery requires that fetus meet birth weight requirements, fetus has a flexed neck and the mothers' pelvis is favorable (Di Renzo et al., 2001). If the first twin is breeched, vaginal delivery is still possible in certain cases (Di Renzo et al., 2001).

#### Studies on Pregnancy Outcomes

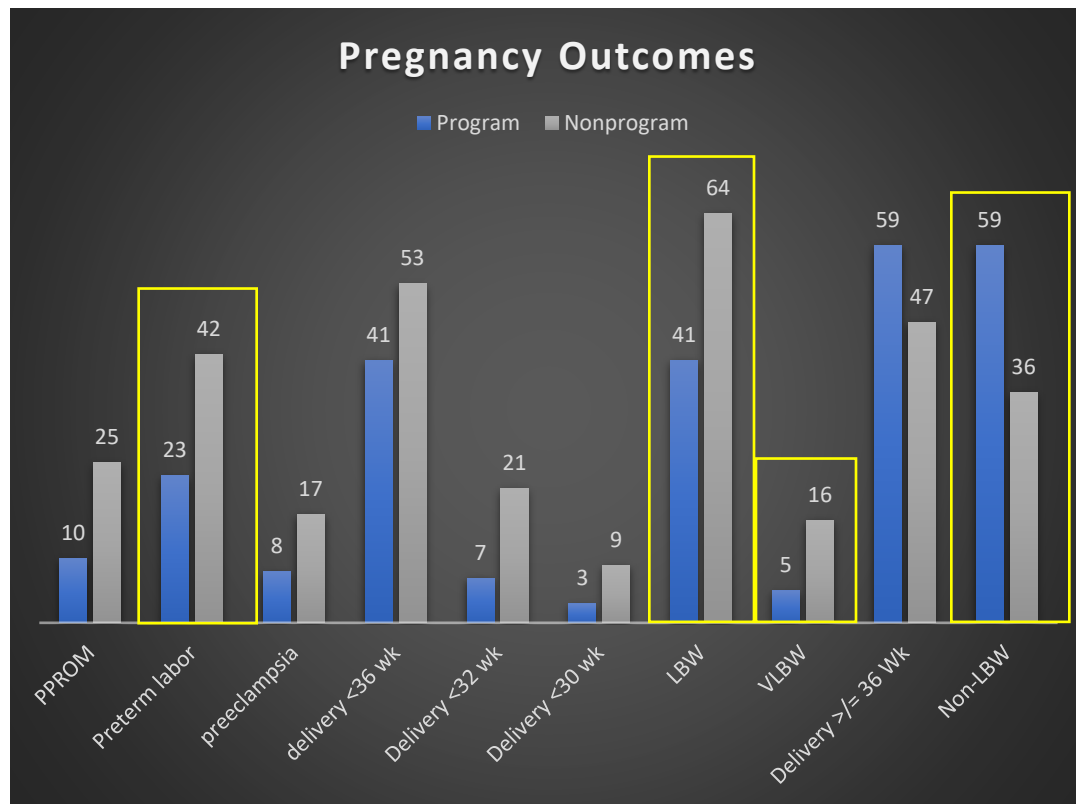
Various studies have been conducted to study the influence of nutrition and education on prenatal outcomes. One study conducted by Luk et al. assessed the influence of prenatal care that focused on nutrition and education on pregnancy outcomes (2003). **Table 8** provides a summary of data on the program and nonprogram participants in the study (Luk et al., 2003). The table shows variables for study population, prenatal care, program visits, and neonatal diagnoses within the study (Luk et al., 2003). Some variables have been excluded because they are irrelevant to the discussion within this twin study.

**Table 8:** Participant variables for the prenatal care and education study

	<b>Program</b>	<b>Nonprogram</b>
<b>Study population</b>		
gestational diabetes (%)	8	7
bleeding >20 week (%)	2	2
height (inches)	65 +/- 0.2	65 +/-0.2
pregravid weight (pounds)	147 +/- 2.4	147 +/-2.2
BMI (wt/ht^2)	24.3 +/- 0.4	24.43 +/-0.3
underweight (%)	17	13
normal weight (%)	58	59
overweight (%)	11	12
<b>Prenatal care</b>		
week of first visit	12 +/-0.4	13 +/-0.5
total prenatal visits	11 +/-0.3	9 +/-0.3
total ultrasound examinations	4 +/-0.09	2.5 +/-0.09
<b>Program visits</b>		
week of first visit	16 +/-0.4	
total program visits	6 +/-0.2	
<b>Neonatal diagnoses</b>		
length of gestation (d)	251.0 +/-1.3	243.6 +/-1.3
average birth weight (g)	2467 +/-37	2217 +/-36
average twin length of stay (d)	9.4 +/-0.9	15.0 +/-1.0
average twin birth cost	16115 +/-2520	30398 +/-2979

As discussed in previous sections, the variables in the Luk et al. (2003) study represent details that appear to be relevant to safe twin pregnancy and delivery. In the Luk et al. (2003) study, pregnancy outcomes for the participants who participated in the program compared to those who did not, verified their hypothesis. Luk et al. (2003) showed distinct differences favoring program participants. **Figure 11** shows these pregnancy outcomes amongst program and nonprogram mothers (Luk et al., 2003). Preterm labor, Low birth weight (LBW), Very low birth weight (VLBW), and Non-low birth weight (Non-LBW) are pointed out in yellow. Low birth weight and premature

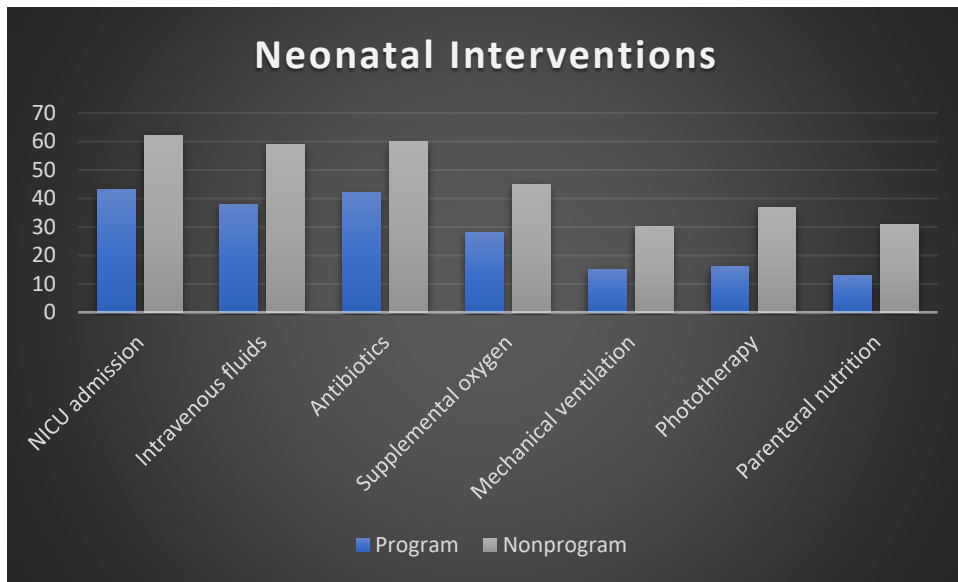
labor are common complications that are of concern in twin pregnancies as discussed in the introduction section.



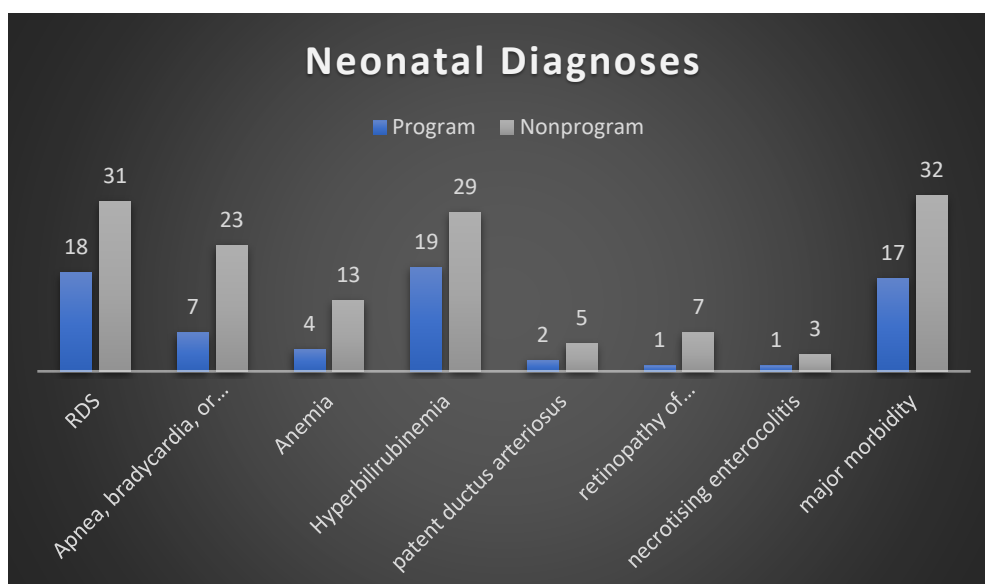
**Figure 11:** Pregnancy Outcomes

To show how beneficial prenatal nutrition and education is to pregnancy outcomes, Luk et al. (2003) also looked at the interventions and diagnoses. **Figure 12** shows neonatal interventions for the program and nonprogram participants (Luk et al., 2003). Again, there is a clear difference between mothers who participated in the program and those who did not. **Figure 13** shows some common neonatal diagnoses comparisons of participants who completed the program as compared to those who were

not in the program (Luk et al., 2003). In all three cases results were fewer in the program cases compared to the nonprogram cases (Luk et al., 2003). The only exception to this were Delivery  $\geq$  36 weeks and Non-LBW, which showed program case results to be greater than that of nonprogram (Luk et al., 2003).



**Figure 12:** Neonatal Interventions



**Figure 13:** Neonatal Diagnoses

Pregnancy outcomes were analyzed in another study with a focus on route of delivery. The Barzilay et al. (2015) study compared cesarean and vaginal delivery amongst twin pregnancies with the goal of observing whether route and birth weight of the second twin correlates with risks. Some of the variables that the study analyzed is displayed in **Table 9** (Barzilay et al., 2015). Outcomes for the group that contained mothers who intended to deliver vaginally are shown in **Table 10** (Barzilay et al., 2015). The outcomes are split by the fetal position, there were 21 cases where the fetuses were in the cephalic-cephalic position and 28 that were in the cephalic-noncephalic position (Barzilay et al., 2015).

**Table 9:** Demographic and clinical parameters

Demographic and clinical parameters	Cesarean delivery (n=142)	Vaginal delivery (n=51)
Median Maternal age, yrs	31	31
Median BMI, kg/m <sup>2</sup>	26.2	24.4
Parity > or = 1, %	33.1	25.5
Monochorionic, %	33.8	11.8
GDM, %	12	15.7
Median Gestational age at delivery, wks	31.4	30.4
Median Birthweight, g		
Twin A	1417.5	1335
Twin B	1258	1195

**Table 10:** Mode of delivery in the vaginal delivery-intention group

Mode of delivery in the vaginal delivery-intention group	cephalic- cephalic, n	cephalic- noncephalic, n
vaginal delivery for both twins	19	27
cesarean delivery for both twins	1	1
cesarean delivery for twin B after vaginal delivery for twin A	1	0

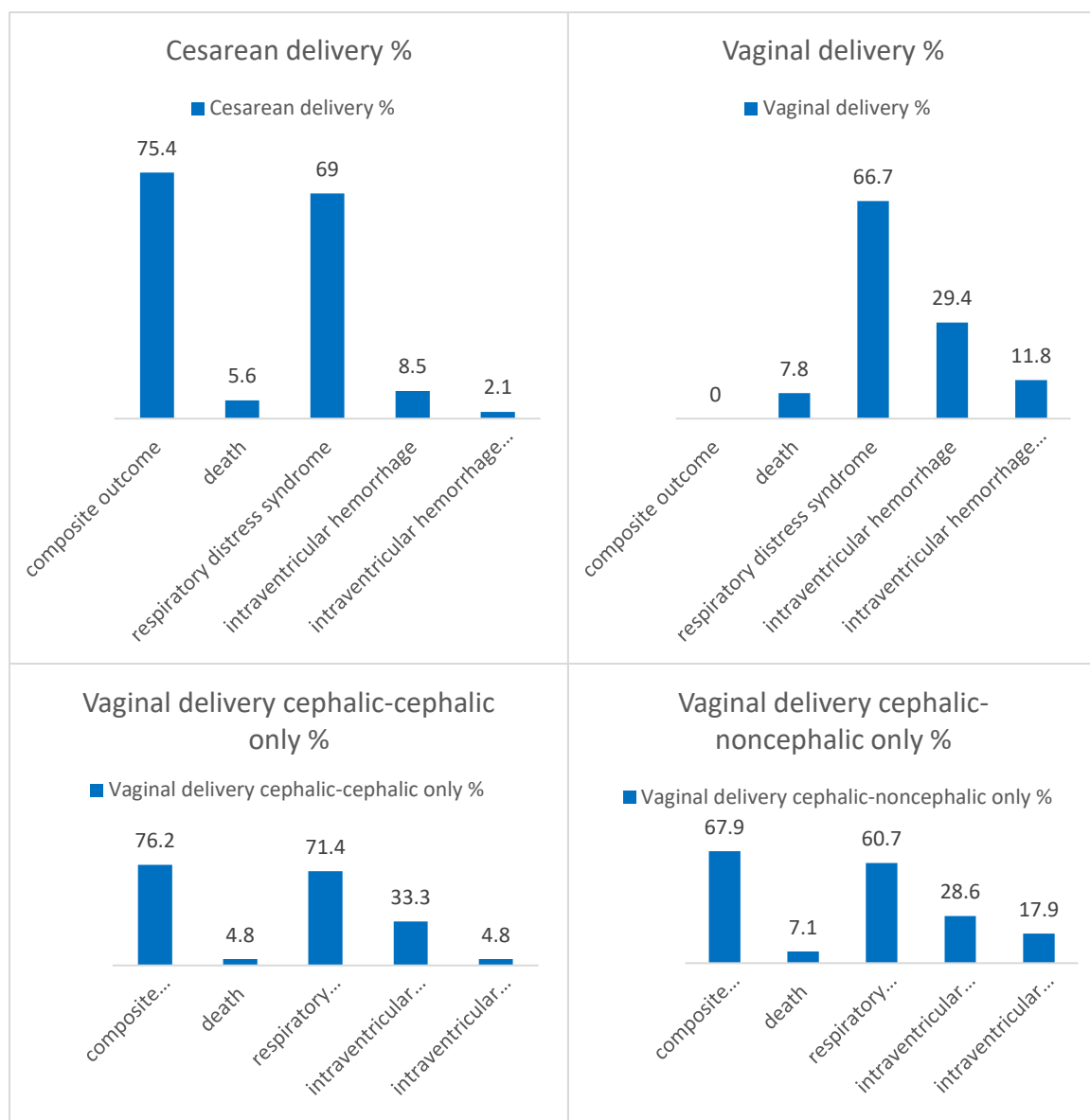
As in the Luk et al. (2003) study, the Barzilay et al. (2015) study analyzed pregnancy outcomes, but with a focus more on the route of delivery and the position of the twins. In this study the neonatal outcome variables were calculated for twin A, twin B, and any twin (Barzilay et al., 2015). **Table 11** displays the details for the neonatal outcomes comparing cesarean and vaginal percentages (Barzilay et al., 2015). **Figure 14** shows a comparison of five particular neonatal outcomes (composite outcome, death, respiratory distress syndrome, intraventricular hemorrhage and intraventricular hemorrhage grade 3-4) regarding the overall percentages for cesarean delivery, vaginal delivery, vaginal delivery of cephalic-cephalic only and cephalic-noncephalic only (Barzilay et al., 2015). Composite outcomes were shown in each graph. It represents the outcomes of neonatal death, respiratory distress syndrome, sepsis, necrotizing

enterocolitis, or intraventricular hemorrhage grade 3-4 (Barzilay et al., 2015). In the two graphs comparing cesarean vs. vaginal delivery, composite outcomes were significantly fewer in the vaginal delivery group (Barzilay et al., 2015). In the vaginal delivery of cephalic-cephalic only vs. cephalic-noncephalic only groups, the results were similar, where cephalic-noncephalic was slightly fewer (Barzilay et al., 2015).

**Table 11:** Neonatal outcome: cesarean vs. vaginal

Neonatal outcome	Cesarean delivery %			Vaginal delivery %		
	Any Twin		Twin A	Twin B		
5-Min Apgar score <7	6.3	3.9	2.8	0	4.3	3.9
composite outcome	75.4	0	61.3	60.8	73.4	66.7
death	5.6	7.8	2.1	5.9	4.2	7.8
respiratory distress syndrome	69	66.7	58.5	56.9	55.6	62.7
necrotizing enterocolitis	4.9	3.9	1.4	2	4.9	2
sepsis	35.3	33.8	14.8	21.6	26.1	23.5
intraventricular hemorrhage	8.5	29.4	7	17.6	4.9	15.7
intraventricular hemorrhage grade 3-4	2.1	11.8	1.4	7.8	1.4	5.9
neonatal intensive care unit admission	90.8	90.2	78.2	82.4	87.3	88.2





**Figure 14:** Outcomes vs. route of delivery and fetal position

The results of the Barzilay et al. (2015) study showed that route of delivery was favorable toward vaginal delivery regardless of the position of the twins. It also showed that vaginal delivery outcomes were unsuccessful regarding intraventricular hemorrhage for twins of very low birth weight (Barzilay et al., 2015). This study also displayed a decreased percentage of cases with respiratory distress syndrome in the cases delivered vaginally (Barzilay et al., 2015).

## Chapter IV.

### Conclusion

Pregnancy and Delivery of twins is different from that of singleton, so it should be managed differently. Protocols used in singleton pregnancy and delivery must be modified to account for the differences in order to allow for safe vaginal delivery of the twins. Technology, lifestyle adjustments, and medication must all be customized to what twins need. **Table 12** summarizes important factors to manage in twin pregnancies to identify and/or prevent complications that may allow for safe vaginal delivery of twins. In an era, where the use of technology surrounds us, there is a potential to use technology to also solve obstetrical problems. Technology has given many women an opportunity; it has allowed many women to conceive. This technology also has the potential to ensure safe vaginal delivery of multiples as well. These forms of technology can also be used to improve prenatal care throughout the trimesters to ensure the mother stays healthy enough to deliver her twins vaginally.

**Table 12:** Management of twin pregnancy & delivery summary

Preparation & Precautions
<ul style="list-style-type: none"><li>• Twin pregnancy and delivery should be routinely managed by experienced staff. Preferably by a diverse team of staff members including obstetricians, nutritionists, personal trainer/ physical therapist, psychologist/therapist and other specialists.</li><li>• Early identification and management are key to a safe pregnancy and delivery. It is helpful in identifying and preventing complications.</li><li>• Physicians should look for TTS-twin to twin transfusion syndrome early in the pregnancy and throughout the pregnancy.</li><li>• Physician experience may be important, even more so during delivery, to manage the various positions of the fetus and ideally allow for safe vaginal delivery when able to.</li><li>• In IVF pregnancies, physicians should educate the parents about all possible complications and precautions to take. In both IVF and naturally occurring twin pregnancies, parents should be prepared for all outcomes.</li></ul>

Technology
<ul style="list-style-type: none"> <li>• A variety of ultrasounds used early on is advisable to identify type of twins and routinely throughout pregnancy to ensure pregnancy is progressing safely and effectively. Routine use of this technology should be more often than is used in singleton pregnancies. <ul style="list-style-type: none"> <li>○ Transvaginal sonography (TVS) – Chorionicity identification</li> <li>○ TVS evaluation of the cervix - Risk of preterm delivery</li> <li>○ Amniocentesis - Aneuploidies and malformations identification</li> <li>○ Ultrasound morphological examination – Malformations identification</li> <li>○ Ultrasound biometric examination - Discordant twins or intrauterine growth retardation (IUGR) identification,</li> <li>○ Doppler velocimetry or ultrasound biophysical profile or NST or fetal behavior - Fetal health evaluation</li> </ul> </li> <li>• Detailed twin growth evaluation for each fetus should be conducted at each prenatal appointment, specifically looking for weight discordance greater than 25%.</li> <li>• Utilize intra-amniotic catheter along with ultrasound and external transducers during time of delivery to obtain a numerical as well as a visual status of each fetus throughout the entire delivery process.</li> </ul>
Lifestyle
<ul style="list-style-type: none"> <li>• Early in the pregnancy, as soon as twin gestation is identified and routinely throughout pregnancy, mothers should be scheduled to see a nutritionist to monitor and adjust mothers' diet and nutritional needs in order to maintain the demands of the pregnancy and stay within preferable weight gain. Ideally, seeing a personal trainer might be advisable. One that is experienced in twin pregnancies. One that may also work with the nutritionist to better advise the mother.</li> <li>• Weight gain is based on pre-pregnancy weight, it should be greater for twins than it is for singletons, see <b>Table 5</b> for details.</li> <li>• Weight gain should be greater in the beginning of the pregnancy and slow down toward the end of the pregnancy.</li> <li>• Nutritional supplements should be taken when diet is not enough, as twin mothers need more than singleton mothers. See <b>Table 6</b> for details, again, nutritional needs are based on pre-pregnancy weight.</li> </ul>
Medication
<ul style="list-style-type: none"> <li>• Medications should be administered throughout pregnancy and delivery to ease pregnancy symptoms and prevent complications. <ul style="list-style-type: none"> <li>○ Emetrol (phosphorated carbohydrate solution), Vitamin B6 (pyridoxine), Zantac, Benadryl (diphenhydramine) and Unisome (doxylamine succinate) can be taken to help with pregnancy symptoms that are often more severe in twin pregnancies.</li> <li>○ Oxytocin if needed to induce delivery</li> <li>○ Epidural administered for pain management and possibly to extend the interval between the two fetuses.</li> <li>○ Tocolytics to prevent preterm labor.</li> <li>○ Progesterone to reduce the risk of preterm delivery, though studies do not appear to be sufficient to confirm its total effectiveness.</li> </ul> </li> </ul>

Technology has been useful in detecting twins and deciphering the type of twins that are growing in the womb. Various types of ultrasound are used to identify chorionicity, malformations, and to observe fetal health. For example, the risk of preterm, being one of the common complications of twin pregnancies, can be identified using Transvaginal sonography evaluation of the cervix. It has also been used to monitor the pregnancy and point out any complications that may arise. Growth discordance is something else that occurs often with developing twins, and Ultrasound biometric examination can be used to identify this unbalanced growth. In addition to the technology equipment, it was noted that twin growth progress is like singleton growth up to a certain point in the pregnancy. For this reason, it would be valuable to follow growth curves that are specific to twin pregnancies, in which parents and physicians can review throughout pregnancy. It appears that 28 weeks of gestation is a crucial moment where many things can go wrong. This may suggest either more in-depth fetal monitoring in greater frequency during this time and leading up to delivery.

During delivery technology is useful in monitoring the status and position of the babies. It would be valuable to use the most updated monitoring equipment during labor, as they may be more efficient at monitoring the two fetuses simultaneously and measuring uterine contractions. Pelvic shape and changes were reviewed briefly in the introduction. There is potential to use technology during pregnancy to assess the shape of the mother's pelvis and evaluate the probability of having complications later during delivery. It would be valuable to conduct further studies on this aspect and its possible benefits toward safe vaginal delivery of twins. This review of technology use showed that

technology is mainly being used for the purposes of identifying, monitoring and prevention. Whereas lifestyle changes are more focused on prevention and preparation.

Lifestyle changes discussed in this literature review focused on maternity weight gain, exercise, and nutrition. Maternal weight gain is important in influencing the outcomes of delivery due to its effect on the fetal weight gain. Twin pregnancies seem to have better outcomes when mothers gain a particular amount of weight that is based on their pre-pregnancy BMI. This weight gain is larger than if she was carrying just one fetus. It is also ideal that the mother gains more weight in the beginning of the pregnancy and less toward the end of the pregnancy. This was shown to allow babies to be larger with less of a chance of causing further complications. Twins are often born low birthweight and premature. By ensuring that mothers gain a larger portion of the weight earlier in the pregnancies, babies are then heavier when it comes time for delivery. In one study, it was found that low birth weight was associated with intraventricular hemorrhage when delivered vaginally. In this same study, they found that respiratory distress syndrome cases were fewer in vaginal delivery. It would be valuable to conduct further studies on the size of the twins during delivery and the safety of vaginal delivery. Evolutionary science shows that babies have difficulty passing through the human pelvis partially due to the size of the head. Would smaller babies have smaller heads and allow for easier delivery? Not enough data regarding this was found in the literature review conducted. Fetal size and pelvis shape comparisons would also be of value for further research.

Exercise during twin pregnancies was a topic that also did not come up significantly in the literature search. This may have been a result of lack of research being

conducted on this topic, it could be a lack of access to the studies present, or it could have been because exercise during twin pregnancies can be complicated and controversial. Certain exercises like swimming are considered ideal as it benefits blood flow and decreases the pressure on the uterus. Bed rest toward the end of the pregnancy has been a controversial topic. Recently, physicians have been moving away from bed rest recommendations unless in complicated pregnancies. While still observing for problems with deep venous thrombophlebitis and weak muscle tone.

Lifestyle adjustments during pregnancy of twins focused mainly on nutrition. It would be advisable that all mothers pregnant with twins consult with a nutrition specialist throughout pregnancy. This would allow for a custom plan that will fit her needs and that of the babies. The plan would adjust for the mothers BMI and the growth progress of the fetuses. The nutritionist would also be able to adjust for any nutrient deficiencies that may come up during the pregnancies. Nutrition seems to play a major role in prevention of complications later in the pregnancy and in delivery. Pregnancy outcome studies showed that mothers who followed prenatal care specific to twin pregnancies displayed fewer complications. Some of the common complications of twin pregnancies -preterm labor and low birth weight- were greatly impacted by the prenatal care. Neonatal interventions and diagnoses were also fewer in program patients as compared to the nonprogram patients. Reaffirming the importance of prenatal care that is geared toward the complexities of twin pregnancies.

Throughout pregnancy various medications can be administered to help with pregnancy symptoms. These symptoms may be more severe in twin pregnancies as hormone levels are significant. It would be interesting to review more medication

combinations and dosages in twin pregnancies as compared to singleton pregnancies. Tocolytics was found to be useful in preventing preterm labor, but only temporary. One study that was reviewed was a meta-analysis of a cohort of studies on progesterone use in preventing preterm labor of twins. Various dosages and two types of progestogen were compared. The study showed no significant advantage to the use of progestogen in preterm prevention based on chorionicity.

If improved prenatal protocols are followed, many complications may be prevented allowing for safe vaginal delivery. Cervical cerclage can also be performed to help prevent premature labor. Up until delivery, tocolytics can be administered to hold off delivery for a short period. But Twin pregnancies are not always so predictable and not all complications are preventable. This study reviewed delivery outcomes through the routes of cesarean vs. vaginal. Composite outcomes were fewer in vaginal delivery, but cases of intraventricular hemorrhage were greater in vaginal delivery. As far as the influence of position of the fetuses in vaginal delivery, there were some differences. Intraventricular hemorrhage grade 3-4 and deaths were more prevalent in vaginal delivery of cephalic-noncephalic groups. Whereas composite outcome, respiratory distress syndrome, and intraventricular hemorrhage were less prevalent in cephalic-noncephalic groups. It is important to note that this study- the Barzilay et al study- focused on very low birth weight babies. As was noted in the introduction, many twins are born with a low birthweight. Still this does not account for all twins, as some may not be low birth weight. It is important to understand that this literature review was limited by the parameters within each individual study analyzed.

This twin study was challenging because it was a complex human study that was conducted through literature review. The complexity lies in the various components that influence the result. This study was limited to what was found in the literature search based on the topics of technology, medication, lifestyle choices and delivery route of twins. There was no direct connection to the participants in the studies found for the analysis. Whatever limits the individual studies had, also limited this literature review. It is important to also clarify that these findings may not apply to all twin pregnancies, because each mother, baby and pregnancy can be different.

Human reproduction is a complex process that is still not well understood. Even more so for someone who has not obtained medical school training and has no experience delivering twins. The introduction section on training brought this to light also. As even some physicians have limited knowledge and experience dealing with twin pregnancy and delivery. But this study helped to show that knowledge is key to successful twin pregnancy and delivery. In addition to knowledge and experience, time also effects twin delivery outcomes. This complex study was completed in less than a year. Different moments during pregnancy, delivery and after delivery was analyzed to create a larger picture.

Twin pregnancy is a complex topic to analyze. The reason is because there are so many components that factor in to allow for safe gestation and delivery. Components such as lifestyle, health status, access to technology and medication all influence pregnancy and delivery outcomes. One-year period limits the amount of time to evaluate each component thoroughly. For this reason, the study focused more heavily on the complications and ways to prevent them in twin pregnancy and delivery.



It is also important to note that even with the best care possible, there are situations that are beyond the current knowledge and abilities of medical staff. Sometimes even with perfect prenatal care, genetic influence may overcome the protocols. All precautions taken, there are some situations that cannot be solved by practice or technology, it is simply in the genetic material of the parents and the babies. This study did not review genetic influence on twin pregnancy and delivery.

The main interest of this study was to gain a deep understanding of each component – technology use, lifestyle influence, medication administration – and how they affect the route of delivery for twins. These studies helped in formulating rough guidelines that may lead to successful pregnancies and vaginal delivery of twins. They also provided data on the complications that often accompany twin pregnancies and delivery. My hypothesis was that vaginal delivery of twins can be safe if precautions are taken regarding lifestyle choices, medication administration, and technology use. If mothers follow a healthy lifestyle that is cautious and maintained by medication administration when necessary, coupled with more frequent routine visits, they will have a chance at a healthier twin pregnancy. This healthier pregnancy may transition into a safe vaginal delivery. It is also expected that if medical professionals use the resources and technologies available in greater frequency as well as build their training and experience, then they will have a better chance of safely delivering twins vaginally. The data obtained by analyzing existent literature showed that there is potential for improvement, but further studies will need to be conducted to finalize these findings.

## Appendix 1.

### Glossary

- A. **ART:** Assisted reproductive technology (Doyle, 1996).
- B. **Breech:** The state in which a baby is positioned feet down within the mother's womb. (The Bump, 2018).
- C. **Cesarean Section:** A surgical procedure in which the baby is delivered through an incision in the mother's lower abdomen (MedlinePlus, 2015).
- D. **Clomiphene:** A medication that induces ovulation (MedlinePlus, 2018).
- E. **Congenital Anomalies:** Birth defects and disorders (WHO, 2016).
- F. **External Cephalic Version (ECV):** A procedure that can be used to turn the baby within the womb for safer delivery (Carroll & Yeomans, 2006).
- G. **Invitro Fertilization (IVF):** A form of ART that involves retaining several ova, fertilizing, and developing them in the lab and then transferring them to the mother's uterus in hopes of conception (Progyny, 2018).
- H. **Multiples:** A gestation that involves more than one infant, i.e. twins, triplets, etc. (Martin et al., 2018).
- I. **Poly Cystic Ovaries Syndrome (PCOS):** Hormonal disruptions that often lead to infertility in women (Mayo Clinic Staff, 2017).

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