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Inheritance of ABO Blood Group and Rhesus Factor and It Implication in Genetic Counselling and Public Health Education

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Authors' contributions

This work was carried out in collaboration among all authors. Author AO did the literature search with author KBS. Author AO wrote the first manuscript and was edited by authors APC, AKBY and BAE. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Introduction: The discovery of the ABO Blood Group and rhesus factor, over century ago, triggered countless enthusiasm. Before then, all blood had been presumed to be the matching, and the often tragic consequences of blood transfusions were not understood.
Objective: The objective of this article sought to explain Inheritance of ABO Blood Group and Rhesus factor which would contribute to knowledge and help in Genetic Counselling.

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Methodology: This is a scoping review to explain Inheritance of ABO Blood Group and Rhesus factor. The LILACS-BIREME, SCIELO, PUBMED, ACADEMIA, SCIENCE DOMAIN databases, some textbooks and google scholar were accessed for the study. Scientific papers published in English were reviewed. A total of 35 reports published were identified and reviewed. Twenty five (25) publications meeting the inclusion criterion were selected for this review. Finally, an analysis was conducted and the papers were assessed in agreement with the study objectives.
Findings: Determining an individual's blood group is important prior to blood transfusion and prior to the donation or receiving of a kidney transplant. Although blood group studies cannot be used to prove paternity, they can provide unequivocal evidence that a male is not the father of a particular child. Aside knowing your genotype before marriage, there is the need for one to know about Rhesus factor to prevent Rhesus factor incompatibility.
Conclusion: The discussion and knowledge generated on the ABO blood group and the Rhesus factor could be used in genetic counselling and public health education to prevent transfusion reaction and Rhesus factor incompatibility.

Keywords: Inheritance; ABO blood group; rhesus factor; genetic counselling.

1. INTRODUCTION

"The discovery of the ABO Blood Group, over a century ago, triggered countless enthusiasm. Before then, all blood had been presumed to be matching, and the often tragic consequences of blood transfusions were not understood. As our understanding of the ABO group grew, not only did the world of blood transfusion become a great deal safer, but scientists could now study one of the first human characteristics proven to be inherited. A person's ABO blood type was used by lawyers in paternity suits, by police in forensic science, and by anthropologists in the study of different populations" [1]. "For years, questions of paternity presented a significant challenge to scientists and potential parents alike. During the first half of the twentieth century, researchers often turned to people's ABO phenotypes when such issues arose; however, ABO blood group information could only be used to exclude potential fathers, rather than confirm the presence of a parental relationship" [1].

2. ABO BLOOD GROUP

"The human ABO blood groups were discovered by Austrian-born American biologist Karl Landsteiner in 1901. Landsteiner found that there are substances in the blood, antigens and antibodies that induce clumping (agglutinations) of red cells when red cells of one type are added to those of a different type" [2].

3. CLASSIFICATION OF ABO BLOOD GROUP SYSTEM

"The ABO blood group system classifies blood types according to the different types of antigens in the red blood cells and antibodies in the plasma. The ABO system alongside the RhD antigen status determine which blood type or types will match for a safe red blood cell transfusion.

Group A: The surface of the red blood cells contains A antigen, and the plasma has anti-B antibody. Anti-B antibody would attack blood cells that contain B antigen.

Group B: The surface of the red blood cells contains B antigen, and the plasma has anti-A antibody. Anti-A antibody would attack blood cells that contain A antigen.

Group AB: The red blood cells have both A and B antigens, but the plasma does not contain anti-A or anti-B antibodies. Individuals with type AB can receive any ABO blood type" [3].

Group O: The plasma contains both anti-A and anti-B antibodies, but the surface of the red blood cells does not contain any A or B antigens. This is indicated in the Table 1. "Since these antigens are not present, a person with any ABO blood type can receive this type of blood" [4].

4.RHESUS FACTOR

"Rh factor (ie, Rhesus factor) is a red blood cell surface antigen that was named after the monkeys in which it was first discovered. Some red blood cells have Rh factor, also known as the RhD antigen. Rhesus grouping adds another dimension. If the red blood cells contain the RhD antigen, they are RhD positive. If they do not, they are RhD negative" [5]. This is indicated in the Fig. 1 below.

Table 1. Diagram showing antigens and antibodies of ABO blood group

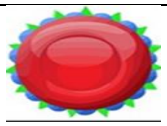
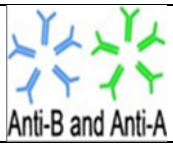
	GROUP A	GROUP B	GROUP AB	GROUP O
Red blood cell type				
Antibodies present			**None**	
Antigens present				**None**

Fig. 1. Diagram showing rhesus positive and negative antigen on red blood cell

5. UNDERSTANDING ABO BLOOD GROUP AND RHESUS FACTOR

In understanding blood group for transfusion, there is the need to take into account both ABO and Rhesus when considering blood types. This means that there are eight main blood types in the ABO and Rhesus Blood Group Systems as indicated in Table 2. The 8 blood groups that may be derived from the ABO and Rhesus Blood Group Systems are A+, A-, B+ B-, AB+, AB-, O+ and O–. It is important to note that for blood transfusion to be possible to prevent transfusion reaction the donor's ABO blood group should match with the recipient's blood. In addition to ABO grouping and matching, Rhesus factor should also be considered as part of grouping and cross matching [5].

Table 2. Showing red blood cell compatibility

Recipient	Donor							
	O-	O+	A-	A+	B-	B+	AB-	AB+
O-	√	X	X	X	X	X	X	X
O+	√	√	X	X	X	X	X	X
A-	√	X	√	X	X	X	X	X
A+	√	√	√	√	X	X	X	X
B-	√	X	X	X	√	X	X	X
B+	√	√	X	X	√	√	X	X
AB-	√	X	√	X	√	X	√	X
AB+	√	√	√	√	√	√	√	√

6. UNIVERSAL DONOR AND UNIVERSAL RECIPIENT

6.1 Universal Donor

"O negative blood contains no A, B, or RhD antigens. Almost anyone with any blood type can receive these red blood cells. A person with group O negative blood is a universal donor. A person with O-negative blood can donate to almost anyone. A person with Rh-negative blood can donate to a person with Rh-negative or Rh-positive blood. A person with Rh-positive blood can only donate to someone with Rh-positive" [6,7].

6.2 Universal Recipient

"It refers to someone of the AB-positive blood type, who can generally receive red blood cells from any ABO type (A, B, AB, or O) and any Rh type (Rh-positive or -negative). These people comprise less than 4% of the population. However, the same caveat applies to this designation as to O negative "universal donors": They are only universal recipients if they have no additional blood group antibodies" [7].

It should be noted AB blood donors are very important, too, as their plasma can be given to essentially any recipient (since it lacks ABO blood group antibodies). So, AB-positive people could be considered both "universal recipients" and "universal plasma donors."

6.3 Inheritance of ABO Blood

"Most genes have two alleles, a dominant allele and a recessive allele. For example: tall (dominant) and dwarf (recessive). If an organism is heterozygous for that trait (possesses one of each allele), then usually the dominant trait is expressed. A recessive allele is only expressed if an organism is homozygous for that trait (possesses two recessive alleles). Although individual humans (and all diploid organisms) can only have two alleles for a given gene, multiple alleles may exist at the population level" [5].

Table 3. Table showing dominant and receive alleles

Alleles Present	Alleles Expressed
Dominant, Dominant	Dominant
Dominant, Recessive	Dominant
Recessive, Recessive	Recessive

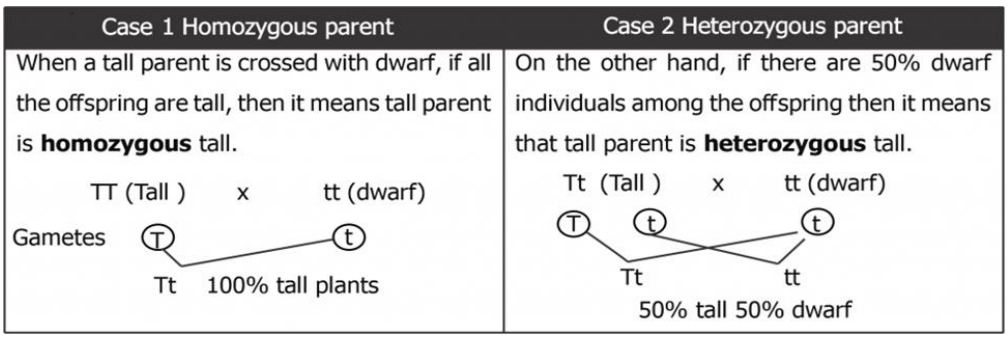


Fig. 2. Diagram showing homozygous and heterzygous alleles

Table 4. Table showing ABO blood group genotype and phenotype

Allele from Parent 1	Allele from Parent 2	Genotype of Offspring	Blood types of Offspring (Phenotype)
A	A	AA	A
A	B	AB	AB (Co – dominant)
A	O	AO	A
B	A	AB	AB
B	B	BB	B
B	O	BO	B
O	O	OO	O (Recessive)

6.4 Genotype Verses Phenotype

"A genotype refers to the genetic characteristics of an organism. A phenotype refers to the physical characteristics. For example, having blue eyes (an autosomal recessive trait) is a phenotype; lacking the gene for brown eyes is a genotype. The genotype of ABO Blood Group include AA, AB, AO, AB, BB, BO and OO. These genotype may however produce the following phenotypes; A, B, AB and O Blood Groups" [5,8].

6.5 Multiple Alleles

"Multiple alleles are defined as three or more alternative form of a same gene, located on same locus on the homologous chromosomes, coding for certain characteristic in a population. A gene controlled by more than two alleles and following Non-Mendelian pattern of inheritance and is described as Multiple Allelism. One example of a trait that has multiple alleles is the human ABO blood group trait" [5,6,7,8].

"ABO blood groups are the best examples for multiple allelism in human beings. The blood group A, B, AB and O types are characterized by the presence or absence of antigens on the surface of RBC. Blood type A person have antigen A on their RBCs and anti B antibodies in the plasma. Blood type B person have antigen B on their RBCs and anti A antibodies in the plasma. Blood type AB person have antigen A and B on the RBCs and no antibodies in the plasma. Blood type O person have no antigens on their RBCs and both anti-A and anti-B antibodies are present in the plasma. Bernstein discovered that these phenotypes were inherited by the interactions of three autosomal alleles of the genes named 'I' located on chromosome 9. IA, IB and IO are the three alleles of the gene" [9,10].

6.6 Codominance

"Codominance is a relationship between two versions of a gene. Individuals receive one version of a gene, called an allele, from each parent. If the alleles are different, the dominant allele usually will be expressed, while the effect of the other allele, called recessive, is masked. In codominance, however, neither allele is recessive nor are the phenotypes of both alleles expressed". [5,10].

Codominance means that neither allele can mask the expression of the other allele. An example in humans would be the ABO blood group, where alleles A and alleles B are both expressed because they are both dominant genes and the O gene is recessive. So if an individual inherits allele A from the mother and allele B from the father, the person would have blood type AB.

Table 5. Table showing multiple alleles and codominace

Allele from Parent 1	Allele from Parent 2	Child's genotype	Child's Phenotype
A	A	AA	A
A	O	AO	A
A	B	AB	AB
B	A	AB	AB
B	B	BB	B
B	O	BO	B
O	O	OO	O

Table 6. Table showing rhesus positive and negative alleles

Table 6a.

Rh Factor	Possible Genotypes
Rh^+	**Rh^+/Rh^+ OR Rh^+/Rh^-**
Rh^-	**Rh^-/Rh^-**

Table 6b.

Parent 1 Rh allele	Parent 2 Rh allele	Child's phenotype
Rh^+	Rh^+	Rh^+
Rh^-	Rh^+	Rh^+
Rh^-	Rh^-	Rh^-

6.7 Inheritance of Rh Factor

Rh status is inherited from our parents, separately from our blood type. If you inherit the dominant Rhesus D antigen from one or both of your parents, then you are Rh-positive (85% of us). If you do not inherit the Rhesus D antigen from either parent, then you are Rh-negative (15% of us). This is indicated in the Table 6. So, is it possible for two people who are Rh-positive to produce a child that's Rh-negative? The answer is yes — but only if neither parent passes along Rhesus D [10,11].

7. RHESUS FACTOR INCOMPATIBILITY

The red cells of certain individuals contain Rhesus factor or an agglutinogen D; about 85% of people are Rhesus positive (i.e. their blood contain this factor) and about 15% are Rhesus negative. When a rhesus negative mother has babies by a Rhesus positive father she may produce rhesus positive babies. Though the first child is usually normal, subsequent infants may be still-born or after birth suffer from jaundice or anemia erythroblastosis because the mother produces antibodies to the babies in utero [11,12]. This is indicated in the Fig. 3.

"Erythroblastosis fetalis, also called hemolytic disease of the newborn, type of anemia in which the red blood cells (erythrocytes) of a fetus are destroyed in a maternal immune reaction resulting from a blood group incompatibility between the fetus and its mother. This incompatibility arises when the fetus inherits a certain blood factor from the father that is absent in the mother. Symptoms of erythroblastosis fetalis range from mild to severe; death of the fetus or newborn sometimes results" [12,13,15].

"Two blood group systems, Rh and ABO, primarily are associated with erythroblastosis fetalis. The Rh system is responsible for the most severe form of the disease, which can occur when a Rh-negative woman (a woman whose blood cells lack the Rh factor) conceives a Rh-positive fetus. Sensitization of the mother's immune system (immunization) occurs when fetal red blood cells that carry the Rh factor (an antigen in this context) cross the placental barrier and enter the mother's bloodstream" [16]. "They stimulate the production of antibodies, some of which pass across the placenta into fetal circulation and lyse, or break apart, the red blood cells of the fetus (hemolysis)" [11,14,22].

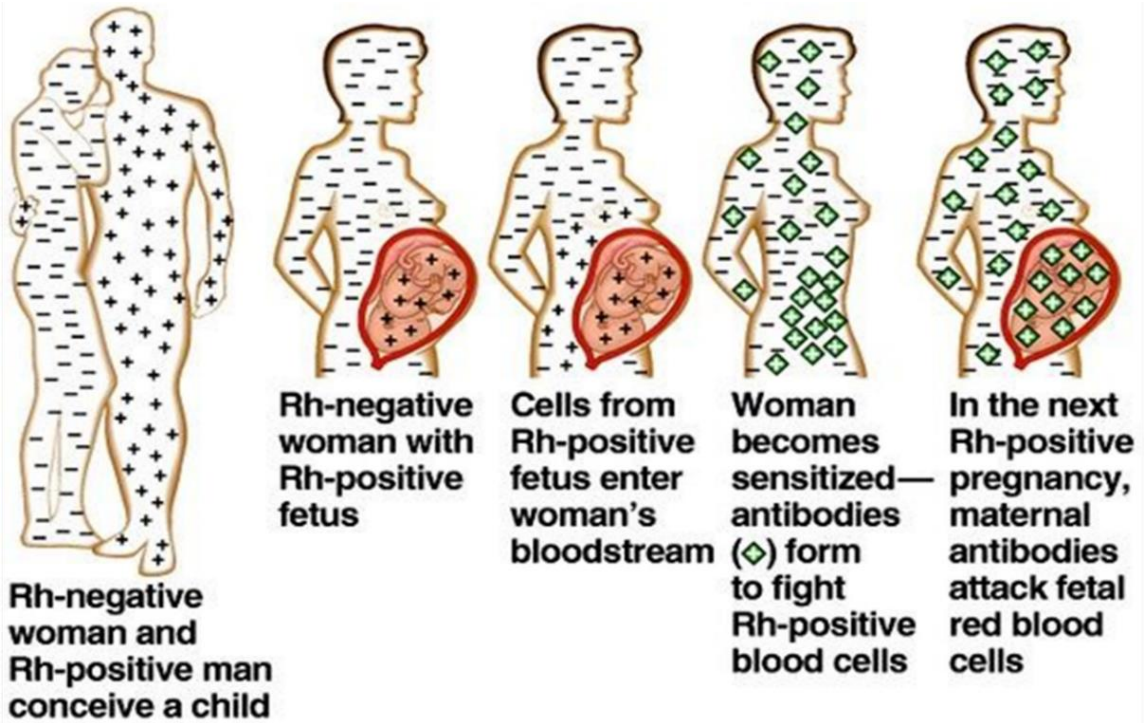


Fig. 3. Diagram showing rhesus positive father, rhesus negative mother and rhesus positive fetus

8. IMPLICATION FOR GENETIC COUNSELLING AND HEALTH EDUCATION

Genetic counselling is the practice through which awareness is created about the genetic aspects of illnesses by qualified and educated professionals with those who are at high risk or either having a heritable disorder or of passing it on to their unborn offspring [25]. Understanding the ABO Blood Group and the rhesus factor are very important in genetic counselling.

"Determining an individual's blood group is important prior to blood transfusion and prior to the donation or receiving of a kidney transplant" [17,18,19]. "Although blood group studies cannot be used to prove paternity, they can provide unequivocal evidence that a male is not the father of a particular child. Since the red cell antigens are inherited as dominant traits, a child cannot have a blood group antigen that is not present in one or both parents. In paternity testing therefore ABO genotyping is superior to ABO phenotyping [20,21]. Aside knowing your genotype before marriage, there's need for one to know about Rhesus factor" [22,23].

"In many African cultures up till today, women who are so unfortunate to find themselves having serial spontaneous abortions due to Rhesus factor incompatibility are considered witches by some of their people. Some of the women would accuse their in-laws of being behind their predicament. It should also be noted that a Rh– person (man or woman) cannot receive blood donation from a Rh+ person even if they have the same blood group. The consequence of such blood transfusion is fatal. It could lead to death as the blood would clot. This is due to the incompatibility in their Rhesus factor. Because Rh factor is genetic, it is not possible to choose which Rh type your baby has. However, if you are an Rh-negative woman with an Rh-positive baby, you can prevent Rh incompatibility by receiving RhoGAM, an anti-Rh antibody at specific times during pregnancy" [23,24]. It is an important topic to discuss with your healthcare provider.

9. CONCLUSION

Many patients rely mostly on their primary healthcare providers for information about their condition. In general, though, patients will require information providers may not have. Before providing patients with any educational materials, providers should be sure to check that the information is current and produced by a credible source. The discussion and knowledge generated on the ABO blood group and the Rhesus factor could therefore be used in genetic counselling and public health education to prevent transfusion reaction and Rhesus factor incompatibility.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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