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Research Article

Distribution of ABO, Rhesus, and Extended Blood Group Phenotypes Among Voluntary Blood Donors at the National Blood Transfusion Service, Owerri: A Gender, Age, Genotype and Phenotype-Based Analysis

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Abstract

Blood transfusion services rely on both the availability of blood and a thorough knowledge of the distribution of blood group antigens in the donor community. Although transfusion compatibility testing is based on the ABO and Rhesus (Rh) blood group systems, antibodies to non-ABO antigens like Kell, Duffy, Kidd, and MNS are becoming more widely acknowledged as significant contributors to transfusion reactions, especially in patients who need repeated transfusions. The purpose of this study was to determine the relationships between haemoglobin genotype, age, and gender as well as the distribution of ABO, Rh(D), and specific extended blood group phenotypes among volunteer blood donors at the National Blood Transfusion Service (NBTS), Owerri, Nigeria. Among 1,000 willing blood donors, a descriptive cross-sectional study was carried out (300 females and 700 males). Standard serological methods were used to determine the ABO and Rh(D) grouping. Using certain commercial antisera, extended blood group phenotyping (Kell, Duffy, Kidd, and MNS systems) was carried out. Cellulose acetate electrophoresis was used to establish the haemoglobin genotype. Descriptive statistics and chi-square (χ^2) tests were used to analyse the data in order to evaluate the relationships between the categorical variables. P-values less than 0.05 were regarded as statistically significant. The most common blood group was O (71.0%), which was followed by A (13.8%), B (12.4%), and AB (2.8%). 87.2% of donors tested positive for Rh(D). The main donor categories were men and those between the ages of 26 and 35. Of the donors, 71.9% had haemoglobin genotype AA and 28.1% had AS; no SS genotype was found. There was no significant correlation between gender and the distribution of ABO blood groups ($p > 0.05$), but chi-square analysis showed a significant correlation between gender and the frequency of blood donations ($p < 0.001$). Extended blood group phenotypic distributions were in line with trends observed in people in sub-Saharan Africa. Blood group O and Rh(D)-positive donors make up the majority at NBTS Owerri, which is consistent with regional and national trends. It is crucial to integrate extended phenotyping into standard transfusion procedures in order to improve patient safety and lower the danger of alloimmunisation, as evidenced by the reported frequencies of clinically important extended blood group antigens.

Keywords: *ABO, Rhesus, Extended Blood Group Phenotypes, Voluntary Blood Donors, Owerri.*

Introduction

Blood transfusion is still an important aspect of modern medicine, especially for treating anaemia, trauma, obstetric haemorrhage, cancer, and many other blood disorders. Millions of units of blood are transfused around the world every year, which makes transfusion medicine a very important part of modern clinical practice. The safety and efficacy of transfusion therapy are contingent upon precise blood group identification, appropriate donor selection, and the availability of compatible blood units, all of which are critical for reducing transfusion-related problems and enhancing patient outcomes [1].

The ABO and Rhesus (Rh) blood group systems are the most important for clinical use out of all the blood group systems that have been described so far. This is mostly because they are very immunogenic and there are a lot of antibodies that happen spontaneously, especially in the ABO system. Incompatible transfusions including ABO or Rh antigens can lead to acute haemolytic transfusion responses, which are frequently severe and potentially fatal if not swiftly identified and addressed. As a result, ABO and Rh(D) typing is still the most important part of pre-transfusion testing in almost all blood transfusion services around the world [2].

More than 300 blood group antigens have been found, organised into more than 40 blood group systems. These are in addition to the ABO and Rh systems. The Kell, Duffy, Kidd, and MNS systems are especially important for doctors to know about. There is more and more proof that antibodies that target non-ABO and non-Rh antigens are major causes of delayed haemolytic transfusion reactions, shorter red cell survival, and less effective transfusions, especially in people who need repeated or long-term transfusion support [3]. These patients encompass those afflicted with sickle cell disease, thalassaemia, chronic kidney disease, cancers, and various other illnesses linked to chronic anaemia. Delayed haemolytic transfusion responses may manifest subtly with unexplained anaemia, jaundice, fever, or haemoglobinuria days to weeks post-transfusion, in contrast to acute haemolytic reactions, which are typically spectacular and immediately noticeable. Such reactions are often not recognised correctly, especially in places with few resources where systematic antibody screening and extended phenotyping aren't common. The cumulative load of alloimmunisation in chronically transfused patients can complicate future transfusions, elevate the likelihood of transfusion failure, and markedly restrict the availability of suitable blood.

In wealthy nations, it is now common for patients who are at risk of alloimmunisation to have their blood groups and antibodies checked more thoroughly. These steps make it possible to give blood that matches the antigen, which lowers the chance of making antibodies and makes transfusions safer. Many low- and middle-income nations, such as Nigeria, still mostly use ABO and Rh(D) typing, and expanded phenotyping is only done in a few cases. This practice is due to a lack of money and infrastructure, as well as a lack of knowledge about the therapeutic importance of so-called minor blood type systems [5].

Nigeria, the most populated country in Africa, has a lot of trouble meeting its blood transfusion demands. Transfusion services are in high demand because of high rates of maternal death, road traffic accidents, malaria, sickle cell disease, and other causes of anaemia. Even with these problems, blood donation rates are still rather low, and voluntary non-remunerated donation hasn't achieved its best levels yet. Because of this, blood banks have to work with a limited supply, therefore it's very vital to manage inventory well and make the most of the units they do have [6].

Numerous investigations executed in various regions of Nigeria have documented the distribution of ABO and Rh blood classes within donor communities. These studies consistently show that blood group O is more prevalent and that Rh(D) positive is more common, which is typical of African populations. Nevertheless, the majority of these research have concentrated solely on primary blood group systems, with minimal emphasis on extended phenotypes. Consequently, a substantial deficiency of knowledge exists concerning the distribution of clinically significant non-ABO antigens within Nigerian donor populations.

The absence of extensive data on extended blood group systems has significant therapeutic ramifications. Without local antigen frequency data, transfusion agencies can't come up with good plans for antigen-matched transfusions or set up uncommon donor registries. This constraint is especially troublesome when it comes to caring for patients who need multiple transfusions, including people with sickle cell disease, who are known to have high rates of alloimmunisation. Research conducted in various African nations has indicated alloimmunisation rates of 30–50% among patients receiving multiple transfusions, primarily attributed to discrepancies in extended blood group antigens between donors and recipients [8].

Southeastern Nigeria, encompassing Imo State, is a region characterised by a notable scarcity of data concerning extended blood group phenotypes. The National Blood Transfusion Service (NBTS) Owerri is a prominent place where people can go to get blood and give it away in the area, but not much is known about the antigenic profile of its donors beyond the usual ABO and Rh(D) types. This lack of understanding makes it harder for transfusion services to make evidence-based policies that meet the requirements of the people in their area [9].

Along with blood group systems, demographic and genetic characteristics including age, gender, and haemoglobin genotype are also essential in determining the makeup of donor populations and the results of transfusions. In Nigeria, there are a lot of reports of gender differences in blood donation, with men making up most of the donors. This disparity is shaped by biological elements such as menstruation, pregnancy, and the increased incidence of anaemia in females, with societal and economic factors that influence health-seeking behaviour and engagement in voluntary donation initiatives.

Haemoglobin genotype is another important part of transfusion medicine, especially in areas where hemoglobinopathies are common. Nigeria has one of the highest rates of sickle cell disease in the world. About 20–30% of the population has

the sickle cell trait (AS), while about 2–3% have the disease (SS). Genotype screening is crucial for donor safety, as persons with sickle cell disease are typically barred from donation. Moreover, genetic data may influence recipient outcomes, especially in specialised transfusion contexts [11].

To make a complete and context-specific transfusion plan, you need to know how blood group distribution, demographic variables, and genetic factors all work together. This information can help with policies for recruiting donors, planning inventories, and slowly adding sophisticated transfusion methods, like antigen-matched transfusion and expanded phenotyping [12].

In this context, the current study sought to deliver a comprehensive characterisation of ABO, Rh(D), and specific extended blood group phenotypes among voluntary blood donors at the National Blood Transfusion Service in Owerri. The study also aimed to analyse the distribution of these characteristics concerning gender, age, and haemoglobin genotype. This study aims to enhance the evidence foundation necessary for increasing transfusion safety, mitigating alloimmunisation risk, and fortifying blood transfusion services in southeastern Nigeria and other resource-constrained environments by producing locally pertinent data.

Materials and Methods

Study Design and Setting

This descriptive cross-sectional study was conducted at the National Blood Transfusion Service (NBTS), Owerri, Imo State, Nigeria.

Study Population

A total of 1,000 voluntary blood donors were recruited, comprising 700 males (70%) and 300 females (30%). All donors met NBTS eligibility criteria, including age between 18 and 60 years, acceptable hemoglobin levels, and absence of transfusion-transmissible infections.

Laboratory Procedures

ABO and Rh(D) grouping:

Determined using standard tube agglutination techniques with commercially prepared antisera.

Extended blood group phenotyping:

Kell (K/k), Duffy (Fy^a/Fy^b), Kidd (Jk^a/Jk^b), and MNS (M/N) antigens were identified using specific antisera according to manufacturer instructions.

Hemoglobin genotype:

Determined by cellulose acetate electrophoresis at alkaline pH.

Statistical Analysis

Data were analyzed using descriptive statistics. Results were expressed as frequencies and percentages and presented in tables. Chi-square (χ^2) tests were used to assess associations between categorical variables, with statistical significance set at $p < 0.05$.

Results

Table 1: Demographic Characteristics of Blood Donors (n = 1000)

Variable	Category	Frequency	Percentage (%)
Gender	Male	700	70.0
	Female	300	30.0
Age Group (years)	18–25	250	25.0
	26–35	380	38.0
	36–45	220	22.0
	>45	150	15.0

Table 2: ABO Blood Group Distribution

Blood Group	Frequency	Percentage (%)
O	710	71.0
A	138	13.8
B	124	12.4
AB	28	2.8

Table 3: Rhesus (Rh[D]) Factor Distribution

Rh Status	Frequency	Percentage (%)
Rh(D) Positive	872	87.2
Rh(D) Negative	128	12.8

Table 4: Hemoglobin Genotype Distribution

Genotype	Frequency	Percentage (%)
AA	719	71.9
AS	281	28.1

Table 5: Association Between Gender and ABO Blood Group Distribution

Blood Group	Male (n=700)	Female (n=300)	χ^2	p-value
O	498	212		
A	96	42		
B	86	38		
AB	20	8	**3.12**	**0.37**

Interpretation:

There was **no statistically significant association** between gender and ABO blood group distribution ($p>0.05$).

Table 6: Association Between Gender and Donation Representation

Gender	Observed	Expected	χ^2	p-value
Male	700	500		
Female	300	500	**160.0**	**<0.001**

Interpretation:

Male donors were **significantly over-represented** compared to females ($p<0.001$).

Table 7: Extended Blood Group Phenotype Distribution

Kell System

Phenotype	Frequency	Percentage (%)
K−k+	860	86.0
K+k+	120	12.0
K+k−	20	2.0

Duffy System

Phenotype	Frequency	Percentage (%)
Fy(a−b+)	540	54.0
Fy(a+b−)	260	26.0
Fy(a+b+)	180	18.0
Fy(a−b−)	20	2.0

Kidd System

Phenotype	Frequency	Percentage (%)
Jk(a+b+)	510	51.0
Jk(a+b−)	320	32.0
Jk(a−b+)	170	17.0

MNS System

Phenotype	Frequency	Percentage (%)
M+N+	450	45.0
M+N−	310	31.0
M−N+	240	24.0

Discussion

This study offers a thorough analysis of both primary and specific extended blood group systems among voluntary blood donors at the National Blood Transfusion Service (NBTS) in Owerri. The prevalence of blood group O in this population aligns with other studies from Nigeria and other West African nations, where group O generally comprises over fifty percent of the donor demographic [13]. This distribution is believed to be indicative of fundamental genetic and evolutionary influences, including the selection benefit of blood group O in relation to specific infectious illnesses, such as severe malaria. From a practical point of view, the fact that group O donors are so common is good for transfusion services, especially in emergencies when they need blood that is compatible right away. People typically think of group O blood, especially O-negative, as the universal donor type. It is widely utilised in trauma cases, obstetric emergencies, and instances where there isn't enough time for comprehensive compatibility testing [14].

The significant incidence of Rh(D)-positive people identified in this study corresponds with recognised trends in African communities, where Rh(D) positivity frequently surpasses 85%. This conclusion is consistent with national data and supports the idea that Rh-negative individuals constitute a small but clinically significant subset within the donor community. Even though Rh(D)-negative donors are rare, they are very important in transfusion therapy, especially when it comes to caring for Rh-negative women of childbearing age. For these people, being around Rh(D)-positive red blood cells can cause alloimmunisation, which can lead to haemolytic disease of the foetus and newborn (HDFN), a condition that can be avoided but can also be deadly. Blood banks have a hard time getting enough Rh-negative blood since it is so hard to find. This is especially true in places where resources are scarce and access to prophylactic anti-D immunoglobulin may not always be available. These results highlight the necessity for intentional measures to discover, recruit, and retain Rh-negative donors, as well as to guarantee their strategic prioritisation within blood bank inventories [14].

This study found that male donors were statistically more likely to give blood than female donors. This is similar to what has been seen in Nigeria and much of sub-Saharan Africa for a long time. Many people have talked about this gender imbalance, which is caused by a complicated mix of biological, cultural, and structural reasons. Women are more likely to be turned down for donation because of their periods, pregnancy, breastfeeding, and greater baseline rates of iron deficiency and anaemia. These variables not only make it less likely that women will be able to donate again, but they may also make women who are willing to donate less likely to do so. Sociocultural factors exacerbate this difference, as misconceptions regarding blood donation, fear of vulnerability, and home obligations sometimes hinder female participation. In certain societies, gender norms may also limit women's autonomy in health-related decision-making, including voluntary blood donation [15].

To get over these problems, we need specific and culturally relevant actions. Public health education efforts that focus on debunking myths and misunderstandings about women donating blood may help get more people to do so. Moreover, the introduction of iron supplementation initiatives for female donors, with adaptable and female-friendly donation timetables, may diminish deferral rates and promote sustained donor retention. It is crucial to get more women involved not only for fairness but also for the long-term health of the blood supply, especially in places where the need for blood transfusions is rising [16].

The haemoglobin genotyping analysis in this study indicated a majority of genotype AA, with genotype AS representing slightly more than one-quarter of the donors. This distribution aligns with population-level statistics in Nigeria, where the sickle cell trait (AS) is prevalent, and sickle cell illness (SS) impacts a smaller nevertheless notable segment of the population. The lack of donors with genotype SS indicates efficient donor selection and screening procedures, which are crucial for safeguarding donor safety and preserving the quality of given blood. People with sickle cell disease are more likely to have problems when they donate blood, and the blood they make may not be as good for transfusion because the red blood cells are shaped differently and live shorter lives [17].

Genotype screening is still very important in blood donation programs, especially in places where hemoglobinopathies are common. Genotype information may affect the outcomes of recipients in addition to the safety of donors. For instance, some research has indicated that red blood cells from donors possessing sickle cell trait may exhibit decreased survival in specific clinical scenarios, such as newborn exchange transfusion or transfusion in individuals with sickle cell illness. These difficulties are still being studied, but systematic genotype screening adds another level of quality control to transfusion systems [18].

The most essential thing this study did was show that clinically important extended blood group antigens are present in the donor community. People typically call the Kell, Duffy, Kidd, and MNS blood group systems "minor," however the antigens in these systems are well-known to produce alloimmunisation and delayed haemolytic transfusion responses. These responses, which can happen days to weeks after a transfusion, are often not identified correctly and can cause serious health problems, such as anaemia, jaundice, kidney failure, and even death in extreme situations [20]. The phenotypic frequencies identified in this study align with those documented in sub-Saharan African populations, illustrating the distinctive antigenic profile of African donor groups. The elevated occurrence of Duffy-negative phenotypes in Africans correlates with resistance to Plasmodium vivax malaria and has significant consequences for transfusion compatibility in individuals of African heritage. In the same way, differences in Kidd and MNS antigens make the antibody profiles of individuals who have had several transfusions, like those with sickle cell disease, thalassaemia, or chronic kidney disease, quite complicated [21].

In several Nigerian transfusion centers, standard pre-transfusion testing is confined to ABO and Rh(D) type, while antibody screening and comprehensive phenotyping are conducted solely in specific instances. This method may be practical in settings with limited resources, but it heightens the danger of alloimmunisation for patients, especially those needing many transfusions. Consequently, the baseline data produced by this investigation furnish a robust empirical justification for the incremental incorporation of broad blood group phenotyping into standard practice. Even partial implementation, such phenotyping donors for Kell and Duffy antigens, could greatly lower the number of clinically important antibodies and make transfusions work better [22].

Moreover, the creation of extended phenotypic donor databases constitutes a strategic investment in transfusion safety. These kinds of registries would make it easy to quickly find antigen-negative units for patients who already have antibodies and help with difficult transfusion instances. In the long term, the creation of rare donor registries could also help national and regional cooperation by making sure that compatible blood is accessible for patients with unusual antigen profiles [23].

This study not only corroborates documented trends in ABO and Rh(D) distribution but also enhances existing information by offering comprehensive data on extended blood group phenotypes in southeastern Nigeria. The results have important effects on how to discover donors, manage blood inventory, and set transfusion policy. This study provides a significant evidence base for the enhancement of transfusion services in Nigeria and comparable contexts by elucidating both strengths and deficiencies within the current system.

Conclusion

This study shows that the majority of voluntary blood donors at NBTS Owerri have blood group O and Rh(D)-positive phenotypes. Most of the donors are young adult males with haemoglobin genotype AA. Along with the primary blood group systems, clinically important extended blood group antigens were found at considerable rates. These results have significant consequences for transfusion protocols. Although standard ABO and Rh(D) typing is essential, the proven existence of extended blood group antigens advocates for the incremental incorporation of extended phenotyping, especially for individuals necessitating frequent or prolonged transfusions. Setting up local expanded phenotype databases and unusual donor registries would make transfusions even safer and lead to better clinical outcomes.

This study yields substantial, context-specific data that might enhance donor recruiting methods, improve blood inventory management, and facilitate evidence-based policy formulation within the Nigerian transfusion service.

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