CHAPTER 2

FUZZY SETS IN MEDICO-LEGAL ASPECTS

This Chapter consists of two fuzzy medico-legal aspects models. The first model analyses, how a father's (mother's) blood group can be identified with the help of mother's (father's) and their children's blood group, in which blood groups have fuzzy membership values. The procedure for the solution is illustrated with a numerical example. The second model demonstrates how the children's blood group can be identified from the blood group of their parents. Here fuzzy theory technique is applied to identify the blood group of offspring, and also the Rh factor of the same. In conclusion, an application related to the above methodology is discussed.

2.1. INTRODUCTION

Land Steiner (1900) discovered [38] two kinds of antigen or

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agglutionogens or iso agglutinogens. Based on it, the human blood is classified in the four types as A, B, AB and O. Identifying the blood group of human beings is very essential as it is very helpful to save ones life in many ways. There are four types of blood groups A, B, AB, and O. The blood groups ‘A’ and ‘B’ have got the antigents ‘A’ and ‘B’ respectively and both considered to be a dominant in nature. The blood group ‘AB’ has ‘AB’ antigen and it is co-dominant in nature, the blood group ‘O’ has no antigen and it is recessive in nature. The usual way of identifying the blood group of off springs is very complex and time consuming.

Most of our real life problems in medical sciences, engineering, management environment and social sciences of the value data are not necessarily crisp, precise and deterministic in character due to various uncertainties associated with these problems. Such uncertainties are usually being handled with the help of the study areas such as probability, fuzzy sets, intuitionistic fuzzy sets, interval mathematics and rough sets etc.

This research paper analyses, how a father’s blood group can be identified with the help of mothers and their children’s blood group and vice-versa. Here fuzzy set theory is applied to identify the blood group with
Rh factor, without any difficulty, so this theory has been applied in this aspect.

2.2. METHODOLOGY I

The method of identifying the parent of a child is very helpful in finding a solution to the disputed parentage. If a mother and her child is available, the father can be identified and at the same time if the parents are available the child can be easily identified. With one parent’s blood group and his/her child’s blood group, the second parent can be identified on many occasions in hospital. The children, who are born at the same time, may be misplaced by the nurse. In some cases, any one parent may be lost forever in an accident. In these circumstances we can easily identify either the parent’s blood group or the child’s blood group depends on which is missing or required to be calculated with the help of available data. Hence, to accomplish this we need compulsorily the blood groups of one parent and a child in order to trace out the other parent’s blood group.

\[ R_1 = \frac{\mu_A(x)}{\max\{\mu_A(x), \mu_B(x)\}} \]; \[ R_2 = \max((1 - \mu_A(x), \mu_B(x)) \]; \[ R_3 = \min(\mu_A(x), \mu_B(x)) \]
2.2.1 FLOW CHART

Start

Input father’s (mother’s) and the child’s blood group

Is it blood group unique?

Yes

Compute $R_1$

No

Does the membership value of father’s (mother’s) blood group $\leq$ Child’s blood group?

Yes

Compute $R_2$

No

Compute $R_3$

Is O blood group membership value equal to 1

Yes

Consider the maximum repeated membership value

No

Does all the blood group membership values are distinct?

Yes

Select ‘O’ blood group membership value as Strong $\alpha$ – cut.

No

Consider the maximum repeated membership value as strong $\alpha$ – cut.

Stop
2.2.2. ALGORITHM

Step 1: Initially, take either mother’s blood group or father’s blood group and child blood group.

Step 2: If the mother’s (father’s) blood group and the child blood group are same, and their membership values are applied in R₁.

Step 3:

(a) If the blood group of mother’s (father’s) and child blood group are different, then verify for any one or two same membership values.

(b) In case the blood group of mother’s (father’s) being lower than child blood group membership value and if the above two conditions are satisfied then we can apply the R₂.

(c) In case the blood group of mother’s (father’s) being higher than child blood group membership value, then their membership values are applied in R₃.

Step 4: The output received through the above mentioned application, keeping O blood membership value as a main factor, then the output values received in step 3 will decide the blood group of father’s (mother’s) based on the following conditions.
(a) If the blood group O membership value is 1, then select the maximum repeated membership value, and consider this as $A_{\alpha}$. 

(b) If the blood group O membership value is less than 1, then select the maximum repeated membership value, and consider this as $A_{\alpha'}$. 

(c) If the blood group O membership value is less than 1, and all the remaining blood group membership values are distinct then select O blood group membership value and consider this as $A_{\alpha'}$. 

2.2.3. GENETIC PROBLEMS (ABO blood system)

<table>
<thead>
<tr>
<th>Mother’s blood type</th>
<th>Child’s blood type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>A</td>
<td>A, B, AB or O</td>
</tr>
<tr>
<td>B</td>
<td>A or AB</td>
</tr>
<tr>
<td>AB</td>
<td>A, B, AB or O</td>
</tr>
<tr>
<td>O</td>
<td>A or AB</td>
</tr>
</tbody>
</table>
2.2.4. **MEDICO-LEGAL ASPECT Rh⁺ AND Rh⁻ BLOOD TYPES**

Possible blood types for parents

<table>
<thead>
<tr>
<th>Mother’s (father’s) and child Rh factors</th>
<th>Father’s (mother’s) Rh factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rh⁺, Rh⁺), (Rh⁺, Rh⁻) and (Rh⁻, Rh⁻)</td>
<td>(Rh⁺ or Rh⁻)</td>
</tr>
<tr>
<td>(Rh⁻, Rh⁺)</td>
<td>Rh⁺</td>
</tr>
</tbody>
</table>

2.2.5. **ILLUSTRATIVE EXAMPLES**

A few applications related to the above methodology, with the help of flowchart, is given below

1. If one of the parent blood group is A and the child’s blood group is AB then another parent’s blood group is either B or AB

\[
\mu_A(x) \times \mu_{AB}(x) = \frac{O}{0} + \frac{A}{0.25} + \frac{B}{0.76} + \frac{AB}{0.76}
\]

\[
= \frac{B}{0.76} + \frac{AB}{0.76}
\]

2. If one of the parent blood group is A and the child’s blood group is A, then another parent blood group is O or A or B or AB
\[ \mu_A(x) \times \mu_A(x) = \frac{O}{0} + \frac{A}{1} + \frac{B}{1} + \frac{AB}{1} \]

\[ = O, A, B, AB \]

3. If one of the parents blood group is O and the child’s blood group is B, then another parent’s blood group is B or AB

\[ \mu_O(x) \times \mu_B(x) = \frac{O}{0.26} + \frac{A}{0.24} + \frac{B}{0.74} + \frac{AB}{1} \]

\[ = B, AB \]

4. If one of the parents blood group is AB and the child’s blood group is B, then another parent’s blood group is O or A or B or AB

\[ \mu_{AB}(x) \times \mu_B(x) = \frac{O}{1} + \frac{A}{0.24} + \frac{B}{0.75} + \frac{AB}{0.24} \]

\[ = O, A, B, AB \]

5. If one of the parents blood group is AB and the child’s blood group is AB, then another parent’s blood group is A or B or AB

\[ \mu_{AB}(x) \times \mu_{AB}(x) = \frac{O}{0} + \frac{A}{1} + \frac{B}{1} + \frac{AB}{1} \]

\[ = A, B, AB \]
6. If one of the Parents blood group is $O^+$ and the child’s blood group is $A^-$ then another parent’s blood group is

$$\mu_{O^+} \times \mu_{A^-} = \frac{O^+ \times O^-}{0.26} + \frac{A^+ \times A^-}{0.74} + \frac{B^+ \times B^-}{0.24} + \frac{AB^+ \times AB^-}{1}$$

$$= \frac{A^+ \times A^-}{0.74} + \frac{AB^+ \times AB^-}{1}$$

$$= A^+ \text{ or } A^- \text{ and } AB^+ \text{ or } AB^-$$

7. If one of the parents blood group is $AB^+$ and the child’s blood group is $B^+$, then another parent’s blood group is

$$\mu_{AB^+} \times \mu_{B^+} = \frac{O^+ \times O^-}{1} + \frac{A^+ \times A^-}{0.24} + \frac{B^+ \times B^-}{0.25} + \frac{AB^+ \times AB^-}{0.24}$$

$$= O^+ \text{ or } O^- \text{, } A^+ \text{ or } A^- \text{, } B^+ \text{ or } B^- \text{ and } AB^+ \text{ or } AB^-$$

8. If one of the parents blood group is $B^-$ and the child’s blood group is $AB^-$, then another parent’s blood group is

$$\mu_{B^-} \times \mu_{AB^-} = \frac{O^+ \times O^-}{0} + \frac{A^+ \times A^-}{0.76} + \frac{B^+ \times B^-}{0.25} + \frac{AB^+ \times AB^-}{0.76}$$
\[
\frac{A^+ \times A^-}{0.76} + \frac{AB^+ \times AB^-}{0.76} = A^+ \text{ or } A^- \text{ and } AB^+ \text{ or } AB^-
\]

9. If one of the parents’ blood group is \(A^-\) and the child’s blood group is \(B^+\), then another parent’s blood group is

\[
\mu_{A^-}(x) \times \mu_{B^+}(x) = \frac{O^+}{0.74} + \frac{A^+}{0.24} + \frac{B^+}{0.76} + \frac{AB^+}{0.76}
\]

\[
= \frac{B^+}{0.76} + \frac{AB^+}{0.76}
\]

\[
= B^+ \text{ and } AB^+
\]

10. If one of the parents’ blood group is \(O^-\) and the child’s blood group is \(O^+\), then another parent’s blood group is

\[
\mu_{O^-}(x) \times \mu_{O^+}(x) = \frac{O^+}{1} + \frac{A^+}{1} + \frac{B^+}{1} + \frac{AB^+}{0}
\]

\[
= \frac{O^+}{1} + \frac{A^+}{1} + \frac{B^+}{1}
\]

\[
= O^+, \ A^- \text{ and } B^+
\]
2.3. METHODOLOGY II

Let genotypes of persons with blood group O, A, B and AB are formed as fuzzy sets with \( \mu_O(x), \mu_A(x), \mu_B(x), \mu_{AB}(x) \) as their membership functions respectively. The blood groups, the genotypes of parents and the off springs [38] we get the following equations.

\[
\mu_O(x) = \frac{O}{0.48} + \frac{A}{0.26} + \frac{B}{0.26} + \frac{AB}{0}
\]

\[
\mu_A(x) = \frac{O}{0.26} + \frac{A}{0.26} + \frac{B}{0.24} + \frac{AB}{0.24}
\]

\[
\mu_B(x) = \frac{O}{0.26} + \frac{A}{0.24} + \frac{B}{0.26} + \frac{AB}{0.24}
\]

\[
\mu_{AB}(x) = \frac{O}{0} + \frac{A}{0.25} + \frac{B}{0.25} + \frac{AB}{0.50}
\]

These values will help us to identify the blood groups of off springs without any confusion. Then

\[
A_{\alpha} = \{x \in X / \mu_A(x) \geq \alpha\} \hspace{1cm} 1
\]

\[
A_{\alpha'} = \{x \in X / \mu_A(x) > \alpha\} \hspace{1cm} 2
\]

\[
R_1 = \mu_{A_{AB}}(x) = \min \{\mu_A(x), \mu_B(x)\} \hspace{1cm} 3
\]
2.3.1. FLOWCHART

Start

Input Parent’s blood group

Determine R

Is Parent’s blood group unique?

Yes
Select ‘O’ type blood group membership value as strong $\alpha$ – cut

No

Does all the blood group membership values are distinct?

Yes
Consider the largest membership value as $\alpha$ – level set

No

Consider the maximum repeated membership value as $\alpha$ – level set

Stop
2.3.2. ALGORITHM

The following algorithm is framed with the help of the flowchart 2.3.1 given in section 2.3.

**Step 1:** The parent's blood group is identified and it is applied in the equation \( \mathbb{z} \).

**Step 2:** The acquired values are analyzed based on two conditions, and the result will help us to identity the blood group of the off springs. The result can be drawn based on the calculation as stated below:

a) The O blood group has strong recessive nature. Two O blood type parents can produce a child with only O blood type and consider as \( A_a \).

b) Select the maximum repeated membership value and consider as \( A_a \).

c) In case the two pairs of membership values are identical then select the maximum membership value and it is named as \( A_a \).
2.3.3. ILLUSTRATIVE EXAMPLES

1. If a man with blood group AB is married to a woman with blood group AB their children can be of any one of the following groups

\[
\mu_{AB}(x) \times \mu_{AB}(x) = \frac{O}{0.25} + \frac{A}{0.25} + \frac{B}{0.25} + \frac{AB}{0.50}
\]

\[
= \frac{A}{0.25} + \frac{B}{0.25} + \frac{AB}{0.50}
\]

The possible blood groups of off springs are A or B or AB.

2. If a man with blood group A is married to a woman with blood group O their children can be of any one of the following groups

\[
\mu_{A}(x) \times \mu_{O}(x) = \frac{O}{0.26} + \frac{A}{0.26} + \frac{B}{0.24} + \frac{AB}{0.0}
\]

\[
= \frac{O}{0.26} + \frac{A}{0.26}
\]

The possible blood groups of off springs are O or A.

3. If a man with blood group O is married to a woman with blood group O their children can be of the following group
\[ \mu_{O}(x) \times \mu_{O}(x) = \frac{O}{0.48} + \frac{A}{0.26} + \frac{B}{0.26} + \frac{AB}{0} \]

\[ = \frac{O}{0.48} \]

The possible blood group of offsprings is only O.

4. If a man with blood group A is married to a woman with blood group B their children can be of any one of the following groups

\[ \mu_{A}(x) \times \mu_{B}(x) = \frac{O}{0.26} + \frac{A}{0.24} + \frac{B}{0.24} + \frac{AB}{0.24} \]

The possible blood groups of offsprings are O or A or B or AB.

5. If a man with blood group B is married to a woman with blood group AB their children can be of any one of the following groups

\[ \mu_{B}(x) \times \mu_{AB}(x) = \frac{O}{0} + \frac{A}{0.24} + \frac{B}{0.25} + \frac{AB}{0.24} \]

\[ = \frac{A}{0.24} + \frac{B}{0.25} + \frac{AB}{0.24} \]

The possible blood groups of offsprings are A or B or AB.
2.4. METHODOLOGY III

Rh\(^+\) is a dominant and Rh\(^-\) is a recessive character. The Rh\(^-\) mother is given a special blood test after delivery of her Rh\(^+\) child. If foetal of Rh\(^+\) cells are present in mother’s blood, she is given injections of rhogan. The rhogan forms a coat around foetal RBC’s in mother’s blood and destroys them before their Rh antigen could initiate antibody formation in Rh\(^-\) mother.

Let the persons with groups O\(^+\), A\(^+\), B\(^+\) and AB\(^+\) are formed as fuzzy set with \(\mu_{O^+}(x), \mu_{A^+}(x), \mu_{B^+}(x), \mu_{AB^+}(x)\) another groups O\(^-\), A\(^-\), B\(^-\) and AB\(^-\) are formed as \(\mu_{O^-}(x), \mu_{A^-}(x), \mu_{B^-}(x), \mu_{AB^-}(x)\) as their membership functions respectively from the following membership equations.

This value will help as to identify the blood groups of off springs, without any confusion.

\[
\mu_{O^+}(x) = \frac{O^+}{0.48} + \frac{A^+}{0.26} + \frac{B^-}{0.26} + \frac{AB^+}{0}
\]

\[
\mu_{A^+}(x) = \frac{O^+}{0.26} + \frac{A^+}{0.26} + \frac{B^+}{0.24} + \frac{AB^+}{0.24}
\]
\[
\mu_{B^+}(x) = \frac{O^+}{0.26} + \frac{A^-}{0.24} + \frac{B^+}{0.26} + \frac{AB^+}{0.24}
\]

\[
\mu_{AB^+}(x) = \frac{O^+}{0} + \frac{A^+}{0.25} + \frac{B^+}{0.25} + \frac{AB^+}{0.50}
\]

and

\[
\mu_{O^-}(x) = \frac{O^-}{0.48} + \frac{A^-}{0.26} + \frac{B^-}{0.26} + \frac{AB^-}{0}
\]

\[
\mu_{A^-}(x) = \frac{O^-}{0.26} + \frac{A^-}{0.26} + \frac{B^-}{0.24} + \frac{AB^-}{0.24}
\]

\[
\mu_{B^-}(x) = \frac{O^-}{0.26} + \frac{A^-}{0.24} + \frac{B^-}{0.26} + \frac{AB^-}{0.24}
\]

\[
\mu_{AB^-}(x) = \frac{O^-}{0} + \frac{A^-}{0.25} + \frac{B^-}{0.25} + \frac{AB^-}{0.50}
\]

2.4.1. **ILLUSTRATIVE EXAMPLES**

Now we will see a few applications related to the above methodology with the help of flowchart 2.3.1,

1. If a man with blood group \(A^+\) is married to a woman with blood group \(O^-\)
   
   their children can be of any one of the following groups

   \[
   \mu_{A^-}(x) \times \mu_{O^-}(x) = \frac{O^+ \times O^-}{0.26} + \frac{A^+ \times A^-}{0.26} + \frac{B^+ \times B^-}{0.24} + \frac{AB^+ \times AB^-}{0}
   \]
\[ = \frac{O^+ \times O^-}{0.26} + \frac{A^+ \times A^-}{0.26} \]

The possible blood groups and the Rh factor of offsprings are \(O^+\) or \(O^-\) or \(A^+\) or \(A^-\)

2. If a man with blood group \(O^+\) is married to a woman with blood group \(A^-\), their children blood groups can be

\[
\mu_{O^+} \times \mu_{A^-} = \frac{O^+ \times O^-}{0.26} + \frac{A^+ \times A^-}{0.26} + \frac{B^+ \times B^-}{0.24} + \frac{AB^+ \times AB^-}{0}
\]

\[
= \frac{O^+ \times O^-}{0.26} + \frac{A^+ \times A^-}{0.26}
\]

The possible blood groups and the Rh factor of an off spring are \(O^+\) or \(O^-\) or \(A^+\) or \(A^-\)

3. If a man with blood group \(AB^+\) is married to a woman with blood group \(AB^-\), their children blood groups can be

\[
\mu_{AB^+} \times \mu_{AB^-} = \frac{O^+ \times O^-}{0} + \frac{A^+ \times A^-}{0.25} + \frac{B^+ \times B^-}{0.25} + \frac{AB^+ \times AB^-}{0.50}
\]

\[
= \frac{A^+ \times A^-}{0.25} + \frac{B^+ \times B^-}{0.25} + \frac{AB^+ \times AB^-}{0.50}
\]
The possible blood groups and the Rh factor of an offspring are A⁺ or A⁻ or B⁺ or B⁻ or AB⁺ or AB⁻.

4. If a man with blood group A⁺ is married to a woman with blood group B⁻, their children blood groups can be

\[
\mu_{A^+}(x) \times \mu_{B^-}(x) = \frac{O^+ \times O^-}{0.26} + \frac{A^+ \times A^-}{0.26} + \frac{B^+ \times B^-}{0.24} + \frac{AB^+ \times AB^-}{0.24}
\]

\[
= \frac{O^+ \times O^-}{0.26} + \frac{A^+ \times A^-}{0.26}
\]

The possible blood groups and the Rh factor of an offspring is O⁺ or O⁻ or A⁺ or A⁻.

5. If a man with blood group A⁺ is married to a woman with blood group AB⁺, their children blood groups can be

\[
\mu_{A^+}(x) \times \mu_{AB^+}(x) = \frac{O^+}{0.25} + \frac{A^+}{0.25} + \frac{B^+}{0.24} + \frac{AB^+}{0.24}
\]

\[
= \frac{A^+}{0.25} + \frac{B^+}{0.24} + \frac{AB^+}{0.24}
\]

The possible blood groups and the Rh factor of an offspring are A⁺ or B⁺ or AB⁺.
6. If a man with blood group $B^+$ is married to a woman with blood group $A^+$ their children blood groups can be

$$\mu_{B^+}(x) \times \mu_{A^+}(x) = \frac{O^+}{0.26} + \frac{A^+}{0.24} + \frac{B^+}{0.24} + \frac{AB^+}{0.24}$$

The possible blood groups and the Rh factor of an off spring are $O^+$ or $A^+$ or $B^+$ or $AB^+$

7. If a man with blood group $O^+$ is married to a woman with blood group $O^-$ their children blood group is

$$\mu_{O^-}(x) \times \mu_{O^-}(x) = \frac{O^+}{0.48} + \frac{A^+}{0.26} + \frac{B^+}{0.26} + \frac{AB^+}{0}$$

$$= \frac{O^+}{0.48}$$

The possible blood group and the Rh factor of an off spring is $O^+$.

8. If a man with blood group $O^-$ is married to a woman with blood group $AB^-$ their children blood groups can be

$$\mu_{O^-}(x) \times \mu_{AB^-}(x) = \frac{O^-}{0} + \frac{A^-}{0.25} + \frac{B^-}{0.25} + \frac{AB^-}{0}$$
\[
\frac{A^-}{0.25} + \frac{B^-}{0.25}
\]

The possible blood groups and the Rh factor of an off spring are A\(^-\) or B\(^-\)

### 2.5. AN APPLICATION

The following data collected from the Kumbakonam Government Hospital are compared with the fuzzy set theory technique.

**Example 2.5.1**

Mr. Vasan with blood group O\(^+\) and his wife Mrs. Santhi with blood group AB\(^+\) have three children Vasuki, Mathi and Andal. Their blood group can be identified as stated below

\[
\mu_{O^+}(x) \times \mu_{AB^+}(x) = \frac{O^+}{0} + \frac{A^+}{0.25} + \frac{B^+}{0.25} + \frac{AB^+}{0}
\]

\[
= \frac{A^+}{0.25} + \frac{B^+}{0.25}
\]

The blood group for Vasuki and Mathi is A\(^+\) and for Andal is B\(^+\).
Example 2.5.2

Mr. Sundaram with blood group B\(^+\) and his wife Mrs. Lakshmi with blood group AB\(^+\) have two children Abinaya and Amirtha. Their blood group can be identified as stated below

\[
\mu_{B^+}(x) \times \mu_{AB^+}(x) = \frac{O^+}{0.24} + \frac{A^+}{0.25} + \frac{B^+}{0.25} + \frac{AB^+}{0.24}
\]

\[
= \frac{A^+}{0.24} + \frac{B^+}{0.25} + \frac{AB^+}{0.25}
\]

The blood group for Abinaya is B\(^+\) and Amirtha is AB\(^+\).

Example 2.5.3

Mr. Mahalingam with blood group O\(^+\) and his wife Mrs. Rajam with A\(^+\) have two children Bala and Mahendran. Their blood group can be identified as

\[
\mu_{O^+}(x) \times \mu_{A^+}(x) = \frac{O^+}{0.26} + \frac{A^+}{0.26} + \frac{B^+}{0.24} + \frac{AB^+}{0}
\]

\[
= \frac{O^+}{0.26} + \frac{A^+}{0.26}
\]

The blood group for Bala and Mahendran is O\(^+\).
Example 2.5.4

Mr. Nelson with blood group $A^+$ and his wife Mrs. Sofia with $B^-$ have four children John, James, George and Mariya. Their blood group can be

$$\mu_{A^+}(x) \times \mu_{B^-}(x) = \frac{O^+ \times O^-}{0.26} + \frac{A^+ \times A^-}{0.26} + \frac{B^+ \times B^-}{0.24} + \frac{AB^+ \times AB^-}{0.24}$$

The blood group for John and James is $O^+$ and for George and Mariya is $A^-$. 

Example 2.5.5

Mr. Ashok with blood group $AB^-$ and his wife Mrs. Vimali with $AB^-$ have only one son child Ganesh. His blood group is

$$\mu_{AB^-}(x) \times \mu_{AB^-}(x) = \frac{O^-}{0} + \frac{A^-}{0.25} + \frac{B^-}{0.25} + \frac{AB^-}{0.50}$$

$$= \frac{A^+}{0.25} + \frac{B^+}{0.25} + \frac{AB^+}{0.50}$$

The blood group for Ganesh is $AB^-$. 

Example 2.5.6

Mr. Kannan with blood group $O^+$ and his wife Mrs. Selvi with $A^-$ have three children Raja, Siva and Lakshmi. Their blood group can be
\[
\mu_{O^{+}}(x) \times \mu_{A^{-}}(x) = \frac{O^{+} \times O^{-}}{(0.48,0.26)} + \frac{A^{+} \times A^{-}}{(0.26,0.26)} + \frac{B^{+} \times B^{-}}{(0.26,0.24)} + \frac{AB^{+} \times AB^{-}}{(0,0.24)}
\]

\[
= \frac{O^{+} \times O^{-}}{0.26} + \frac{A^{+} \times A^{-}}{0.26}
\]

The blood group for Raja is O\(^+\) for Siva is A\(^-\) and for Lakshmi’s is A\(^+\).