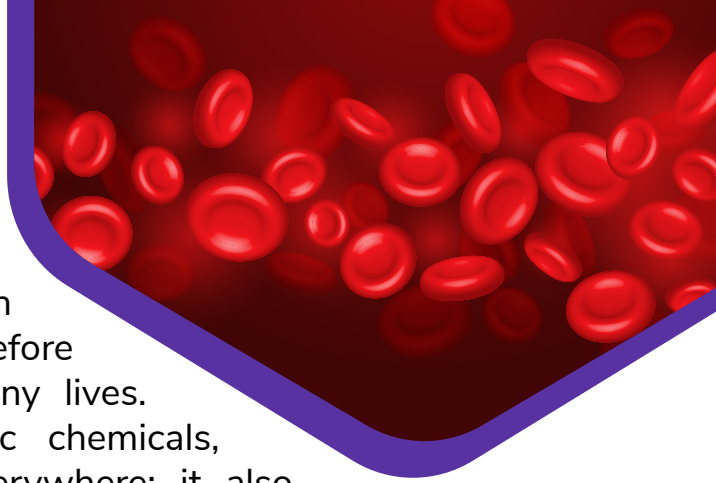




Anemia Detection Using Smartphone Images of **Conjunctiva, Nail bed, Palm and Tongue**

| Abstract



Anemia is one of the serious health issues among women of reproductive age and children below 5 years. Screening of anemic patients before it reaches a severe condition can save many lives. Traditional testing methods require specific chemicals, machines, devices that are not present everywhere; it also requires physical presence of nurses, laboratory workers and doctors. These methods are costly, time consuming and produce bio hazard waste thus polluting the environment. Non-invasive method for hemoglobin estimation can be used as a modern day solution to provide point of care diagnosis and telemedicine that will help in saving time and money of individuals while assisting in continuous monitoring of blood hemoglobin. Such methods also make anemia screening possible. All the devices developed so far have specific device requirements that may not be accessible or difficult to operate by common people for self assessment. So the proposed method is easy to use and doesn't depend on the availability of comprehensive laboratory infrastructure or trained personnel.

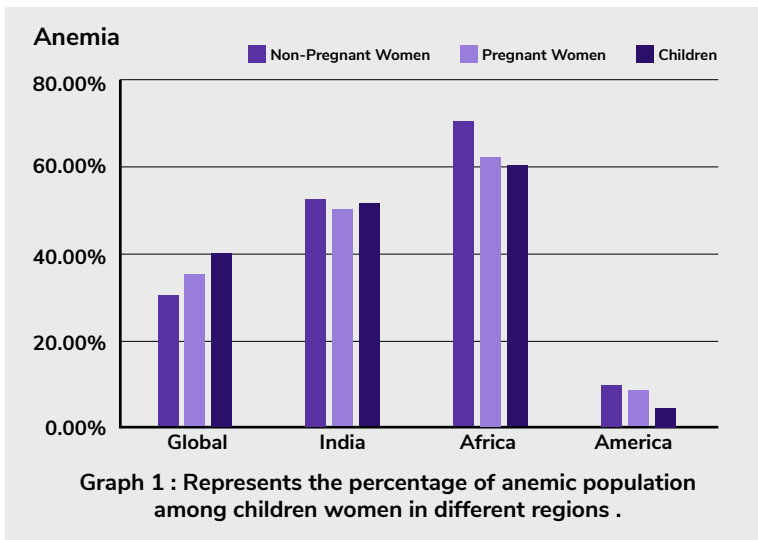
| Introduction:

According to WHO “Anemia is a condition in which the number or size of red blood cells, or the hemoglobin concentration, falls below an established cut-off value, consequently impairing the capacity of the blood to transport oxygen around the body”. The estimation values are differentiated according to the gender, age-group and pregnancy condition and the level of hemoglobin also tells the severity of anemia. 3 represented in table 1 (taken from WHO website).

Among the causes of anemia Iron and some micro nutrient deficiency is one of the major causes of anemia. 4 Anemia limits the oxygen transport in the body and thus reduces the physical and mental capacity. It increases maternal mortality, stillbirths miscarriages among pregnant women; causes low birth weight and increases infant mortality; reduces the physical and mental performance of children ⁵⁶.

a) Statistics

Anemia is a serious condition worldwide, about 40% of pregnant women and 42% of children worldwide are anemic. Conditions are more severe in south Asia, central and west Africa. In India 53% of women in reproductive age¹ and 54 % of children in the age of 6-59 months² are anemic. Detailed regional data is graphically represented in Graph 1.



WHO targeted to reduce the anemia by 50% among the women of reproductive age as per Global nutrition target 2025- anemia.⁷ and sustainable development goals. To achieve this target cost effective screening is required, but till then not so much effective evidence for the cost effective screening.⁸ If it is identified at its mild or moderate stage severe anemic conditions can be easily avoidable.

Population	Non-Anemia*	Anemia*		
		Mild ^a	Moderate	Severe
Children 6-59 months of age	110 or higher	100-109	70-99	Lower than 70
Children 5-11 years of age	115 or higher	110-114	80-109	Lower than 80
Children 12-14 years of age	120 or higher	110-119	80-109	Lower than 80
Non-Pregnant woman (15 years of age and above)	120 or higher	110-119	80-109	Lower than 80
Pregnant woman	110 or higher	100-109	70-99	Lower than 70
Men (15 years of age and above)	130 or higher	110-129	80-109	Lower than 80

Table 1: The table gives the detailed level of hemoglobin for anemia and non-anemia population among different age groups and severity of anemia according to the level of hemoglobin present.

b) Traditional Method of Testing

In India hemoglobin test cost upto Rs.220 on 12 July, 2021.⁹

Most commonly used methods for hemoglobin testing are Sahil's test, Hemoglobincyanide Method, Vanzetti's Azide Methemoglobin, Reagent-less Method. These methods are costly, time consuming, require specific chemicals and equipment and other disadvantages listed below in table 2. Most importantly the chemicals used in these tests are biohazardous and pollute the environment.

Method	Chemicals/Equipments	Time	Cost
Sahil's method	<ul style="list-style-type: none"> • Hemoglobin tube, pipette, stirrer, and a comparator. • HCL. 	20 min	
Hemiglobincyanide Method	<ul style="list-style-type: none"> • A spectrophotometer or photoelectric colorimeter, Pipette 5 ml, Sahli's pipette. • Drabkin's Solution, Cyanmethemoglobin standard solution with a known hemoglobin value. 		
Vanzetti's Azide Methemoglobin	<ul style="list-style-type: none"> • Sodium azide. 		
Reagent-less Method.			
Hematology Analyser method	<ul style="list-style-type: none"> • Hematology analyser machine. • Reagent depends on the type of machine used. 	10 min	Machine cost: 3- 10 lakh Test cost:

Table 2 : different methods available in market chemical or resources require for those methods time for the procedure and cost of the test.

c) Physical Examination of Anemia

4 levels of physical examination are used to confirm anemia in a patient. These include:

color tint of the lower eyelid conjunctiva, nail-bed rubor, nail-bed blanching, and palmar crease rubor. The color tint of these regions don't depend on the skin color of a person due to absence of melanocyte (melanin producing cells).¹¹ Conjunctival pallor presence can be directly correlated with the condition of anemia and determination of hemoglobin level.¹² Physical examination done by doctors is subjective. So there are chances of subjective bias hence it is less accurate.



Eye Conjunctiva



Nailbed



Tongue



Palm

d) Development of Non-invasive Methods

Invasive methods are painful, may cause infection, costly, time consuming and need experts to take blood samples and perform the estimation technique so using modern technologies and developing non invasive method is need of an hour. In the last decade the development of non-invasive method attain the researchers attentions. The most famous methods and the advantages and disadvantages are listed below in table 3.

Method	Chemicals/Equipments	References
Hemoglobin concentration estimation using optical sensor by modifying the beer- lambert's law.	<ul style="list-style-type: none"> • MAX30100 sensor, Screen, LED, software. • All the required materials needed for the estimation are not present among the common public. • Light use for the estimation may be ionising and cause harmful effect to the patients. 	13
Hemoglobin estimation device use optical fiber LED light and optical sensor.	<ul style="list-style-type: none"> • Device is costly to develop. • Can't be present everywhere. • May be difficult to operate by some users. • Optical artifacts may give errors in results. 	14
PPG characteristics features of fingertip video using MGGP-based model.	<ul style="list-style-type: none"> • Use of special video camera. • Use of specific softwares. • Video preprocessing. 	15

Table 3: different non-invasive methods developed recently and problems associated with them.

e) Machine Learning Use for Other Diseases

In recent years, machine learning and deep learning models have been developed for disease diagnosis from the images of X-ray, MRI, PET, even sound signals: heart beat, speech; ECG, EMG graphs signals, For example: muscular edema identification which is an early sign of blindness and other diseases from OCT images;¹⁶ this technique can also be used effectively in early stage cancer detection. recently deep learning methylation pattern detection algorithm is enable to detect ct-DNA in blood plasma ^{16,17}; Detection of viral, non viral and covid 19 pneumonia from chest Xray images.¹⁸ Early detection of CHD (Congenital heart disease) in fetus.¹⁹ Detection of Type 2 diabetes and kidney diseases from the images of retinal fundus.²⁰

Currently available Machine learning models.

Problems associated with them.

f) Penetration of Smartphones in Public

Smartphones are making an important part into the lives of younger as well as to some extent older generations as well. According to the ICT report 2020 80% of the world population are accessible to mobile phones and 51 % of the population worldwide are accessible to the internet.²¹

Situations like covid-19 taught us how healthcare sector can run without the physical interaction for small problems.²²

Proposed Solution

Smartphones can be used to take pictures of eye conjunctiva region, nail bed region and machine learning algorithms can be trained on these pictures for feature extractions and can be directly related to the level of hemoglobin level in the body.

Past Studies

All the past studies and models are detailed in table 4.

Region	Model used	Comment	Sensitivity	Reference
Conjunctiva	Neural networks weight adjustment using backpropagation.	Very less data of just 99 patients was taken. They also used standard methods of classifications like SVM, k nearest neighbor etc. but didn't get high accuracy.	97%	23
Conjunctiva	Ridge regression method.	Sample size is very small. Algorithm so developed didn't considered all the important features.	97%	24
Conjunctiva	U-Net Based Conjunctiva Segmentation Model.	Sample size is very small. Algorithm so developed didn't considered all the important features.	96% with training and 85.7%	25
Nail	Algorithm developed using linear regression weights and nail skin color feature extracted using MATLAB.	No use of any specific equipment, but they use only 1 region nail bed and there can be other reasons for nail colourations e.g nailpaints, jaundice, turmeric.	97% FN - less FP - high	26
Palm		It have very less sensitivity	75% sensitivity	27

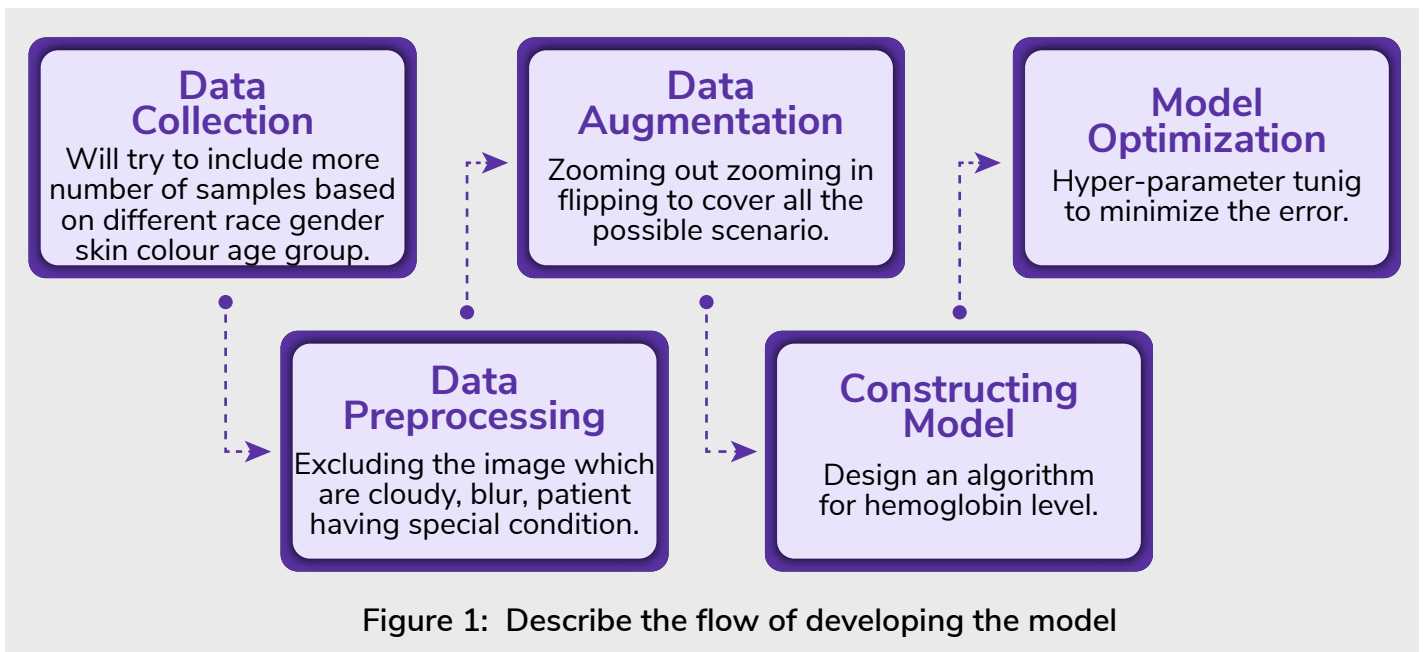
Table 4: Past study details and scope for improvement

Novelty in Our Study

REAN Foundation is working to develop an algorithm using the images of four regions: conjunctiva, nail bed, palm crease and tongue. The combined region algorithm will be more accurate and reliable.

Plan of Action

The plan we will follow for the development of the feature in a figure 1.



Benefits

- Non invasive
- Low cost
- Accessible
- Quick
- Highly sensitive
- No special equipment required
- Eco-friendly

Novelty in Our Study

- It serves the purpose of home healthcare for self diagnosis of the hemoglobin level and check which meal type and to include supplements in diet for keeping hemoglobin level at appropriate level.
- The chemicals used for testing are biohazardous and also strips veils used for testing increase the bio waste. This app with prevent environment as well.
- Even doctors can use the application during OPD screening as physical examination may have subjective bias. This application is based on the advanced machine learning and deep learning algorithms, therefore.
- The traditional methods are invasive hence may be uncomfortable for pediatric patients. This is non-invasive and simple In those villages where dispensaries are available with 1 or 2 healthcare workers, but may not have technology or facilities for testing. so the app being developed by REAN Foundation can help healthcare workers for point-of-care treatment (on the spot testing) and early disease diagnosis. Healthcare workers can be provided with the phone and trained to use the app in a short span of time and at limited cost.

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