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Fall 2025

VIScora: A Retinal Imaging and Laser Doppler Approach for Noninvasive Blood Viscosity Detection and Disease Prediction

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ABSTRACT

Blood viscosity is a vital physiological parameter influencing cardiovascular and ocular health by regulating blood flow. It is determined by red blood cells, plasma proteins, and hematocrit levels. Abnormal viscosity can cause hypertension, myocardial infarction, clotting disorders, or hemorrhages. VIScora (a coined term from viscosity and retina) is a minimally invasive diagnostic tool for at-home monitoring. A finger-prick sample is analyzed with a portable device, while a companion app integrates retinal scans and laser Doppler velocimetry (LDV) to assess risks. Synchronizing with medical records, VIScora promotes early detection, sustainability, and reduced healthcare costs through accessible, energy-efficient technology.

Keywords: *VIScora, viscosity, personalized care, monitoring, diagnostic, blood flow, early detection, retinal scan, imaging.*

DEFINITION AND EXPLANATION OF THE ISSUE AND SOLUTION

Blood viscosity represents a critical physiological parameter, fundamental to aspects of both ocular and cardiovascular health. Essentially, it describes the thickness and stickiness of blood, directly influencing the ease with which blood flows through the circulatory system. A comprehensive understanding of the implications of abnormal blood viscosity is essential for the early detection and management of various health conditions (Bhende et al., 2018).

Blood is a complex fluid composed of plasma, red blood cells, white blood cells, and platelets. Plasma, the liquid matrix, transports nutrients, hormones, and waste products. Red blood cells are crucial for oxygen transport, white blood cells play a vital role in immune defense against infections, and platelets are integral to the clotting process (Boyd & Turbert, 2023). In medical contexts, normal blood viscosity values are generally considered to be between 3.5 and 5.5 centipoise (cP), a unit of dynamic viscosity (Bhende et al., 2018).

Several factors influence blood viscosity, including the concentration of red blood cells (hematocrit), plasma proteins (such as albumin and globulin, which contribute to immune function and nutrient transport), and other cellular components (Boyd & Turbert, 2023). Maintaining normal blood viscosity is paramount for efficient circulation (Khurana, 2010). Deviations, whether an increase or decrease, can lead to severe health complications (Bhokwani, 2021). Issues with blood viscosity could stem from various factors, including fluctuations in red blood cell production, dehydration, or anemia (Boyd & Turbert, 2023). Unhealthy blood viscosity levels could result from either an overabundance or a deficiency of red blood cells (Gaddi et al., 2023).

To fully grasp the negative implications of atypical blood viscosity, it is crucial to understand the effects of both high and low levels. Primarily, elevated blood viscosity poses a significant threat to cardiovascular function, while increased viscosity leads to greater resistance within blood vessels, subsequently elevating blood pressure. This, in turn, necessitates the heart to work harder, imposing additional strain, effects that are often exacerbated with age. High blood viscosity also has the potential to raise the risk of heart attacks due to the increased propensity for blood clot formation, which could obstruct blood flow and lead to fatal complications (Rehman, Chaudhry, & Miao, 2022).

Conversely, abnormally low blood viscosity carries its own set of dangers. Causes could include a low platelet count (thrombocytopenia) or certain bleeding disorders, which elevate the risk of minor or major hemorrhaging (What is hematology?, n.d.). This condition could also influence or be influenced by other disorders, such as how diabetes impacts hemorrhaging rates (Rehman, Chaudhry, & Miao, 2022). While seemingly less impactful than high blood viscosity, low blood viscosity is arguably more dangerous because it impairs the body's ability to form clots. This means an individual with very low blood viscosity could experience excessive bleeding even from a paper cut (What is hematology?, n.d.).

Examples of disorders associated with high blood viscosity include Polycythemia Vera (a blood cancer characterized by red blood cell overproduction), Multiple Myeloma (a plasma cell cancer that can increase blood protein levels), and Waldenström Macroglobulinemia (a type of non-Hodgkin lymphoma marked by excessive IgM antibodies, leading to hyperviscosity). Disorders linked to low blood viscosity include Hemophilia (a genetic disorder where blood lacks clotting agents), Hypoproteinemia (low blood protein levels often due to malnutrition or kidney disease), and various hemorrhagic disorders that lead to excessive bleeding and could reduce blood cell counts and viscosity (What is hematology?, n.d.).

Given these diverse and profound implications, the importance of monitoring and managing blood viscosity becomes unequivocally clear. The proposed solution, VIScora, aims to provide the public, irrespective of their socioeconomic background, with the ability to routinely monitor their blood viscosity levels at home, thereby offering a proactive approach to combat the adverse effects of atypical blood viscosity (Rehman, Chaudhry, & Miao, 2022).

EXPLANATION OF SOLUTION

The VIScora solution would consist of a diagnostic kit designed to measure blood viscosity. The core component would be a portable device, operating similarly to a blood glucose meter, where a small blood sample would be obtained via a finger puncture for analysis. This blood viscosity measurement would be obtained via a small finger-prick blood sample, similar to a blood glucose test, which the portable device analyzes to determine the flow properties of the blood. Based on this analysis, the device can identify potential risk factors for blood-related diseases and other conditions affecting red blood cell health, sending these results securely to the user's app for monitoring and integration with medical records.

Given its minimally invasive nature, this machine would be complemented by a downloadable mobile application. This application would feature a scanning function, enabling users to perform retinal scans of their eyes. Retinal scans are recognized as an effective, non-invasive, and cost-efficient method for assessing overall body health (Gaddi et al., 2023; A Smartphone-Based Tool, 2018). They could reveal indicators such as hemorrhaging and blood clots (Bhokwani, 2021). This feature would be applicable to individuals of all ages and would not be impacted if the customer is blind, as retinal scans can still be obtained from blind individuals. A primary function of the app would be to securely synchronize the data collected from retinal scans and the risk factor data from the blood viscosity device with the user's primary physician, if desired. This capability would enhance efficiency by ensuring that medical records are consistently updated (Synchronize data, n.d.).

These eye scans would contribute to assessing cardiovascular health by providing non-invasive indicators of blood flow and potential anomalies, such as hemorrhaging or clot formation (Bhokwani, 2021; Gaddi et al., 2023). Retinal scans would be performed using the smartphone application, allowing users to monitor ocular and systemic health conveniently. Separately, the rate of blood flow in peripheral microvessels would be measured directly using laser Doppler velocimetry (LDV) incorporated in the portable VIScora device (What is the Laser Doppler Imager?, n.d.). LDV uses laser light to detect the movement of red blood cells in small vessels, such as capillaries, enabling accurate inference of blood viscosity. The device then integrates these measurements with the app, which securely synchronizes results with medical records for streamlined monitoring and disease risk assessment (Synchronize data, n.d.). By distinguishing between smartphone-based retinal imaging and device-based LDV, VIScora would ensure both accessibility and measurement accuracy in evaluating blood viscosity.

The development of this kit addresses the critical importance of blood health in both disease prevention and detection. Disorders like hemophilia, characterized by a lack of clotting agents, place patients at severe risk of excessive bleeding even from minor cuts (What is hematology?, n.d.). Conversely, conditions such as Polycythemia Vera lead to an overproduction of red blood cells, resulting in thicker blood and an increased risk of strokes or aneurysms due to restricted blood flow. Since these blood disorders are often not visibly apparent, this product could enable undiagnosed individuals to become aware of their potential risk. While a premature diagnosis from this product would necessitate confirmation through an official medical diagnosis, VIScora would empower consumers to regularly test themselves at home, mitigating concerns about cost (Rehman, Chaudhry, & Miao, 2022).

Furthermore, a significant consideration in the design of this product is its applicability to diabetic patients, who frequently experience minor hemorrhaging due to elevated blood sugar levels, which can increase blood viscosity. This device would therefore be valuable for conditions beyond just primary blood disorders. Similarly, the device could go as far as to potentially diagnose certain blood cancers, such as leukemia, where increased blood viscosity is observed in conditions like chronic granulocytic leukemia due to the larger size of granulocytes (a type of immune cell) (Rehman, Chaudhry, & Miao, 2022). In summary, VIScora would allow for the analysis of blood viscosity through the rate of blood flow within the body, utilizing technologies such as laser Doppler velocimetry (What is the Laser Doppler Imager?, n.d.), retinal scans (Gaddi, Swamy, & Vishwanath, 2023; A Smartphone-Based Tool, 2018), and a blood glucose meter-like device, all integrated through an app that also records and manages all data (Synchronize data, n.d.; Biswas, 2022).

AN EXPLANATION OF THE IMPACTS

Environmental

This project is envisioned to support environmental sustainability by potentially reducing the necessity for frequent traditional medical visits and reliance on paper-based reporting systems through its app feature (Synchronize data, n.d.). This could minimize the carbon footprint associated with patient travel and paper documentation. By leveraging digital health monitoring, VIScora encourages efficient resource utilization and aims to reduce waste generated by disposable medical testing kits. Additionally, incorporating energy-efficient coding and hardware into the device design is a priority to lower overall energy consumption, promoting a more sustainable approach to personal healthcare technology. The use of a framework like Flutter/Dart for app development, which allows for a single codebase across iOS and Android, inherently reduces development time and effort, contributing to efficiency (Biswas, 2022). The app's design, which loads content sequentially, further conserves device battery life and resources. Ultimately, by offering portable and advanced diagnostic technology directly into the home, VIScora could minimize patient trips to the hospital, thereby reducing vehicular emissions and traffic congestion caused by medical commuting (Synchronize data, n.d.).

Social

VIScora is designed to promote social well-being by empowering individuals to take a proactive role in managing their health through convenient, real-time monitoring. By making blood viscosity tests and retinal scans accessible from home, it could bridge healthcare gaps for individuals in rural or underserved areas, ensuring they can monitor their health without significant geographic or logistical barriers (Gaddi, Swamy, & Vishwanath, 2023; A Smartphone-Based Tool, 2018). The app aims to foster health awareness and education, encouraging users to prioritize preventative care and make informed decisions about their well-being. Its user-friendly interface would be developed to ensure that people of all ages and technical skill levels can benefit from its features, thereby promoting inclusivity and broader health equity. Importantly, VIScora would be designed for accessibility to individuals regardless of their disabilities; for example, the device could be used on blind patients without affecting the accuracy of the eye scan (Gaddi, Swamy, & Vishwanath, 2023).

SUPPORTING INFORMATION

Eye Scans:

While VIScora is a hypothetical model, it is crucial to base its functionalities on accurate research.

A healthy eye, depicted in a diagram (Fig. 2), demonstrates the posterior segment of the eye, which is screened for retinal tears and other issues (A, 2021; Bhende et al., 2018). Key anatomical parts visible in such a scan would include the macula, vitreous, optic nerve, and retinal blood vessels (Boyd & Turbert, 2023; Parts of the Eye, n.d.). The macula, a darkish spot towards the back, is essential for central vision, translating light into images for the brain. The optic nerve, centrally located, also contributes to this light-to-image translation. The vitreous is simply a gel-like fluid that supports the eye's structures. Damage to any of these vital parts could prove to be detrimental, having the potential to permanently lose eyesight (Parts of the Eye, n.d.). This is why the kit is very important and especially applicable. Catching these issues early on, in a safe and cost-effective manner, could be a game changer for many, as this kit would be applicable to people of all financial and medical backgrounds.

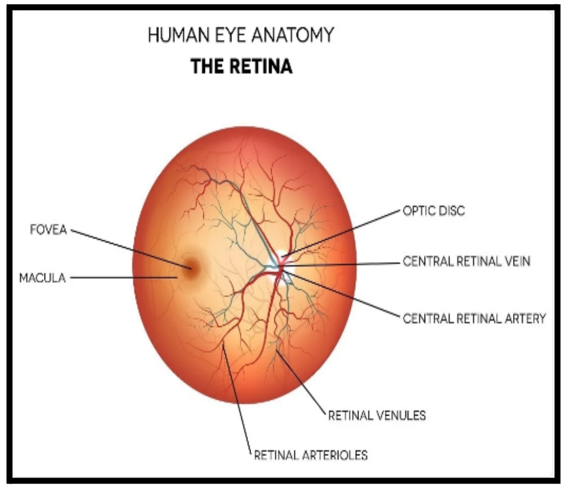

Figure 1. *Diagram of Optical system* This image illustrates key anatomical features of a healthy retina, including the optic nerve head, macula, and major retinal blood vessels. The uniform coloration and absence of lesions or hemorrhages are indicative of normal ocular health.
Note. Reprinted from *Eye Anatomy: Parts of the Eye and How We See* by K. Boyd & D. Turbert, 2023, American Academy of Ophthalmology. https://www.aao.org/eye-health/anatomy/parts-of-eye

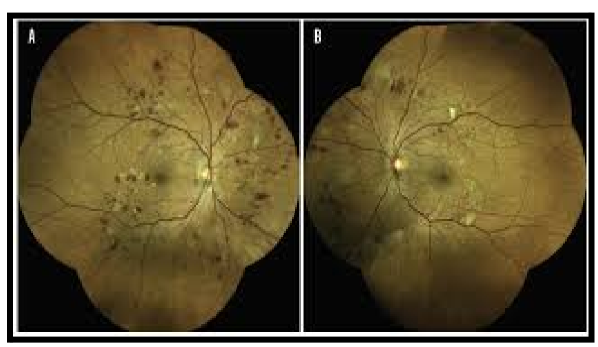

Figure 2. *Diabetic patient retinal scan* This image illustrates the retinal scan of a diabetic patient, displaying hemorrhaging in the darker places (A = left eye, B = right eye). This

illustrates how retinal scans can detect vascular issues beyond optometric health.
Note. Reprinted from *How to quickly read an eye scan?* by D. Bhokwani, 2021, eophtha. https://www.eophtha.com/posts/how-to-quickly-read-a-macular-oct-scan

Figure 3 depicts a retinal eye scan of a patient with diabetes. The major point to note here are the black spots that span across the eye scan. These are minor hemorrhages in the retinal blood vessels Bhokwani, 2021; Gaddi, Swamy, & Vishwanath, 2023). These have the potential to cause blindness. However, it is important to note that having access to these scans early on can show the viscosity of a person's blood (Bhokwani, 2021). This can also help to diagnose other types of diseases, such as diabetes in this case Gaddi, Swamy, & Vishwanath, 2023). In the case that a person's blood viscosity is too high, these are manifested in the form of blood clots that can be detected through these scans (Bhokwani, 2021). By being able to display signs of blood viscosity, VIScora would diagnose conditions early on.

Delving deeper into Laser Doppler Velocimetry and its relation to blood viscosity: LDV primarily functions by directing a laser beam onto moving particles, such as red blood cells within microvessels (those in the eyes) (Gallanti, n.d.). As the light interacts with these moving cells, it scatters, resulting in a shift in frequency. This frequency shift increases when cells move towards the light source and decreases when they move away, establishing a direct, proportional relationship. By observing these frequency shifts, LDV is able to precisely measure the speed of blood flow. This measurement, in turn, helps determine blood viscosity, as the speed of blood flow directly reflects its thickness—slower flow indicates high viscosity, while faster flow suggests low viscosity (What is the Laser Doppler Imager?, n.d.). Both extremes, if pronounced, are detrimental if seen on extreme sides of the scale. This non-invasive approach to determining blood viscosity would allow healthcare professionals to identify diseases and conditions early on, thus being able to provide aid (Bhokwani, 2021; Gaddi, Swamy, & Vishwanath, 2023).

CODE/APP STRUCTURE

The VIScora application would be designed with the following structure and features, leveraging specific technologies for optimal performance and user experience.

1. App Structure and Features

- **Device Integration:** VIScora would integrate with hardware components, including the mini machine for blood viscosity measurement and external sensors for retinal scans as well as LDV.
- **User Interface (UI):** A simple and intuitive UI would guide users through the entire process, encompassing blood testing, retinal scanning, result display, and data synchronization with healthcare providers (Healthcare Mobile App Development, 2024).
- **Data Processing:** Upon collecting data from the hardware (blood viscosity and retinal scan), VIScora would process this information and present results to the user.
- **Cloud Storage & Security:** Health data would be securely stored (encrypted) and synchronized to a cloud service for both storage and optional sharing with healthcare providers.
- **Notifications and Reports:** Based on the collected data, VIScora would notify users of any identified risk factors and generate detailed reports for either the user or their physician.

2. Technologies Used (and why)

- **Programming Languages:** Flutter/Dart would be chosen for its ability to create a single codebase that runs natively on both iOS and Android devices, significantly reducing development time and ensuring platform consistency (Biswas, 2022).
- **Backend Services:** Firebase or AWS would be utilized for cloud storage, user authentication, and real-time database synchronization. Additionally, AWS Lambda or Google Cloud Functions could be employed to handle data processing tasks efficiently.
- **Device Integration:** Bluetooth or USB protocols would be implemented to facilitate seamless data synchronization from the blood viscosity meter to the app (Khan, 2023; Sayhan, 2024; Is there a method, n.d.).
- **Security:** End-to-end encryption and SSL/TLS would be fundamental for securing data transmission. OAuth would be used for robust user authentication and authorization.

3. App Workflow and Code Outline

a. Step 1: User Interface

- **Home Screen:** An introductory screen providing basic app functionality, with clear buttons for initiating blood viscosity testing and retinal scanning.
- **Blood Test Screen:** A step-by-step guide on how to perform the blood test, including visual instructions and a "Start Test" button that **would trigger** the sensor.
- **Retinal Scan Screen:** Utilizes the device's camera to capture the eye scan (Gaddi et al., 2023; How to Take Retinal Images, 2020).
- **Results Screen:** Displays test results in an easily understandable format, highlighting any detected risk factors.
- **Settings and Syncing:** A dedicated page for syncing data with healthcare providers, managing user profile settings, and adjusting app preferences. This page would also offer an option to print out retinal scans.

b. Step 2: Device Integration (Bluetooth)

c. Step 3: Retinal Scan

d. Step 4: Data Syncing and Reporting

Illustrative Code Snippets for Retinal Scan Functionality**:**

```dart
import 'package:camera/camera.dart';
import 'package:flutter/material.dart';

class RetinalScanScreen extends StatefulWidget {
  @override
  _RetinalScanScreenState createState() => _RetinalScanScreenState();
}

class _RetinalScanScreenState extends State<RetinalScanScreen> {
  CameraController? _controller;
  late List<CameraDescription> _cameras;

  @override
  void initState() {
    super.initState();
    _initializeCamera();
  }

  Future<void> _initializeCamera() async {
    _cameras = await availableCameras();
    _controller = CameraController(_cameras[0], ResolutionPreset.high);
    await _controller!.initialize();
    setState(() {});
  }
```

```
  @override
  void dispose() {
    _controller?.dispose();
    super.dispose();
  }

  @override
  Widget build(BuildContext context) {
    if (!_controller!.value.isInitialized) {
      return Center(child: CircularProgressIndicator());
    }

    return Scaffold(
      appBar: AppBar(title: Text("Retinal Scan")),
      body: CameraPreview(_controller!),
      floatingActionButton: FloatingActionButton(
        onPressed: () {
          // Capture the image and process
          _controller!.takePicture().then((XFile file) {
            print("Retinal scan taken: ${file.path}");
            // Process the image here for analysis
          });
        },
        child: Icon(Icons.camera),
      ),
    );
  }
}
```

Figure 3. *Code in the app* These lines of code outlines how retinal scans would be made possible through phones and the accompanying app of this diagnostic product.

```dart
import 'package:cloud_firestore/cloud_firestore.dart';
import 'package:firebase_auth/firebase_auth.dart';

// Function to store data in Firebase
Future<void> storeBloodData(String userId, int viscosity, String retinalScanPath) async {
  CollectionReference users = FirebaseFirestore.instance.collection('users');
  await users.doc(userId).set({
    'viscosity': viscosity,
    'retinalScan': retinalScanPath,
    'timestamp': FieldValue.serverTimestamp(),
  });
}

// Example of storing the data when the test is completed
void saveResults() {
  String userId = FirebaseAuth.instance.currentUser!.uid;
  int viscosity = 450; // Replace with the actual viscosity data
  String retinalScanPath = "/path/to/retinal_scan.jpg"; // Replace with actual scan path

  storeBloodData(userId, viscosity, retinalScanPath);
}
```

```dart
import 'package:printing/printing.dart';
import 'package:pdf/pdf.dart';
import 'package:pdf/widgets.dart' as pw;
import 'package:flutter/material.dart';
import 'dart:io';

class RetinalScanPrinter extends StatelessWidget {
  Future<void> printRetinalScan(String path) async {
    final pdf = pw.Document();
    pdf.addPage(pw.Page(build: (pw.Context context) {
      return pw.Center(child: pw.ImageProvider(File(path).readAsBytesSync()));
    }));
    await Printing.layoutPdf(onLayout: (PdfPageFormat format) async => pdf.save());
  }

  @override
  Widget build(BuildContext context) {
    return Scaffold(
      appBar: AppBar(title: Text('Retinal Scan Printer')),
      body: Center(
        child: ElevatedButton(
          onPressed: () => printRetinalScan("/path/to/retinal_scan.jpg"),
          child: Text("Print Retinal Scan"),
        ),
      ),
    );
  }
}

void main() {
  runApp(MaterialApp(home: RetinalScanPrinter()));
}
```

Figure 4. *Code to store and print retinal scans using the app* The code displays how the accompanying app to this diagnostic tool would store the retinal scans of patients, and also the commands to print them as well.

CONCLUSION

The proposed VIScora system offers a promising and timely solution to the critical need for accessible, at-home blood viscosity monitoring. By integrating a minimally invasive device with a comprehensive mobile application that leverages retinal scanning and laser Doppler velocimetry (Gaddi, Swamy, & Vishwanath, 2023; What is the Laser Doppler Imager?, n.d.; A Smartphone-Based Tool, 2018), VIScora would empower individuals to proactively manage their cardiovascular and ocular health. This innovative approach could facilitate early detection of various blood-related conditions, from common issues like diabetic hemorrhages to serious disorders such as polycythemia vera and even certain blood cancers (Rehman, Chaudhry, & Miao, 2022; Bhokwani, 2021). Beyond its diagnostic potential, VIScora is designed with a strong commitment to environmental sustainability and social equity, aiming to reduce healthcare's carbon footprint and bridge gaps in diagnostic accessibility for underserved communities. While currently a conceptual framework, the development of VIScora would represent a significant step forward in personalized healthcare, enabling earlier interventions, potentially reducing long-term healthcare costs, and ultimately fostering a more informed and health-conscious public.

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