A Neglected Disease - Sickle Cell Diagnostic Test Strip
Sierra Leone
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Lehigh University

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Sickle cell disease (SCD) is a common, life-threatening, but largely neglected inherited blood disorder [1,2,3]. Globally, more than 300,000 people are born with SCD each year [2,4,5], with 85% of those babies being born in Africa [5]. SCD occurs when individuals inherit two copies of a mutated hemoglobin A (HbA) protein, the dominant and normal oxygen-transporting protein found in red blood cells [4]. Sickle cell trait (SCT) occurs when an individual inherits one copy of a mutated hemoglobin, and one normal copy of HbA [6]. The most common and severe type [2,4] of SCD occurs when two copies of mutated hemoglobin S (HbS) are inherited, a type of SCD typically referred to as sickle cell anemia (SCA) [3,5]. In the deoxygenated state, these HbS molecules stick together, causing the red blood cells to become sickle shaped [4]. This sickling can cause red blood cells to become trapped in small blood vessels, preventing blood flow [2,4], and causing different symptoms. These complications can include severe anemia [5,7], painful episodes [1,7], organ damage [1,7], and increased risk for infection [4,1,5].

Additionally, in low and middle-income countries (LMIC), SCA is also responsible for a significant reduction in life expectancy [3,7,8]. Although there is limited data available, estimates suggest that in sub-Saharan Africa, the probability of death among children with SCA could be as high as 50-90% depending on the location, healthcare access, and infectious disease rates [3]. Due to these high mortality rates among children in sub-Saharan Africa, it is estimated that in some areas SCD may be responsible for up to 5%-16% of under-5 child mortality [8].

Despite this, neonatal screening and early detection have been shown to significantly reduce mortality rates [1] by allowing for several potentially life-saving interventions, including penicillin prophylaxis [1,2], pneumococcal immunization [2], education on symptom management [1,2], and hydroxyurea treatments [2,5]. The significant benefits of these early interventions has led SCA screening among newborns to become standard in the United States and other high-income countries for years [2,4], allowing mortality rates due to SCA in these countries to drop significantly [1].

Despite these benefits, SCA screening is not commonplace in sub-Saharan Africa [2] due to the lack of feasible screening options. In high-income countries, SCD is primarily diagnosed using isoelectric focusing (IEF) or high performance liquid chromatography (HPLC) [5]. These tests are infeasible in most LMICs, since they are expensive, lab-based, and require reliable electricity supplies [1]. Several small-scale screening initiatives have been implemented throughout LMICs. These programs typically include collecting dried blood spot (DBS) samples from newborns in high-risk areas, and sending them to centralized laboratories for isoelectric focusing analysis [7]. Two such programs were initiated in Angola and Uganda; however, these initiatives were time consuming and expensive (with costs estimated to be $15.36 and $9.94 per test, respectively) [7]. The lack of a low-cost, point-of-care screening device in LMICs leads individuals with SCA to be left undiagnosed until they present with clinical symptoms in late childhood, when interventions such as penicillin prophylaxis are less effective [1].

To address this need and improve on current technologies, this project is currently in the concept phase of designing a sickle cell anemia diagnostic test to be used as a screening device in LMICs. With the goal of field-testing the device in Sierra Leone, a low-income country with one of the worst health statuses in the world and an under-5 child mortality rate of 140 per 1,000 live births [9], the design is being focused to meet the ASSURED criteria established by the World Health Organization [10].This framework specifies that the most appropriate diagnostic tests for use in LMICs are affordable, sensitive, specific, user-friendly, rapid and robust, equipment-free, and deliverable to end-users [10]. Recent efforts have therefore been focused on establishing a lateral flow device which will meet these criteria. Specifically, lateral flow devices are known for being easy to use, equipment-free, rapid, and for having high sensitivity and specificity. Additionally, they are typically very low cost. Bangs Laboratories, Inc provides a cost estimate for lateral flow test, with the combined materials and labor costing approximately $0.38 per test [11]. Although this estimate does not include research costs, it is a high-end high estimate, and provides a good approximation of the final cost of our device considering economies of scale. Considering that labor is typically approximated at twice the cost of raw materials [11], this estimation would mean that our device has a similar price point of the competitive test currently being researched by Bond et. al, and would therefore be affordable in LMICs.

By focusing on the development, commercialization, and implementation of a low-cost, one-step, specific and sensitive lateral flow device, this sickle cell anemia diagnostic tool has the potential to make SCA screening in Sierra Leone and other LMICs possible. As inexpensive and effective early interventions are available for sickle cell anemia [1,2,5], a diagnostic device of this kind could significantly improve the quality of life and life expectancy for a large population.

Team members Jannah Wing and Maria Lancia traveled to Sierra Leone in August 2019 to conduct stakeholder interviews and better understand the implementation process of the device. They are joined in leading the project by Ashleigh Crawford. Seven additional team members are divided between three sub-groups focused on device accuracy, cost minimization and a small scale manufacturing process, respectively. The above students are advised by principal investigator Dr. Xuanhong Cheng in technical development and are directed by Khanjan Mehta with his connections in Sierra Leone and his experience with social entrepreneurship. Entrepreneurial development of the diagnostic is guided by Dr. Sabrina Jedlicka and Jordan Inacio through the technical entrepreneurship program.

The teams also expand the development of a business model through entrepreneurial training incorporated in their curriculum. Additionally, several potential partners in Sierra Leone have already been identified who will help to provide access in the field to end users. Specifically, our team is working with World Hope International, the largest NGO in Sierra Leone. This partnership has already provided us with logistical and networking support during fieldwork this past summer, and will continue to aid us in navigating the Sierra Leonean market and regulatory frameworks. Furthermore, during the fieldwork this summer, the team networked with several physicians, hospital leaders, and sickle cell activists who are interested in working with us to run a clinical trial/patient retention study and to implement a sickle cell screening program in the future. Opportunities for future action have been established with Masanga Hospital, Dr. Cheedy Jaja, and the Sickle Cell Carriers Awareness Network (SCCAN), specifically.

Although to date no specific partners have been established who will help with commercializing any resulting technologies, faculty mentor Khanjan Mehta has experience commercializing medical technology for LMICs. Specifically he has worked closely with Wancheng Bioelectron Co. in China, a medical device manufacturer. The team will collaborate with him to identify companies for outsourcing the product manufacturing and NGOs who can help fund the distribution.

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