REPUBLIC OF RWANDA

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Special Collaborative Research Grants to Address COVID-19 Pandemic in Rwanda

Creating and promoting research-based knowledge, products and services to improve science and technology development in Rwanda

June 2021

EPUBLIC OF RWANDA

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Concept Note

Special Collaborative Research Grants to Address COVID-19 Pandemic

A: Background:

In December 2019, a cluster of pneumonia cases of unknown etiology was reported in Wuhan, Hubei Province, China. On 9 January 2020, China CDC reported a novel coronavirus as the causative agent of this outbreak, and since then the virus was named severe acute respiratory syndrome coronavirus or SARS-CoV-2 by the International Committee of Taxonomy of Viruses (ICTV). The virus causes the disease named coronavirus disease 2019 (COVID-19) and the WHO refers to the virus as COVID-19. The WHO reports that as of 12th May 2020, more than 4.0 million cases of COVID-19 were reported worldwide, resulting into over 270,000 number of people who died of COVID-19 infection worldwide. At the guidance by the NCST Council in a meeting dated 27th March 2020, National Council for Science and Technology (NCST) published Request for Applications (RFA) for one year first phase of research and innovation proposals in the following four areas.

B: Thematic areas for COVID-19 pandemic research schemes

The research schemes to address COVID-19 pandemic were decided and categorized into four main areas based on priorities that would address national interest: a) improving diagnostics; b) society resilience; c) innovative protective equipment; and d) monitoring and predicting the impact of COVID-19 pandemic.

1. Improving Diagnostics and Real-Time testing for COVID-19 infection

Studies on development of diagnostic tests for COVID-19 are required for rapid qualitative detection of nucleic acid from respiratory specimens of infected persons. There are several types of COVID-19 tests mainly the direct COVID-19 antigen detection and indirect rapid antibody detection tests. The goal of this research is to focus on real-time hands-on diagnostic tests tor results that can be based upon to quickly identify and isolate individuals with COVID-19 infection. Studies focus on results that support national efforts to intensify preparedness levels, through real-time alert response to isolate and treat COVID-19 patients prior widespread of infections to larger contact populations. This research focuses on availability of timely and accurate diagnostics. The results will support active case finding, isolation and immediate comprehensive care.

2. Improving Society Resilience to Mitigate the Impact of COVID-19 Pandemic in Rwanda

Coronavirus disease outbreak has challenged all countries globally regarding level of preparedness to prevent the widespread of COVID-19 infection to wider and an increasing population. The goal is to achieve feasible vaccine and lifesaving dependable treatment and mitigate the effects of the virus on

the quality of life of patients affected, families and society. Although achievable, even after the vaccine and treatment of COVID-19 is obtained, there is a need for research to assess how communities will establish mechanisms for resilience to mitigate the adverse impact of COVID-19 due to social isolation, social distancing, immobility and overall social and economic wellbeing of communities affected. The overall goal of these studies is to assess what mechanisms that could improve Rwandan society resilience to mitigate the impact of a pandemic i.e. what mechanisms are required to support the communities towards self-reliance, turn to more reasonable and sustainable future in conditions of COVID-19 pandemic or other similar viral and/or infectious disease pandemics.

3. Strategic Innovations for Protective Equipment for Prevention and Management COVID-19 Infection in Rwanda

The WHO has provided rational use of protective equipment and materials against COVID-19 pandemic. However, the need for high-quality applied research studies to demonstrate innovative technology in the manufacture of equipment for public prevention and/or management of coronavirus disease are vital. Studies are to assessing various innovations and strategies that are feasible to maximize and optimize medical and engineering options as precautional measures in the prevention and management of COVID-19 infection. The goal of these studies is to apply research to demonstrate innovative equipment for prevention and management of COVID-19 to bridge supply chain gap in availability of locally made products required in the management of COVID-19 infection. For sustainable and long-term national capabilities, applied research will critically demonstrate concrete novel products on strategic innovations to assess various equipment for the prevention and/or management of COVID-19 infection and/or other potentially virulent viral or other infectious diseases.

4. Predicting and Monitoring the Impact COVID-19 pandemic in Rwanda

Clinical presentations of COVID-19 range from no symptoms (asymptomatic) to severe pneumonia. In European countries, 30% of diagnosed COVID-19 cases were hospitalized and 4% had severe illness, and this changes from time to time depending on availability and use of vaccines and measures to prevent ad curtail COVID-19. The trend is similarly high in the America countries, and higher in some countries. In most African countries, morbidity and mortality rates are lower than in European and American countries. These studies will use existing data to generate a model to predict COVID-19 infection and morbidity rates to inform policy and practice on measures for containment and slowing the virus spread to prompt ‘flattening of the curve’ of COVID-19 infection, as well as continuation of social economic activities. Besides, from a public healthcare perspective, the goal is to assess and characterize public health preparedness levels in terms of setting up quarantine facilities to prevent risks of widespread infectious and assess uncertainties associated with the virus regarding infectivity during the incubation period and recovery.

REPUBLIC OF RWANDA

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Summary of Awardee names, project titles, budget and institutions

"Special Collaboration Research to Address Covid-19 Pandemic"

S/N	NAME OF AWARDEE/ PROJECT TITLE	FUNDIN/ INSTITUTION
Four (4) Projects on Improving Diagnostics and Real-Time testing for COVID-19 infection		
1.	**Name:** Dr. Pacifique Ndishimye **Title:** Production of Molecular Based Point-of-care Protocol for SARS-CoV-2 Detection Among Humans, and Comprehensive Atlas of Possible Coronavirus Immune Response Differences Between Humans, and Non-Human Primates	**Funding:** Sixty Million Rwandan Francs (**60,000,000.00)**) **Institution:** Rwanda Biomedical Center (RBC)
2	**Name:** Dr. Dieudonne Mutangana **Title:** Development of on-site rapid diagnostic test for early detection of COVID-19 based on CRISPR-Cas and Surface-Enhanced Raman Spectroscopy	**Funding:** Fifty-Nine Million Nine Hundred Ninety-Nine Thousand Rwandan Francs (**59,999,000.00)** **Institution:** University of Rwanda
3	**Name:** Mr. Jean Jacques Nshizirungu **Title:** Quantifying Productivity gains from using Artificial Intelligence (AI) in detecting COVID-19 patterns from Chest X-Rays	**Funding:** Fifty-Eight Million, Three Hundred Ninety-Six Rwandan Francs (**58,000,396.00)** **Institution:** King Faisal Hospital
4	**Name:** Mrs. Clarisse Musanabaganwa **Title:** Development of RT-Nucleic Acid Based Rapid Diagnostic Test for SARS-COV2	**Funding:** Sixty Million Rwandan Francs (**60,000,000.00)** **Institution:** Rwanda Biomedical Center

Six (6) Projects on Improving Society Resilience to Mitigate the Impact of COVID-19 Pandemic		
5	**Name:** Dr. Julius Kamwesiga **Title:** The impact of selenium supplementation in the treatment of COVID 19 positive patients in Rwanda	**Funding:** Fifty-Nine Million Nine Hundred Seventy-Four Thousand, and Ten Rwandan Francs (**59,974,010.00)** **Institution:** King Faisal Hospital
6	**Name:** Mrs. Clarisse Musanabaganwa **Title:** Genomic characterization and epidemiological Profile of COVID19 in Rwanda	**Funding:** Fifty-Nine Million Eight Hundred Seventy-Six Thousand Four Hundred Ninety-Four Rwandan Francs (**59,999,020.00)** **Institution:** Rwanda Biomedical Center
7	**Name:** Mr. Evariste Twahirwa **Title:** A Technological Empowered Healthcare Delivery in the Era of COVID-19	**Funding:** Fifty-Nine Million Nine Hundred Ninety-Two Thousand Five Hundred Ninety Rwandan Francs (**59,992,590.00)** **Institution:** University of Rwanda
8	**Name:** Dr. Anne Marie Kagwesage **Title:** Analyzing the Resilience of Primary and Secondary Education Systems to Mitigate the Impact of COVID-19 Pandemic in Rwanda	**Funding:** Fifty-Nine Million Nine Hundred Fifty-Nine Thousand Seven Hundred Twenty-Five Rwandan Francs (**59,959,725.00)** **Institution:** University of Rwanda
9	**Name:** Dr. Jacob Mahina **Title:** Mitigating the social and economic impact of COVID-19 pandemic in private higher education of Rwanda.	**Funding:** Forty-Three Million Two Hundred Thirty-Seven Thousand Five Hundred Rwandan Francs (**43,237,500.00)** **Institution:** University of Tourism, Technology and Business Studies

10	**Name:** Mr. Andre Ndagijimana **Title:** Bioethanol and hand sanitizer production from sugar cane molasses to quickly respond to their local increasing demand towards COVID-19 pandemic.	**Funding:** Fifty-Nine Million Seven Hundred Seventy-Five Thousand Seven Hundred Rwandan Francs (**59,775,700.00)** **Institution:** National Industrial Research and Development Agency (NIRDA)
Two (2) Projects on Strategic Innovations for Protective Equipment for Prevention and Management COVID19 Infection in Rwanda		
11	**Name:** Mr. Joseph Habiyaremye **Title:** Design and development of emergency ventilator	**Funding:** Sixty Million Rwandan Francs (**60,000,000.00)** **Institution:** Rwanda Polytechnic IPRC Kigali
12	**Name:** Dr. Bernard Munyazikwiye **Title:** Design and Manufacturing of a Smart COVID-19 Tracing System	**Funding:** Fifty Million Nine Hundred Ninety-Six Thousand Nine Hundred Fifty Rwandan Francs (**50,996,950.00)** **Institution:** University of Rwanda
Five (5) Projects on Predicting and Monitoring the Impact COVID-19 pandemic in Rwanda		
13	**Names:** Prof. Jean Marie NTAGANDA **Title:** Mathematical Models for Predicting and Monitoring the Impact of COVID-19 in Rwanda	**Funding:** Fifty-Nine Million Eight Hundred Seventy-Nine Thousand Four Hundred Rwandan Francs (**59,879,400.00)**. **Institution:** University of Rwanda
14	**Name:** Dr. Francine Birungi **Title:** Longitudinal datasets hub for predicting and monitoring COVID-19 evolution in the community and mitigation measures outcomes in Rwanda (Predict Project)	**Funding:** Sixty Million Rwandan Francs (**60,000,000.00)** **Institution:** University of Rwanda
15	**Name:** Dr. Thierry Habyarimana **Title:** Predicting the risk of SARS-Cov2 infection and co-morbidity and Reducing Socioeconomic Impacts: Identification of high-risk population	**Funding:** Fifty Nine Million Nine Hundred Ninety Nine Thousand Four Hundred Rwandan Francs (**59,999,400.00)** **Institution:** Institut d'Enseignement Supérieur de Ruhengeri

16	**Name:** Dr. Joseph Nkurunziza **Title:** Predicting the infections, evolution and outcome of COVID-19 pandemic in Rwanda using SIR model	**Funding:** Fifty-Nine Million Nine Hundred Ninety-Nine Thousand, and Twenty Rwandan Francs (**59,999,020.00)** **Institution:** University of Rwanda
17	**Name:** Mr. Christophe Mpirimbanyi **Title:** Impact of COVID-19 on surgical care in Rwanda	**Funding:** Sixty Million Rwandan Francs **(60,000,000.00)** **Institution:** King Faisal Hospital

REPUBLIC OF RWANDA

NATIONAL COUNCIL FOR
SCIENCE AND TECHNOLOGY (NCST)

SPECIAL COLLABORATIVE RESEARCH GRANTS TO ADDRESS COVID 19 PANDEMIC

Four (4) Projects on Improving Diagnostics and Real-Time testing for COVID-19 infection

1. Production of Molecular Based Point-of-care Protocol for SARSCoV-2 Detection among Humans, and Comprehensive Atlas of Possible Coronavirus Immune Response Differences Between Humans, and Non-Human Primates. Principal Investigator: Dr Pacifique Ndishimye, Rwanda Biomedical Center (RBC); Amount: FRW 60 million Rwanda; Collaborators: Dr Julius Nziza, Gorilla Doctors; Dr Richard Muvunyi, Rwanda Development Board (RDB); Dr Phiyani Lebea, Tokabio, South Africa; Dr Fathiah Zakham, University of Helnsiki (Finland); David Kelvin, Dalhousie University, Canada

A: Background: Covid-19 has spread to almost all countries of the world and caused massive losses both in health and economic viewpoints. Apart from humans, scientific evidence also shows that primates are very sensitive to human diseases. Mountain gorillas for instance are prone to some respiratory illnesses that afflict humans. A common cold can kill a gorilla. In Rwanda, where tourism is an important source of revenue, and the government has prioritized the protection gorillas during COVID-19 with restrictive measures, there is no scientific evidence available about any potential transmission of COVID-19 from humans to gorillas or vice-versa. In addition, the adequacy of immunological defense mechanism in gorillas has not been tested yet. Some scientific experts are indicating that primates, including mountain gorillas, are likely susceptible to complications arising from the COVID-19. Today, more than 600 mountain gorillas live in Virunga massif where Volcanoes National Park is located. Not only many primate populations are already endangered, but also a spread of COVID-19 could put them in even more danger.

B. Goal and Objectives

The main goal of this study is twofold; first, to produce a Comprehensive Atlas of Possible Coronavirus Immune Response Differences Between Humans, and Non-Human Primates; second, in collaboration with our partners, to produce a molecular-based point-of-care protocol for SARS-CoV-2 detection.

Objective 1: The Humans' sample (from recovered, active, and naive), as well as non-human primates samples (from chimpanzees, mountain gorillas, baboons, golden monkey, African green monkeys) testing regime includes:

- To assess the production of neutralizing antibodies among different groups of humans and non-human primates,
- To stimulate the T cells and assess their activities (activation markers expression, production of cytokines);
- To document a scientific proof of respiratory infections among the non-human primates' routes of transmission;
- A possible functional comparison of SARS-CoV-2 immune responses pathways (susceptibility, protective immunity) between humans, and non-human primates;
- Possible epidemiology of SARS-CoV-2 in different selected non-human primates' reservoirs.

Objective 2: The detection protocol includes the following:

- A point-of-care (hardware) instrument that is fit for purpose.
- A biological assay that includes a simple extraction (heat and chill) protocol and fluorescent-dye based detection of Covid-19.
- A software capable of depositing the test results into a central database from distant geographies where the assay is performed into a secure central database.

A: Mountain gorilla physical Examination; B: Sampling; C-D: RNA extraction process of nonhuman primates' samples at Wildlife Virology laboratory- Rubirizi, Kigali

Methods: Isolated strains will be sequenced using the Next Generation Sequencing. Obtained sequences will be analyzed and compared to several other strains identified in other places. Amplicons will be prepared for sequencing. The detection protocol will include the use of a molecular diagnostic approach for COVID-19 diagnosis using real-time loop-mediated isothermal amplification (RT-LAMP). Here there will be three sets of virus and virus "equivalents" testing.

i) The first stage involves testing primers/probes against a synthesized and/or cloned virus target into a vector.

ii) The second stage will include testing of deactivated viral titres from a Guthrie card. The main reason for this kind of testing stage is to control and optimize the nucleotide extraction method before the isothermal PCR detection protocol.

iii) The third and final test run will be testing clinical samples for both the extraction method and isothermal PCR detection to assess the functionality of the assay within various matrices applicable for SARS-CoV-2 testing.

D: Expected Outcomes are:

- A comprehensive atlas of possible SARS-CoV-2 immune response differences between humans, and non-human primates;
- A thorough assessment of mountain gorilla's susceptibility to SARS-CoV-2;
- A protocol for recommendation for preventing nonhuman primates given the current covid-19 outbreak;
- A T16 LAMP instrument capable of conducting Covid-19 assays at point-of-care;
- A LAMP based functional assay that can detect SARS-CoV-2;

- An IT system based on a web application that can transmit test results from the field to a central database.

2. Development of On-Site Rapid Diagnostic Test for Early Detection of Covid-19 Based on CRISPR-Cas and Surface-Enhanced Raman Spectroscopy. Principal Investigator: Dr Mutangana Dieudonne, University of Rwanda; Amount: FRW 59,999,000 million; Collaborators: Prof. Lingen Zeng, Foshan University (Xhina, China) and Dr Souopgui Jacob, University of Rwanda

A: Background

During unpredicted epidemic outbreaks such as COVID-19, establishment of early-stage diagnostic tools, which can favor timely diagnosis, and control the spread of the disease in order to sustain and monitor people's lives are always a priority in personalized medicine. Most employed tools such as real-time PCR (Polymerase chain reaction) and ELISA (Enzyme linked immunosorbent assay)-based techniques are still expensive, tedious and their sensitivity is of concern.

CRISPR/Cas systems (clustered regularly interspaced short palindromic repeats)/ associated Cas proteins), hold promise in the development of novel and reliable diagnostic tools. CRISPR/Cas systems present the potential to turn into the next-generation diagnostic tools, owing to its high sensitivity, and specificity since they can be multiplexed and reach SNPs (Single nucleotide polymorphisms) detection.

B: Goals and Objectives

The project aims to develop a high fidelity CRISPR kit for COVID-19 nucleic acid detection based on CRISPR-Cas12a and a probe-based lateral flow biosensor or handheld SERS system. The design uses:

- use CRISPR Cas12a/b as the recognition system
- Reverse transcriptase Loop-mediated isothermal amplification (RT-LAMP) as the signal amplification technique, and
- Lateral flow strip and/or fluorescence reader or portable SurfaceEnhanced Raman Spectroscopy will be used for results readout.

C: Methods

The research project considers the following methodology approaches:

i. **Clinical evaluation of COVID-19 and impact assessment**: Study the main content and key scientific and technical issues to be solved
   - Site selection and data collection: data available for lab analysis
   - Laboratory analysis: Identification of COVID19
   - Data modeling and interpretation: Mapping of the disease status in the country
   - Manuscript writing and submission: Manuscript accepted for publication

ii. **Reverse transcription Loop-mediated isothermal amplification**: Lab design, development and testing of the diagnostic test device kit
   - Primer design and synthesis: design of reporter molecule and capture probe (designed primers ordered using specific software)
   - Preliminary establishment of the RT-LAMP detection system: RT-LAMP system design and software modelling
   - Optimization of the RT-LAMP reaction system, Sensitivity test of the RT-LAMP detection method and Optimization of the RT-LAMP reaction system
   - CRISPR/Cas12 reaction design: Model designed and tested
   - Design of CIALFB onepot system: The device is operationally tested and protocol optimization (High sensitive and specific biosensor chip)

iii. **Test performance**: Application of COVID-19 Rapid Diagnostic Test – On field testing of accuracy, sensitivity, specificity

- Testing the kit on samples: COVID-19 detection in sub-clinical samples (with Wider pathogenic applicability)
- Results comparison (with gold standard methods): Rapid vs. classic wet lab: Sensitivity, specificity and accuracy tested (with High sensitivity, specificity and accuracy)

D: Expected outcomes

Expected research results include:

- Product of COVID-19 nucleic acid rapid test kit and a handheld SERS detector: developed CRISPR-based lateral flow biosensor for the detection of COVID-19 nucleic acid for on-site detection. This is a quick, easy and cheap Covid-19 detection kit with high sensitivity (the detection limit can reach a level $(10^{-18}\mathrm{M})$, which is equal to a single microbial gene copy detection), high specificity (LAMP coupled with the specific recognition of gRNA ensures the ultra-high target detection), and Broad applicability: Freeze-dried products, easy to transport at room temperature
- Application for one related invention patent
- Publish one high-level scientific paper

3. Quantifying Productivity gains from using Artificial Intelligence (AI) in detecting COVID-19 patterns from Chest X-Rays. Principal Investigator: Mr. Jean Jacques NSHIZIRUNGU; Amount: RWF 58,000,396.00 million; Collaborators: Audace NAKESHIMANA, Ivan RUKUNDO, Yvonne KEEZA-KAMILI

A. Background

Coronavirus disease (COVID-19) presents with non-specific respiratory symptoms that vary in severity and range from mild, severe to life threatening conditions requiring advanced mechanical respiratory support. Currently, identification of viral RNA in reverse transcriptase polymerase chain reaction (RT-PCR) is regarded as the gold standard diagnostic test for COVID-19. However, RT-PCR has been shown to have limitations such as high number of false negatives and delayed results more especially in resource limited settings. Chest imaging has been used to complement clinical evaluation and laboratory workup in diagnosis and management of patients highly suspected or confirmed to have COVID-19 and most centers have reported literature on Chest CT manifestations in COVID-19 compared to other imaging modalities. In fact, there is developing literature identifying higher sensitivity of Chest CT for diagnosis of COVID-19 as compared with initial RT-PCR from swab samples. However, due to some limitations of CT in terms of infection control, availability in resource-limited areas, portability, some centers have used Chest radiography (CXR) and Lung ultrasound (LUS) to identify lung abnormalities pertinent to COVID-19.

B. Goals and Objectives

The overall objective of this study is to quantify potential productivity gains from use of Artificial Intelligence (AI) in detecting COVID-19 patterns from Chest X-Rays. Specific objectives are:

i) to build highly accurate AI models capable of detecting COVID-19 patterns from Chest X-Ray, as well as
ii) (ii) to create a setup that would allow us to measure improvements in speed of diagnosis and accuracy by radiologists assisted by AI in diagnosing COVID-19 from Chest X-Ray.

C. Methods

Researchers shall perform a retrospective and analytical study in which Chest X-Ray images of confirmed COVID-19 patients are studied by radiologists to detect the patterns in the image that are typical to COVID-19 infection.
The first component of the study will comprise image annotation steps and will be done by expert radiologists based in Kigali, Rwanda using Insightiv's Teleradiology platform (i.e. online). They will use Chest-X-ray images collected by combining open-source and proprietary data from different partner institutions around the world. Phase 2 and 3 of the study will be done by expert software engineers and machine learning engineers based in Kigali, Rwanda, using cloud-based Graphical Processing Units (GPUs) to train different algorithms on detecting COVID-19 patterns from images annotated by radiologists, as well as on evaluating the algorithms.

D. Expected outcomes

By leveraging AI and Chest X-Ray imaging modality, the study will provide a cost-effective technology for risk assessment and early isolation of COVID-19 suspects, a win-win for suspected patients who are isolated and treated early without spreading the disease, and for the healthcare system which is overwhelmed with high cost and volume of patients.

4: Development of a Rapid, Low-cost RT-RPA-Based Test for the Service Acute Respiration Syndrome: Principal Investigator: Ms. Musanabaganwa Clarisse, Rwanda Biomedical Centre; Amount: FRW 60,000,000 million; Collaborators: Dr Annette UWINEZA, University of Rwanda; Mr. Angus Nassir and Francis Makokhah, Kenya Institute of Bioinformatics (KIBs)

A: Background:

Coronavirus disease 2019 (Covid 2019) is a highly infectious disease that has rapidly spread all over the world leading to thousands of deaths, hospitalizations, and far-reaching economic and social disruptions. Covid-19 infection can spread from person-to-person contacts, and can also be spread through contact with contaminated environmental surfaces. According to a study by Chin et al (2020), the virus can persist on environmental surfaces for days on end. For example, the virus can remain viable on surgical masks for 7 days, on steel and wooden surfaces for 4 days, on glass and banknotes for 2 days, and on clothes and wooden surfaces for 1 day (Chin et al., 2020; Van Doremalen et al., 2020). Despite the importance of the environment in spreading the infection, no major attempt has been made to detect or monitor the presence of the virus on environmental surfaces. This projects seeks to address this anomaly and provide a rapid, cost-effective, sensitive, specific, and accurate test for SARS-COV2.

Further, according to the WHO, testing, isolation, and contact tracing form the backbone of containing the pandemic. Testing is thus the key first step needed to stop the virus from spreading further. However, Africa has not adopted widespread testing despite the fact that it is the most vulnerable region with poor health systems, dilapidated hygiene and sanitation facilities, and poor economic indicators. Lack of widespread testing is attributed to the expensive nature of the RT-PCR test, need for advanced laboratory facilities and highly trained scientists, stable electricity, and the complexity and lack of versatility of the RT-PCR test making it unsuitable in many parts of Africa. Current testing methods are also encumbered by the need for expensive reagents, lack of portability, and take a lot of time for the results to come out. Therefore, there is a need for the development of an accurate, highly sensitive and specific rapid test that can be conducted in rural Africa without the need of expensive lab equipment and highly trained scientists.

B: Goals and Objectives:

The project aims to determine the sensitivity and specificity of the COV 2 nucleic acid rapid diagnostic test (NARDT) and elaborate feasibility plan for manufacturing of COV2 NARDT in in Rwanda and Kenya. The project has the following specific objectives:

1. To determine sensitivity level of NARDT for COVID-19
2. To determine the specificity level of NARDT for COVID19
3. To elaborate feasibility plan for establishment of COV2 NARD Plant manufacturing in Rwanda

C: Methods

The research project uses the following methods:

- **i)** Samples: Oropharyngeal or nasopharyngeal samples will be collected, transported, and stored where necessary according to the WHO guidelines and CDC recommendations
- **ii)** Laboratory Settings and Processes: Previously collected, anonymized samples from current COVID19 patients will be used to validate the novel Cov NARDT assay platform. The Cycle threshold of the patient's samples to be used will be ranging between 16-39. RNA COVID-19 concentration will be measured using Nano spectrophotometry. The Template average Concentration will be calculated using the following formula N1 V1=N2 V2. The sensitivity and specificity of the NARDT will be calculated and those measures will be validated by RT-PCR according to WHO guidelines and Rwanda National Reference Laboratory

iii) Test principle: The test is based on the reverse-transcriptase recombinase polymerase amplification (RT-RPA). Briefly, crude extraction or pure extraction yields RNA which is then isothermally amplified using RPA primers tagged with fluorescent probes. The resulting amplicons are placed on a PCRD card and if the virus is present 2 lines appear, if absent a single line appears

iv) RNA Extraction: Crude extraction can help obtain viral RNA in less than 5 minutes and avoid the laborious processes and cost associated with commercial extraction kits. For validation of the test principle, the pure extraction method will be used, and crude extraction optimized later

v) Statistical analysis: A non-parametric LOESS curve will be generated as previously done to characterize the relationship between the likelihood of a positive RDT in the field and the log COV RNA concentration measured in the laboratory. A logistic regression model will be fit to the dose–response data, and will be used to estimate the COV RNA concentrations with 95% confidence intervals at which 50, 75, 90, and 95% of the RDTs would be expected to turn positive (level of detection [LOD]). A multivariate regression model will be fit to explore the relationship between participant age and sex and testing RDT positive, after adjustment for COV RNA concentration

vi) Packaging of NARDT: The NARDT will come as a kit containing the Twist DX Basic RT kit, separate Rnase inhibitor, probes and primers, and PCRD cassettes

vii) Capacity building: Health professionals who are part of an ongoing COVID19 active case program across the country will be trained to use COVID 19 NARDT. A total of 20 health professionals will be demonstrating competence in completing the RDT procedure and interpretation of test results.

D: Expected outcomes

The project is expected to develop an accurate, highly sensitive and specific rapid test for SASCOV2.

- Product: Validated new testing principle for real time detection of SARS-COV2
- Data: Produced the preliminary data on sensitivity and specificity of RT NA-RADT for SARS-COV2

The key outcomes of the projects are:

- Improvement of sensitivity through temperature optimization and RT/MgOAC titration
- New models for use of saliva samples in place of nasal/oropharyngeal swabs – nasal swabs considered as invasive and uncomfortable
- Elimination of extraction step through use of optimized crude samples to make it a true POC/field test
- Assessment of minimum template requirements - up to fg quantities of DNA
- Multiplexing two primer-probe pairs e.g, Spike gp and RdRP and ORF3 or 8 all in one reaction for double detection of virus as the second step of validation

Six (6) Projects on Improving Society Resilience to Mitigate the Impact of COVID-19 Pandemic

5: The impact of selenium supplementation in the treatment of COVID 19 positive patients in Rwanda. Principal Investigator: Dr. Julius KAMWESIGA, Homeland Health Initiative (HHI) and the AIDS Health Care Foundation Rwanda (AHF); Amount: Fifty-Nine Million Nine Hundred Seventy-Four Thousand, and Ten Rwandan Francs (59,974,010.00); Collaborators: Mr. Eliah Shema Executive Director Homeland Health Initiative; Dr. Brenda Asiimwe Kateera MD, MPH Country Program Manager, AHF Rwanda

A. Background

Socio-economic pressure on health care systems and health care workers, fragile economies can suffer double given transmission mode and rate of COVID 19 if innovative strategies are not applied. Selenium supplementation has proven prevention evidence in cases of coxsackievirus and other viruses in many parts of the world. Little is known about the role of selenium in the treatment of COVID19 specifically. However, general knowledge of SARS viruses points to significant benefits of selenium in the management of enveloped viruses. Selenium deficiency in the body allows dormant enveloped viruses including SARS2-COVID19 through mutation synthesis to be more active and harmful strains. This enables these infections to progress into a disease that can range from mild to life-threatening diseases. Selenium is hypothesized to act as a transcriptase inhibitor hence leading to reduced viral replication. Selenium is known to boost the immune system and as a detoxifying mineral.

B. Goals and Objectives

The general objective of this project is to determine the impact of selenium supplement on COVID 19 treatment outcome.
Specific objectives of this study are:

- To determine the effect of selenium supplement on the immune response to COVID19.
- To determine the effect of selenium supplement on reducing COVID 19 severity & length of hospital stay in positive patients
- To determine the effect of selenium supplementation on COVID-19 on mortality rate.

C. Methods

All participants will receive the standard treatment of care irrespective of the experimental assignment. Unblinding will only be allowed in times of emergency related to side effects of the prescribed intervention. The trial intervention or placebo will be provided to the participant once daily or 12 hours, 8 hours, 6-hour schedules or even more to the discretion of the physician if the condition was critical. The intervention and placebo will be blinded to the investigator and patient. Coding will be used and will be disclosed to independent statistician during analysis time

D. Expected outcomes

The primary outcome measures for this study will be the changes in immune markers including CD4/CD8 T-cell counts, or change of cytokines (IL1, IL-6) and other inflammatory markers (CRP) that will allow us to determine the impact of selenium supplementation in the management of COVID19. For analyses of the CD4 T-cell count changes, patient samples will be taken at baseline (1st day of interaction), and at 7th day, 14th day, and every other 7th day until the participant exits from the treatment facility. Secondary outcomes will include viral suppression, mortality, and length of hospital stay, admission to HDU, Admission to ICU, mechanical ventilation and adverse events.

6: Genomic characterization and epidemiological Profile of COVID-19 in Rwanda

Principal Investigator: Ms. Musanabaganwa Clarisse, Rwanda Biomedical Centre; Amount: FRW 59,999,020 million; Collaborators: Dr Annette UWINEZA, Professor Mutesa Leon and Professor Claude Mambo Muvunyi, University of Rwanda; Mr. Angus Nassir and Francis Makokhah, Kenya Institute of Bioinformatics (KIBs)

A: Background

Evidence reveals that COVID-19 outbreak is of zoonotic origin, specifically bats seem to be the reservoir of COVID-19 virus, although the intermediate host(s) has not yet been identified. Corona Viruses (COVs) are enveloped positive-stranded RNA viruses with nucleocapsid. For addressing pathogenetic mechanisms of SARS-CoV-2, its viral structure, and genome must be of consideration. The transmission in Rwanda has been increasing overtime although COVID19 prevention measures and policies are being implemented. Although the WHO guided on diagnostic point of view and key biomarkers have been proposed, there remain gaps in understanding molecular patterns and genetic diversity in COVID 19 patients located in the African region. Besides, major gaps still exist in determining molecular factors influencing the susceptibility and vulnerability to severe coronavirus disease within a specific group of population.

B: Goals and Objectives

The project aims to determine the genetic pattern and diversity of severe coronavirus infection in infected patients and hence identify the outbreak transmission chain in Rwanda. More significantly, this study will provide understanding of the outbreak evolution in Rwanda and observing transmission dynamics through building phylogenetic trees. The project has the following specific objective:

1. To compare the diagnosis of Covid-19 from positive and control cases in Rwanda using both serological and molecular techniques and establish the relationship between the SARs-Cov-2 viral load and disease outcome
2. To determine the sequences of the Covid-19 positive cases reported in Rwanda and corelate with disease outcome
3. To determine the expression of the ACE-2 gene and protein receptor in the Covid-19 positive and control cases and corelate to clinical data
4. To perform protein-protein interaction analysis of the SARs-Cov-2 and ACE-2 receptor and truncated domains and establish its value for use as a diagnostic biomarker

C: Methods

Research methods:

The study will employ a cross-sectional survey design that will target all Covid-19 confirmed or suspected cases treated in Rwanda at the sampling time.

- Clinical Specimen and RNA extraction**:** Nasopharyngeal or oropharyngeal swab which were collected from symptomatic and symptomatic patients to detect SARS-CoV-2 by real-time reverse transcriptase (RT)-PCR will be used for RNA extraction with Biamp viral RNA mini kit (QIAGEN, Hilden, Germany) following the manufacturer's instructions. All specimens will be handled under a biosafety cabinet according to laboratory biosafety guidelines of Rwanda National Reference Lab.
- Sequencing analysis**:** Using reverse transcriptase, cDNA will be synthesized from RNA extracted from the cultured cell medium in which the virus will be replicated. For this project the Whole Genome Sequencing will be performed using Illumina Mini-Seq machine

- Data Quality Assessment: Investigating quality control of sequence reads using FastQC. Fast QC is a Java-application that provides quality checks on raw sequence data coming from high-throughput sequencing pipelines. To improve the quality of data reads below an average score of 20 bp will be discarded for contamination. The reads will be trimmed using Trimmomatic. Trimmomatic is a flexible pipeline tool used for quality filtering.
- Alignment and Assembling: Aligning the reads to a reference genome using a three-step process. Assembling and merging the read transcripts with an annotated file of the reference genome to produce a single annotation file using Cuffmerge.

D: Expected outcomes

The findings of the project will have the following clinical implications:

- Screening the Covid-19 positive and suspected cases by both molecular and serological techniques would inform of the diagnostic ability of each of the tests and provide insight into the ability of each test to predict severe disease and guide into the triaging of patient
- Determining the association between the viral load and disease severity would guide towards the evaluation of the management approaches and ensure that only very severe cases are managed by hospitalization while mild cases can be monitored at home or at outpatient facilities
- Determining the SARs-Cov-2 recombination/mutation events by sequence analysis would inform of the disease transmission patterns and guide towards the adoption of management practices that are tailored as per the observed transmission patterns.
- Assessing the ACE-2 levels in the Covid-19 samples in Kenya would inform of the role of this receptor in modulating viral infectivity and subsequently establish the susceptibility of the Kenyan population to Covid-19. Corelating the expression of this receptor with the patient clinical data would inform of the therapies to foster especially in patients with preexisting conditions. In addition, evaluating the role of this protein as a prognostic indicator would provide insight into the development of ideal point of care diagnostics to fast track disease detection.
- Research outputs shall be communicated via scientific conferences and policy reports and subsequently published in open access peer reviewed international journals to inform a wider scientific community

The key expected outcomes:

- COVID19 transmission in Rwanda identified
- New spots for vaccine and therapeutic development and hence contribute to the global efforts
- Evidence on genetic diversity for COVID19 in African will be generated

7. A Technological Empowered Healthcare Delivery in the Era of COVID-19. Principal Investigator: Mr. Evariste TWAHIRWA; Amount: RWF 59,992,590.00; Collaborators: Kambombo Mtonga, Kayalvizhi Jayavel, Willie Kasakula and Peace Bamurigire

A. Background

Having originated from Wuhan China, the Covid-19 virus is almost in all continents including Africa. Covid-19 has caused a collapse of social life due to the nature of how it is transmitted. However, some countries have begun to relax on strict lockdown measures, allowing social services including schools, markets and offices to reopen. The same is true of Rwanda, where social services such as markets, shops and supermarkets and restaurant have started to operate, which is a key step in reviving the economy. Although it will take time before life returns to normal, however, we highlight two aspects of social life where technology will prove vital in ensuring that business, schools, hospitals, office space and general day to day social life of people continues as smooth as possible. This can only be the case if measures are put in place that will boost public confidence in systems and places of work, shopping and mode of transportation.

B. Goals and Objectives

The main goal is to design, develop and deploy technology enabled preventive solutions to combat community spread of covid-19 through Mobile App integrated, effective health/mask screening kits and social distancing/Count alerts.

Specific objectives are:

1. Design and develop a smart and portable vital sign Screener “Health Neighbour Smart Kit (HeNSk)”
2. Develop a low complexity facial recognition algorithm for mask checking and alert accordingly to allow or deny access/entry.
3. Develop a mobile app which interconnects public transport drivers, health personnel and ambulance drivers to allow them communicate and coordinate their efforts in taking necessary measures in handling potential Covid-19 cases.
4. Design and develop a smart distance checking camera system called "Smart Distance Check Kit (SdChek) and alert accordingly.
5. Develop a low complexity distance checking algorithm that allows the camera to scan and check the distance between customers and also between customer and front desk employees.
6. Derive new insights through predictive analysis up on the collected data, query and visualize through dashboard plots.

C. Methods

The study seeks to provide legitimate IoT based solutions to aid the creation of an enabling environment leading to the improvement of the Rwandan society’s resilience to mitigate the impact of Covid-19 pandemic. It is important that for any such solution(s), the beneficiaries of the solution should be involved during the development of the solution. This is because, although people may not know what the solution is, but they have first-hand experience with their problems. Hence, we leverage local knowledge by involving local IoT experts in the project team. Where a need for health expertise will be required, the relevant qualified health professionals will be consulted so as to ensure that we adapt our solution(s) to local context. It must be noted that to achieve the above highlighted objectives, existing off the shelf components will be used, making our solutions low cost and environment friendly.

D. Expected outcomes

The expected outcomes of this project include:

1. **Screening Module:**

- **Health Neighbor Smart Kit (HeNSk)**
  - Public is screened for health conditions and updated/alerted via App to concerned authorities automatically
  - Can be deployed in all public places which has more people gathering like public transports, Malls, Conference halls, Worship places, Marriage halls, market places etc.
  - Portable and deployable at any place of need

- **Face Mask Recognizer**
  - Public is screened for masks, alerted and denied entry without mask.
  - Can be deployed in all public places which have more people gathering like public transports, Malls, Conference halls, Worship places, Marriage halls, market places etc.
  - Installable at any place of need

2. **Smart Distance Module:**

- **Smart Distance Check Kit (SdChek)**
  - Automated queue management
  - Useful in any people crowded locations
  - Portable and deployable at any place of need

- **Distance alert**
  - Alerts on distance reduction
- **Count alert**
  - Prescribed count of people maintained based on meeting halls/marriage/worship places.
  - Count down displayed at the entrance, based on which doors can be opened or remains closed.
  - **Smart App:**
  - Mobile App has details synced with Health Neighbor Smart Kit (HeNSk) and communicates accordingly to health workers and ambulance drivers.
  - Data acquired can be analyzed further for meaningful insights and actionate accordingly.
  - Details and visualization charts area wise, gender wise (face recognition) etc., can be a possibility

8. Analyzing the Resilience of Primary and Secondary Education Systems to Mitigate the Impact of COVID-19 Pandemic in Rwanda. Principal Investigator: Dr. Anne Marie Kagwesage, University of Rwanda; Amount: FRW 59,959,725.00; Collaborators: Omar Rugwiro, Flip Sides Murikira Ltd; Patrick NSHIMIYIMANA, National Institute of Statistics Rwanda; Dr. Makoni Kudzai, Silveira House and ESAP 9 Zimbabwe)

A. Background:

Among the measures taken to limit the spread of COVID-19 is the closure of all public and private schools at all levels. This shift from physical student-teacher learning to online education impacted mostly the primary and secondary education systems. Short-term challenges are already manifesting including a new learning environment for primary and secondary school learners, the unplanned burden of expenses for poor families, job insecurity for private schools' teachers, maintenance of private schools' infrastructures, etc. With the current pace of this pandemic, more consequences are to be expected into the future.

B: Objectives

The **general objective** of the present study is to Analyze the Resilience of Primary and Secondary Education Systems to Mitigate the Impact of COVID-19 Pandemic in Rwanda.

Specific Objectives are:

- **i)** Assessing the societal knowledge, perception, and attitude on the impacts of COVID 19 pandemic in Rwanda;
- **ii)** Understanding the role and interests of actors in improving the Resilience of Primary and Secondary Education Systems during and after COVID-19 pandemic in Rwanda;
- **iii)** Investigating the preparedness and effectiveness of ongoing e-learning platforms and tools in teaching and learning process at Primary and Secondary Education levels in Rwanda;
- **iv)** Considering and integrating stakeholders' suggestions to Mitigate the Impacts of COVID-19 pandemic on Primary and Secondary teaching and learning process and outcomes
- **v)** Establishing strategic approaches for accurate, timely, and consistent communication with the community (students, staff, parents, stakeholders) regarding COVID-19 preventive measures and the steps being taken to ensure smooth post-crisis continuity

C: Methods

This is a quantitative study to assess the knowledge and attitudes regarding Covid-19 among children, adults, and disadvantaged groups in sequential steps:

Step 1: We developed a set of categories of needs relating to social exclusion and identity formation based on existing knowledge in literature;

Step 2: We discussed the established categories in round-table consortium meetings

Step 3: We established appropriate sites for interview rounds as well as an initial list of potential respondents to include a cross-section of the Vulnerable population, based upon location, gender, age, education and current means of livelihood;

Step 4: We established categories form the base for the first round of semi-structured interviews with 20 members of the vulnerable Households

Step 5: In the second round, 80 interviewees will be shown a card with a list of categories

Step 6: In the third round of interviews a second group comprised of the strategic actors that influence how Vulnerable are perceived (community leaders; government officials; international actors; members of the popular media; development, human rights, and indigenous peoples NGO workers) and a cross-section of 25 ordinary members of neighboring communities, will be asked to comment on the list of categories of identity-formation and exclusion.

Step 7: A picture of Every student needs of personal contact and exclusion will be drawn based upon existing knowledge, paying particular attention to the links that are made between how their adequate hardware/software/internet access and social exclusion.

D: Expected outcome are

- **i)** The research findings will lead to an overview of the existing COVID-19 situation (nationwide) to establish a better and more systematic understanding of COVID 19 in regards to primary and secondary education systems
- **ii)** The study will uncover study guided strategies to mitigate negative impacts on teaching and learning to support and build resilient, sustainable and inclusive primary and secondary educational systems to foster socio economic development and well-being.
- **iii)** Researchers and Academic staff from University of Rwanda collaborate with Civil society NGO in this research to come up with research findings and recommendations to guide policy makers in the setting and implementation of recovery policies
- **iv)** A citizen surveillance system is established (oversight of access to and quality of preventive measures)

9. Mitigating the social and economic impact of COVID-19 pandemic in private higher education of Rwanda. Principal Investigator: Dr. MATUNDURA NYANDUSI Moses; University of Tourism, Technology and Business Studies (UTB), Amount: FRW 43,237,500.00; Collaborators: Dr. Callixte Kabera, UTB

A: Background:

COVID-19 is a humanitarian and societal crisis of unprecedented speed and scale. It has both immediate and long-lasting implications for how people work and participate in society. Private universities, which enroll over half of Rwandan higher education students, are concerned by COVID19 pandemic not only result in a loss of students, but academic staff as well. The private universities predict high numbers of dropout cases due to COVID-19. The students who usually pay for themselves are employees in private companies which are either suspended or unable to pay them. For the others source their school fees either from parents or other sponsors, all of whom are socially and economically hit by the pandemic.

B. Goal and Objectives

The goal of this project is to provide to direct beneficiaries such as the students, lecturers, parents, universities the social and economic situation analysis as a way to create resilience for curbing the effects of COVID-19

Objectives:

1. To analyze the social and economic situation of private higher learning institutions pre and during COVID-19 Pandemic in Rwanda.
2. To identify the social and economic effects faced by private higher learning institutions during COVID-19 Pandemic in Rwanda.
3. To suggest the strategies as solution to COVID-19 Pandemic educational disruptions in private higher learning institutions in Rwanda.
4. To assess the contribution of private HLIs resilience to mitigate the Impact of COVID-19 Pandemic in Rwanda.

C. Methods

- The research project will sample purposively the private higher learning institutions in Rwanda.
- The information for this study will be gathered through questionnaires and interviews
- The research project will work on large amounts of textual information and systematically identify, categorize and excerpt information desired to answer research questions of this research project.
- The findings will be disseminated through different ways like academic conferences, publication, door to door messages, public service announcements, news releases and government or community websites

D: Expected Outcomes are:

- Inform on the strategies as solutions to COVID-19 Pandemic educational disruptions in private higher learning institutions.
- Document on contributions of private HLIs resilience to mitigate the Impact of COVID-19 Pandemic.

10. Bioethanol and hand sanitizer production from sugar cane molasses to quickly respond to their local increasing demand towards Covid-19 pandemic. Principal Investigator Andre Ndagijimana, National Industrial Research and Development Agency (NIRDA); Amount: FRW 59,775,700.00; Collaborators: Dr. MUGANGA Raymond, University of Rwanda; Dr Niyonzima Niyongabo Francois, INES-Ruhengeri; Prof Dr. A. Rajendran, LCPL (India)

A: Background

This project intends to assess feasibility of producing *Aloe vera*-based hand sanitizers using bioethanol from sugar cane molasses and other vegetable by-products to mitigate Covid- 19 pandemic. By using hand sanitizer, it is a convenient way and less time consuming to ensuring hand hygiene which will lessen the spread of Covid-19 pandemic.

The requirement of hand sanitizers is expected to continue for an extended time. Thus, the ethanol availability has to be ensured in order to help people meet the demand for adequate hand hygiene. Because of Covid-19 pandemic the need for sanitizers is higher, yet availability is low or high cost. Yet the production of bioethanol from edible agricultural products may cause rise of cost of these crops leading to food insecurity. Bioethanol derived from agriculture waste, which is most abundant at global level, is the best option.

B: Goals and Objectives

The overarching goal of this research project is to assess feasibility of production, and operationalize a bioethanol plant and to develop *Aloe vera*-based hand sanitizers.

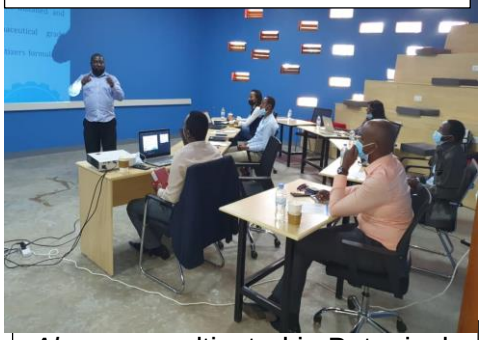
Specific objectives:

i To install and operationalize a bioethanol processing plant at NIRDA Research Center in Huye District;
ii To initiate the bio-ethanol production from sugar cane molasses and other vegetable by-products for a standardized hand sanitizers production;
iii To formulate *Aloe vera*-based hand sanitizers and conduct its efficacy and safety evaluation

C: Methods and Materials

We will initiate a bioethanol processing unit. The NIRDA ethanol pilot plant stopped after 1994 Genocide against the Tutsi. A pilot plant was re-operated up to 2007. However, because of some important parts were completely damaged, NIRDA bioethanol production plant ceased its activities. We will use sugar cane molasses from Kabuye Sugar works, which are not valued and are regarded as by-products and considered as waste or simply used as source of energy. This molasses are important key materials for bioethanol production. The combination of *Aloe vera* gel with glycerol and propylene glycol at appropriate proportion will be used as humectant. The *Aloe vera* will be supplied by local cultivation companies and processed in NIRDA.

Training of the Research Team



Aloe vera cultivated in Botanical garden of NIRDA

Other excipients including:

- The fermentative yeast *Saccharomyces cerevisiae*, nutrients and citric acid for ethanol production
- Carbomer powder which is used as clear gel thickner, emulsion stabilizer and suspending agent
- Glycerol which is used as humectant, moisturizing, emollient, skin softening. Skin repairing, prevent skin barrier from drying

- Methyl paraben, methyl/Propyl parahydroxybenzoate which is used as antimicrobial agent designed for preservation of a wide range of cosmetics, toiletriess and topical pharmaceuticals.
- Triethanolamine which is used as pH adjuster

The Procedure will be as follows:

- We will use molasses from the tanks diluted with water to obtain the sugar concentration around 10-15%,
- We will use a yeast culture tank, with nutrition supply of ammonium and magnesium phosphate or sulfate,
- We will use diluted and treated molasses and the yeast from storage fed to the fermentation chamber,
- Fermentation takes around 30-70 hours based on the pH, temperature and sugar concentration
- The rectification process will be used to produce 95% ethanol

Activities and Milestones

Some of planned activities in the project are following as shown at Fig 1 below:

- Organization of first research meeting
- Conducting the technical Audit by planning & monitoring team
- Preparation of MoU and contracts for equipment, excipients and raw material acquisition
- Aloe vera planting materials acquisition
- Bioethanol formulation from sugar cane molasses
- *Aloe vera* gel-based hand sanitizer formulation

D: Expected outcomes

The expected outcomes are the following:

- Bioethanol processing plant installed and operationalized;
- Bioethanol with pharmaceutical grade produced;
- *Aloe vera*-based hand sanitizers formulated and produced.
-

Two (2) Projects on Strategic Innovations for Protective Equipment for Prevention and Management COVID19 Infection in Rwanda

11. Design and development of emergency ventilator. Principal Investigator: Mr. Joseph HABIYAREMYE, IPRC, Kigali; Amount: RWF 60,000,000; Collaborators: Prof. Stephan Russia, UR; Prof Javier Martin-Torres, University of Aberdeen (Scotland)

A. Background

The novel COVID-19 is in the family of SARS and MERS coronaviruses and its implications include high fever, severe cough, difficulty breathing pneumonia, organ failure and death. This means that if the respiratory system fails, a patient will need an artificially breathing system and we can daily see, then number of victims is exponentially growing this will surely make some shortage in ventilators and manufacturers (from rich countries) will be concentrated with saving first their countries this make African countries to not have access to ventilators.

B. Goals and Objectives

The main objective of this project is to design and develop an emergency ventilator which will support COVID-19 Patients in this pandemic period. However, this emergency ventilator can also be used in private or public hospitals and ambulances to save multitude of lives with breathing difficulties.

Specific objectives are:

- Design and develop the mechanic part.
- Design and develop the control part.
- Perform clinical testing parameters
- Enhance technology integration in the health sector for rapid development of a more efficient and cost-effective healthcare service delivery system in Rwanda.
- Train more biomedical engineers, enabling an environment for hands-on skills development and R&D capability in biomedical engineering and e-health.

C. Methods

For developing a ventilator, expertise from different field is required. For the first prototype the project gathers together electrical, mechanical and biomedical engineers the team also included some medical doctors to help for clinical concepts. Basically, the development of a ventilator follows 3 different concepts:

- Clinical concept for the ventilator
- Mechanical design for the ventilator
- Control and electrical concept for a ventilator

D. Expected outcomes

At completion to the project, following are expected outcomes:

- A certified emergency ventilator
- More jobs which will be created, when it comes to mass production
- Internship and training for students

12. Design and Manufacturing of a Smart COVID-19 Tracing System. Principal Investigator: Dr. Bernard Munyazikwiye, University of Rwanda; Amount: FRW 50,996,950.00; Collaborators: RUZIBIZA Samantha, STES Group Ltd

A: Background

The premise of this research is based on some challenges for contact tracing including incomplete identification of contacts, inefficiencies in paper-based reporting systems, and delays in steps of identification of contacts to isolation of suspected cases of COVID-19 among contacts.

This research project will assess feasibility of using a digital solution that consists of hardware and software using RFID (Radio-Frequency Identification) technology with a non-contact temperature measurement to manage dynamic relationships between cases and contacts. This is because contacts may have links to multiple cases, and may become cases that generate further contacts. At software level, the contact history data can be processed centrally, typically either by a health authority like Rwandan Ministry of Health MINISANTE, the Rwanda Biomedical Center (RBC) or by individual devices.

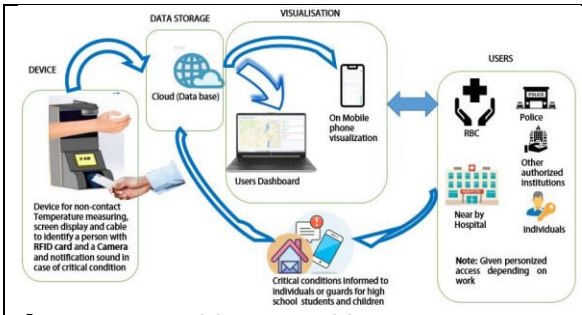
B: Goal and objectives

The overall goal of this research is to develop and demonstrate 'made in Rwanda' innovative products, which are effective non-contact temperature measuring machines for prevention and management of COVID-19 infection and other infectious diseases alike.

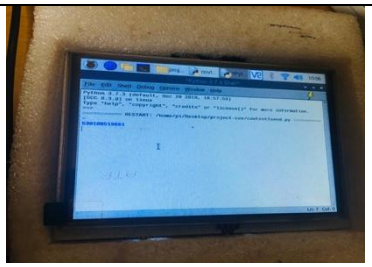
Specific Objectives:

i) To develop Digital tool for monitoring health conditions and storage of personal information to easy tracing when a person is found with COVID-19

ii) To measure the effectiveness of proposed innovative machine against the spread of COVID-19 infection

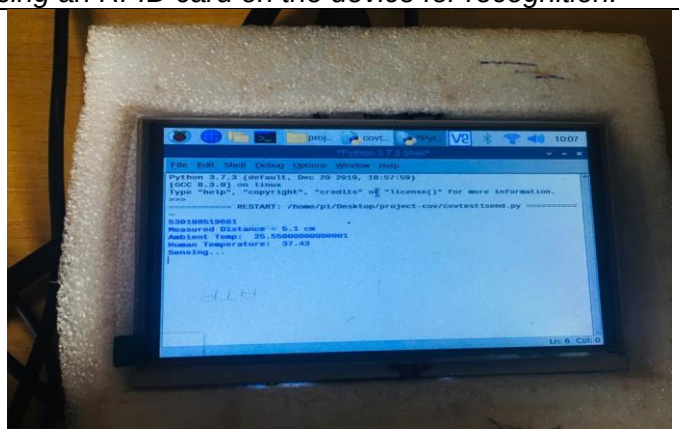


A: Smart Covid-19 Tracking System



B: The first prototype device Images and how it is used: *Placing an RFID card on the device for recognition.*

C: Place a wrist near the non-contact temperature sensor



D: Readings are displayed on the screen and recorded online for remote control with the software application

C: Methods

The process of contact tracing in Rwanda currently follows the following steps

- COVID-19 case investigators identify all clinical data.
- Use of human memory history to recall all contacts during the 2 days to 14 days window
- Development of a roster of close contact and anyone who was in touch with the index case within the window period in time and space (within 1 m),
- An active contact follow-up is therefore initiated by the command post to monitor, on a daily basis, any sign leading to possible cases.

D: Expected results, outputs and Outcomes are

The project will result in the following:

- Potential reduction of spread of COVID-19 as a result of identifying infected people before infecting others
- Reduced loss of time and money or resources to conduct COVID-19 test for people with no basic symptoms

Expected Outputs include:

- The project intends to make devices to test with people on eight (8) different institutions before they are distributed around the country. To implement this project, investigators shall host the software for data storage and monitoring on servers and register at least 500,000 users
- The project shall implement nine (9) functional non-contact temperature measuring devices
- The project study involves five (5) UR-CST students with different skills
- Hosted software to track measurements from the devices in the real-time
- Training of six (6) personnel from UR-CST to support the implementation and scale up the project

The Expected outcomes are

- Reduction in spreading COVID-19 as a result of people's awareness of their health conditions
- An increment in people's awareness about COVID-19 as a result of regular temperature measurement on different sites. Only further evaluation and diagnostic testing may be required for people with high temperature to determine if someone has a COVID-19 infection.
- Reduction in time and money spent on tracing contacts and unnecessary tests

Five (5) Projects on Predicting and Monitoring the Impact COVID-19 pandemic in Rwanda

13. Mathematical Models for Predicting and Monitoring the Impact of COVID-19 in Rwanda. Principal Investigator: Dr. Jean Marie Ntaganda, University of Rwanda; Amount: FRW 59,879,400.00; Collaborators: Dr. Matylda JABLONSKA-SEBUKA, Lappeenranta-Lahti University of Technology, Finland; Dr. Betty NANNYONGA, Makerere University, Uganda; Isambi Sailon MBALAWATA, Dar es Salaam University, Tanzania

A: Background:

To control human and animal diseases, the mathematical modeling and simulation are very important tools since that they can provide projections of the likely future, provide descriptions of the natural history of infections at a population and individual level, and provide insights into the impact of possible interventions. The dynamical biological processes are better modeled by means of systems of deterministic differential equations (ordinary (ODE), partial (PDE), or delay (DDE). Scientists have contributed a lot in modelling the spread of epidemics and the plans for controlling the spread. The development of the mathematical model of COVID-19 should take into account the known specific characteristics of this new disease. In Rwanda, the flow of COVID-19 can be modeled using deterministic mathematical compartmental epidemic models, stochastic differential equations (SDEs) and network models

B. Goal and Objectives

The goal of this project is to develop a mathematical modeling framework for predicting and monitoring the COVID-19 pandemic in Rwanda. Developed models will help in understanding the disease transmission dynamics, as well as give insights into the effectiveness of control strategies by providing forecasts of the disease burden on the country and hence of eventual health care saturation, infrastructure and facilities needs hospitals, in quarantine centers.

Objectives:

1. Build a deterministic mathematical model able to capture the dynamic transmissions of COVID-19 in Rwanda;
2. Build a stochastic model able to capture the inherent random, and uncertain factors influencing the spread and control of COVID-19 in Rwanda;
3. Develop a graph-based network model for COVID-19 propagation in Rwanda based on a random network of contacts between individuals;
4. Develop a statistical framework to analyse the response and impact of COVID-19 pandemic in Rwanda from a multi-discipline perspective and investigate the eventual situation of endemicity of COVID-19;
5. Connect the developed models to existing database through a well-designed App to automate data processing and produce a dashboard to allow quick actions from health care authorities.

C. Methods

The model will be constructed by using deterministic, stochastic and networking approaches.

- **Study design**: The total effective Rwandan population size will be divided into eight compartments: Susceptible (S), Exposed (E), Quarantine (Q), Infectious (I), Undocumented infected (Iu), Hospitalized (H), Recovered (R) and Dead (D); that is the mathematical model SEQIHRD. All the compartments will be linked by parameters to be estimated using data. Two

cases will be studied (1) the population is assumed to be closed (there is a pure confinement or lockdown) and (2) the post lockdown where the population is free to move even borders are open, i.e. the population is living with COVID-19.

- **Data collection**: secondary data will be used. They will be collected from clinical records of RBC (Rwanda Biomedical Centre) and other well established data bases. During the analysis of post lockdown, researchers will be interested in effective measures used to contain the outbreak. Therefore, primary data will be collected using questionnaire that will be designed according to the needed variables.

- **Epidemiological models:** Through the transfer diagram, the compartmental mathematical model SQEIHRD will be developed in form of Ordinary differential equations by considering the special characteristics of the pandemic in Rwanda. The deterministic model may then be extended into a stochastic model and network model by taking into account the random fluctuations observed along the time of the outbreak.

- **Model parameters estimation and validation**: The estimation of parameters will be done using Least Square Method and others may be found from literatures or medical experiments. Once the model is validated as accurate it will be used to study different scenario specified in the call. It will be used for monitoring and prediction using the dashboard to allow quick actions from authorities in charge of COVID-19. Furthermore, a statistical model capturing all the collected data can be identified and used for prediction.

D: Expected Outcomes are:

- Improved scientific understanding of the disease
- Inform decision making on easing lockdown measures
- Inform policy makers and health care professionals for post-corona strategies
- Preparedness for eventual future infectious diseases.

14. Longitudinal datasets hub for predicting and monitoring COVID-19 evolution in the community and mitigation measures outcomes in Rwanda. Principal Investigator: Dr. Francine Birungi, University of Rwanda; Amount: FRW 60 million; Collaborators: Dr. Vincent Mutabazi, Rwanda Biomedical Center; Dr. Charles Ruranga, African Centre of Excellence for Data Science (ACE-DS), UR; Prof. Marc Twagirumukiza, Ghent University Belgium; Dr Edward De Brouwer, KU Leuven University, Belgium

A: Background:

The coronavirus disease 2019 (COVID19) caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) has spread to the whole world in a very fast manner. All countries worldwide elaborated strategies to prevent and manage COVID-19 and mitigate its effects. Diagnostic tests have been designed to detect COVID-19 ARN or antibodies against the virus. Strategies to prevent and control COVID-19 and mitigate its effects have been initiated in all countries at different levels. However, these strategies need continuous adjustment as the characteristics and the dynamics of the virus are progressively discovered. There is need for accurate data on the prevalence, incidence and evolution of the disease. This project comes to add new knowledge on the dynamics of COVID-19 in Rwanda by highlighting the trends in its characteristics.

B. Goal and Objectives

The goal of this project is to provide data and predictions models for the control and management of COVID-19.

Objectives:

1. To gather all existing collected data on COVID-19 in Rwanda in a single data hub server.
2. To collect prospective data on COVID-19 in the community through mobile surveys applications
3. To leverage both traditional mathematical modelling techniques, statistical methods and machine learning methods for prediction models.
4. To provide a live monitoring dashboard for the burden of COVID-19 in the community but also the potential impact on hospital/treatment centre admissions and overall infection rates
5. To predict the impact of various public health measures on the pandemic evolution in the country

C. Methods

The set objectives will be achieved through 2 approaches:

Building a longitudinal datasets hub for predicting and monitoring COVID-19 evolution in the community and in health facilities:

- Gathering all existing datasets on Covid-19 in Rwanda (National Joint Taskforce for COVID-19, RBC, MOH)
- Integrating other data collected from ongoing cohorts or similar covid-19 projects, including a) the International citizen project to assess adherence to public health measures and their impact on the COVID-19 outbreak (20-country research consortium led by Antwerp University); and b) the National Institute of Statistics of Rwanda (NISR) data.
- The survey that will leverage mobile App questionnaires: A minimum of 1200 people per district (36.000 person throughout Rwanda) will be required for mobile App responses weekly (minimum frequency being 2 times per week). A minimum sample of 200 persons per district will be reached out by the data collector with validation call or face-to-face questionnaire. The

questionnaires will be translated in 3 languages, Kinyarwanda, English and French in Mobile applications

Building an analytical layer on top of the Data Hub, which will leverage both traditional mathematical modelling techniques, statistical methods and machine learning methods for predicting and monitoring the burden of COVID-19 in the community, on hospital/treatment centre admissions and overall infection rates and monitor the impact of various public health measures on the pandemic evolution in the country

D: Expected Outcomes are:

- Establishment of a robust database gathering various source of data useful for basic epidemiological studies and daily policy-driven decisions but ultimately to be used for the predicting model.
- Improved understanding of national, regional and international dynamics of COVID-19 as a result of this study findings aggregated with other research findings.
- COVID-19 prevention methods and strategies will be developed based on study findings
- COVID-19 pandemic controlled through application of the findings from this study

15. Predicting the risk of SARS-Cov2 infection and co-morbidity and Reducing Socioeconomic Impacts: Identification of high-risk population. Principal Investigator: Dr. Thierry Habyarimana; INES-Ruhengeri, Amount: FRW 59,999,400.00; Collaborators: Prof. Gabriele Costantino and Dr. Giannamaria Annunziato, University of Parma, Italy

A: Background:

Sub-Saharan Africa is sadly familiar with epidemies, but SARS-Cov2 is posing unprecedented threats. Paradoxically, its low-to-medium clinical severity slows and hampers the early recognition of cases, and the supposedly high number of asymptomatic or pauci-symptomatic individuals is seen as a major engine for contagion. From a clinical point of view, the information on why some people remain asymptomatic, other develop mild conditions, some other, instead, develop serious pneumonia, microtrombosis, vasculopathy and eventually die is still scanty. What is known, is that SARS-Cov2 infection can induce a hyper immune response and a systemic inflammatory state. Understanding why this happens to some but not to the others, is crucial for stratification of patients and efficient use of medicines and medical resources.

B. Goal and Objectives

The goal of this project is to evaluate the oxidative status of a population of individuals (for example, a community center, a University) that can allow the adoption of personalized measures to reduce both the clinical and the socioeconomic impacts of possible outbreaks

Objectives:

1. To identify the communities, with risk of becoming hotspots of future outbreak or regions with identified cases of infection.
2. To measure the plasma redox state within the identified communities.
3. To map the chosen communities according to the redox state of their components, and this will become the background signal for that community
4. To set guidelines to the Community Health facilities to implement a system of control of the redox markers among the population

C. Methods

Most of the work will include analytical laboratory analyses using mainly the following techniques:

- Engagement of Community Health facilities, hospital and universities to develop and establish ‘electronic medical files’ for the population to delineate a predictive statistical model which can be used to early detection of outbreaks and/or hot spot
- Quantification of the oxidative status using FRAS Technologies. Two tests will be performed: dROM (Reactive Oxygen Metabolite) and PAT (Plasma Antioxidant Test) tests

D: Expected Outcomes are:

- Establishment of systematic evaluation of the plasma redox state of a community which goes beyond the contingent case of the SARS-Cov2 pandemic
- Inform on strategic plan for health sector in Rwanda
- Implementation of the district-wide (with potential for nation-wide) approach where cutting-edge of scientific concepts are immediately translated into technological applications, with the ambition to significantly improve the reactivity of the communities and to reduce the social and economic burdens linked to COVID-19 outbreak.

16. Predicting the infections, evolution and outcome of COVID-19 pandemic in Rwanda using SIR model. Principal Investigator: Dr. Joseph Nkurunziza, University of Rwanda; Amount: FRW 59,999,020.00; Collaborators: Prof. Martina Anto-Ocrah, University of Rochester, New York_USA

A: Background:

Since the first case was reported in Rwanda on March 14, 2020, various measures have been taken to slowdown the spread of the virus. However, due to its high infection rate and lack of virus immunity to everyone, the number of infected persons have continued to increase. The rising numbers of COVID-19 infections have the potential to devastate the health care system in Rwanda if the spread is not controlled. There is a need of a reliable, country-specific forecast model to help in the prediction of infections and evolution of the virus. Such a model is necessary to monitor and assess the impact of the policies taken to slowdown the spread and consequences of the COVID-19 virus

B. Goal and Objectives

The goal of this project is to build a prediction model which provide a picture of the predicted progress of COVID-19 in Rwanda and test the impact of limiting the contact risks under the precaution measures taken to slowdown the spread of the virus

Objectives:

1. To measure the transmission rate of the virus in Rwanda and determine the basic reproduction number (R0) of COVID-19 in Rwanda;
2. To assess the recovery rate of COVID-19, estimate the number of infectives, and the cumulative morbidity of COVID-19 in subsequent periods;
3. To estimate the risk of healthcare capacity in terms of access consideration, functional requirements, location, and uncertainties associated with the spread of the virus.

C. Methods

- The data will be collected from two sampling sources:

Sampling Source 1: The first sample will utilize the list of all COVID-19 patients and recoveries as the sampling frame. From the selected sample, the primary data will be collected and used to assess the infectivity, incubation, and recovery among different population categories.

Sampling Source 2: The second sample will be selected from the list of all health facilities in Rwanda. The primary data will be collected from the selected sample and analyzed to assess the healthcare capacity and determining which health facilities are capable of receiving COVID-19 patients in case the virus continues to spread in Rwanda

- Prediction model

To build a mathematical prediction model of COVID-19 pandemic in Rwanda, an extended Susceptible – Infected – Removed (eSIR) model was used. While the standard SIR model assumes constant transmission rate, the extended SIR model assumes a varying rate of virus transmission from infected person to a normal person, which is due to different measures taken to slow the spread of the virus like lockdown of cities, social distancing, and others.

D: Expected Outcomes are:

- Availing a mathematical prediction model that will be used to control the spread and the outcome of the pandemic in Rwanda specifically,
- Inform on the impact assessment of preventive measures taken by the government of Rwanda in response of flattening the curve of infection,
- Inform on the healthcare capacity in terms of availability of functional requirements in case the virus continues to increase in Rwanda.

17: Impact of COVID-19 on surgical care in Rwanda: Principal Investigator: Dr MPIRIMBANYI Christophe, King Faisal Hospital; Amount: FRW 60,000,000 million; Collaborators: University of Rwanda, Global surgery research Hub (Rwanda), College of Surgeons of East, Central and Southern Africa (COSECSA), School of Medicine (UGHE), RBC

A: Background

The COVID-19 pandemic has profoundly affected health care delivery. With the increasing number of cases, health care systems around the world have faced strains, with shortages of health care workers, personal protective equipment (PPE), ventilators and other resources. Surgical practice has faced dramatic changes in this pandemic. In certain parts, elective surgery and clinics have been cancelled to prioritize resources for the increasing COVID-19 patients and decrease risk to patients and health care worker.

In Rwanda, access to surgical care is limited with insufficient surgical capacity and high unmet surgical needs, with most of the care provided in urban areas. In various surgical specialties, patient waiting lists are long with insufficient operating room space and hospital beds. Patients must wait for long periods to get the care they need. With the surge of COVID19, there is a need to study to what extent COVID19 pandemic has affected surgical care delivery in Rwanda. The impact will be assessed in terms of surgical volume, elective versus emergency cases by specialty, transfer patterns to referral hospitals and outcomes (mortality, morbidity and length of hospital stay). Knowing the impact of the pandemic on surgical care will enable developing measures to address the surgical burden and provide appropriate care to patients in need, as well eventually putting in place strong measures for possible future public health crises.

B: Goals and Objectives:

The project aims to assess the impact of COVID-19 on accessibility to surgical care in Rwanda.
The project has the following specific objective:

i) To determine the number of surgeries performed (Emergencies vs electives by specialty) over a 15 weeks period from March 22nd to June 30th, 2020 (During COVID-19 outbreak)
ii) To determine the number of surgical outpatients by different surgical specialties received over a 15 weeks period from March 22nd to June 30th, 2019 (Before COVID-19 outbreak)
iii) To determine type of surgical cases managed during Covid-19 pandemic lockdown across different surgical specialties
iv) To compare both periods (before and during COVID-19 outbreak) as far as number of cases, in-hospital mortality, morbidity, and length of hospital stay are concerned with respect to different surgical specialties
v) To identify challenges encountered by surgical care providers to provision of surgical care over the 15 weeks period during COVID-19 pandemic lockdown
vi) To develop a tool kit to be used by Rwandan Surgical community during next pandemic outbreaks

C: Methods

The project will be a mixed method study with concurrent explanatory design:

- **Study site**: Multi-centric, nation-wide, including private and public hospitals that provide surgical care. Private hospitals will be stratified into hospitals and polyclinics whereas public institutions will be stratified into two categories: referral hospitals (university teaching hospitals, provincial and other referral hospitals) and district hospitals (DHs)
- **Sampling technique**:
    - Stratified multi-stage cluster sampling will be used
    - Qualitative data will be collected through focus group discussions (FGDs) using a semi structured interview guide: A focus group discussion engaging 6 to 12 people made of

surgeons, anesthesiologists, gynecologists, and theatre nurses will be constituted to foster active participation and in-depth discussion
        - Quantitative data will be collected through cross-sectional survey using a pre-established questionnaire
- **Data collection, processing and analysis**: Data on surgical cases will be summarized and cleaned in MS Excel spreadsheet. The questionnaire will be completed online using survey monkey, data will be extracted in excel format cleaned and coded, then analyzed using STATA.

D: Expected outcomes

The findings of the project will have the following clinical implications:

- Screening the Covid-19 positive and suspected cases by both molecular and serological techniques would inform of the diagnostic ability of each of the tests and provide insight into the ability of each test to predict severe disease and guide into the triaging of patient
- Determining the association between the viral load and disease severity would guide towards the evaluation of the management approaches and ensure that only very severe cases are managed by hospitalization while mild cases can be monitored at home or at outpatient facilities
- Determining the SARs-Cov-2 recombination/mutation events by sequence analysis would inform of the disease transmission patterns and guide towards the adoption of management practices that are tailored as per the observed transmission patterns.
- Assessing the ACE-2 levels in the Covid-19 samples in Kenya would inform of the role of this receptor in modulating viral infectivity and subsequently establish the susceptibility of the Kenyan population to Covid-19. Corelating the expression of this receptor with the patient clinical data would inform of the therapies to foster especially in patients with preexisting conditions. In addition, evaluating the role of this protein as a prognostic indicator would provide insight into the development of ideal point of care diagnostics to fast track disease detection.
- Research outputs shall be communicated via scientific conferences and policy reports and subsequently published in open access peer reviewed international journals to inform a wider scientific community

The key expected outcomes:

- COVID19 transmission in Rwanda identified
- New spots for vaccine and therapeutic development and hence contribute to the global efforts
- Evidence on genetic diversity for COVID19 in African will be generated