Improving Access to Quality COVID-19 Vaccines using Digital, AI, and GIS tools

Draft background paper[1]

Workshop jointly convened by:

- National Agency for Food and Drug Administration and Control, Nigeria (NAFDAC)
- Medicine Quality Research Group, IDDO & MORU, University of Oxford
- Supply & Market Dynamics and Medicine Quality Working Group of the COVID-19 Clinical Research Coalition
- mPedigree
- Global Health Strategy Group for Digital Health and AI for Health

Purpose of the workshop (and follow-on activities):

COVID-19 vaccines, combined with other public health interventions, are vital to ending the pandemic. Their storage and distribution is a major logistical challenge. Additional, but so far neglected, issues are ***substandard and falsified (SF) and diverted COVID-19 vaccines, fuelled especially when access to vaccines is heavily constrained***. The problem stems first and foremost from ***poor traceability, which is exacerbated by weak infrastructure and inadequate tracking across borders***. To complicate future challenges, there will be ***markets in richer parts of the world for booster vaccines and vaccines reconfigured for new variants absorbing available supply, proliferation of different types of vaccines and of 'new' and 'superseded' generations of vaccines, spare-doses redistribution/reallocation, and many competing products***. When vulnerable communities think that they are protected when they are not, this risks impairing the effectiveness of vaccination programs. Falsified, degraded, and diverted vaccines also risk ***speeding the emergence and spread of viral variants***, undermining vaccines, and prolonging the pandemic. Efforts to set up ***vaccine manufacturing facilities in low-resource settings are undermined if vaccine supply chains and vaccine reputation cannot be protected***.

Digital, AI, GIS and similar tools are important parts of a ***package of joined-up interventions*** for tracking COVID-19 vaccines and securing quality all along the supply chain, and for more quickly identifying and managing the risks of SF and diverted COVID-19 vaccines. Success depends on creating a ***supportive ecosystem of interested parties*** with shared goals, ***aligning manufacturers, private digital/AI/GIS innovators, regulators, and health-service providers***, and efficiently deploying already available technology that is adapted for the needs of users and workable in even the toughest of low-resource settings. If the world is to finally exit from the pandemic, like the successful development of the vaccines themselves, ***we need a sense of urgency and the same can-do attitude and resources to concatenate the timeline for putting together a joined-up set of inventions, from ten years to less than a year***.

Regulators in ***Nigeria*** are keen to engage on account of their recent efforts to deploy cutting-edge technologies and strengthen their institutional capacity—including piloting innovations specifically targeting COVID-19 vaccines—and their desire to explore whether such innovations can be scaled-up to benefit other countries, and be made stronger, by extra digital/AI/GIS innovations, with ***Nigeria a lead innovator in this activity***. One possible outcome may be the '***Abuja Principles'*** for using such technologies to ensure access to ***quality COVID-19 vaccines for all, in all places, at all times***.

The challenge:

[1] This note prepared by Andrew Farlow, head of Global Public Health Initiatives for Oxford in Berlin, and co-chair of the Market Dynamics; Medicine Quality Working Group of the COVID-19 Clinical Research Coalition. Please address suggested changes/edits

Because a high proportion of the population of the planet will need to be vaccinated in a very short time-frame, it is reckoned that sales of COVID-19 vaccines may run to many tens of billions of dollars in the next few years. Breaking into this with substandard and falsified (SF) and diverted COVID-19 vaccines, exploiting inequitable coverage, without being traced, might be ***extremely lucrative for some***. To complicate the challenge, markets in richer parts of the world will be ***absorbing available supply*** on account of ***booster vaccines and vaccines reconfigured for new variants*** even as there will be needs in low and middle-income countries, the presence on the ground of ***'new' and 'superseded' generations of vaccines***, ***spare-doses redistribution/reallocation,*** and multiple issues with ***manufacturing capacity***. ***Vaccine degradation*** (included in the term 'substandard' by WHO[2]) due to storage and transport at inappropriate temperatures, is also ***a major risk*** without robust regulated supply chains. The challenges will evolve in new and hard-to-predict ways when excess capacity eventually emerges.

There have been numerous reports over the last two decades of vaccine falsification, for example of rabies, cholera, meningitis, yellow fever and hepatitis B vaccines, but these have never been marketed on the scale of COVID-19 vaccines. Most have been for small groups of vulnerable populations or for yearly cohorts of populations, and often at low price. Never before have we faced ***a global vaccination programme as vast as the current one and anywhere near as potentially lucrative, even as there is the danger of many going without***.

All these phenomena will confuse and alarm communities, damage public confidence in immunization programs, reduce vaccine uptake, and make it even harder to globally escape from the pandemic. ***We should not wait till SF has got out of hand, but nip the problems in the bud as early as possible***. It is far easier to tackle the risk of SF vaccines than the reality of widespread SF vaccines, at which point the effort may draw attention to what is going on and paradoxically weaken confidence in vaccines. Like the pandemic itself, ***a penny of prevention is worth a pound of late response***. As the Medicine Quality Research Group, of the University of Oxford, puts it: "We urgently need joined-up interventions to reduce the risk of diverted, and SF COVID-19 vaccines on global public health, through significant enhancements in global capacity for their prevention, detection and response."[3]

Nigeria as a case study to open up the box:

Before the pandemic, in September 2019, a call to action, "***Africa Strategy for Pharmaceutical Supply Chain Traceability***," was made. Twenty-five African countries and six health financing and donor organizations declared their commitment to implement ***GS1 traceability standards*** to help achieve greater ***supply-chain integrity*** and to fight SF medicines in their respective countries. Following this commitment, Nigeria developed and launched a ***National pharmaceutical Traceability Strategy*** in October 2020. To this end, Nigeria's National Agency for Food and Drug Administration and Control (NAFDAC) developed a 5-Year Traceability Implementation plan, based on using the ***GS1 Global Traceability standard (GTS)***, and established a traceability office and a technical working group to drive the activities in this 5-year implementation plan.[4] GS1 GTS provides a framework for organizations to design and implement traceability systems based on GS1 system of standards to ensure ***end-to-end traceability, i.e. the ability to track and trace products through their entire life-cycles and through all parties involved in their production, custody, sale,***

[2] World Health Organisation. Appendix 3 WHO member state mechanism on substandard/spurious/falselylabelled/ falsified/counterfeit (SSFFC) medical products working definitions. In: Seventieth World Health Assembly. 2017. Accessed April 8, 2021. https://www.who.int/medicines/regulation/ssffc/A70_23-en1.pdf?ua=1

[3] Page 3, Infectious Diseases Data Observatory. Medical Product Quality Report – COVID-19 Vaccines (Infectious Diseases Data Observatory - Medical Product Quality Report: COVID-19 vaccines

[4] https://www.nafdac.gov.ng/speech-by-nafdac-dg-at-national-pharmaceutical-traceability-strategy-launch-october-08-2020

use or destruction. The success of this pilot would provide valuable insights for embedding or scale-up to other products.

When the pandemic struck, Nigeria saw the unprecedented opportunity to implement a **traceability pilot for COVID-19 vaccines**, so becoming the first country in Africa to deploy this standard in monitoring COVID-19 vaccines along the healthcare supply chain ("***lean traceability***" according to the Director General of NAFDAC). As a proof of concept, the pilot would "Support the ***design and validation of a traceability model according to local country requirements*** and ***the development of a prototype system that can be tested in real time***." As well as detecting potential infiltration of the supply chain, it would reduce incidences of wastage and expiration, shortages, and pilferage. Through collaboration with UNICEF, WHO and GAVI, the Agency was able to mandate vaccine manufacturers to implement ***GS1 barcodes***.[5] These capture: the Global Trade Identification Number (GTIN); batch number; expiry date; serial number, which together with the GTIN uniquely identifies every product pack; Global Location Number, which uniquely identifies each supply chain partner; and a 2D-Datamatrix barcode embedding traceability data and Human Readable Interpretationfor COVID-19 vaccines exported to Nigeria. The initial product was Covishield®, the ***Oxford/AstraZeneca COVID-19 vaccine***, manufactured by The Serum Institute of India. ***Android-enabled scanners*** were procured for automatic capture, and mobile phones with the Trackgenic® mobile scanning application were also used, and relevant data saved in a ***central repository*** within the Agency. The results of the public-sector pilot were released by NAFDAC at the end of June 2021.[6] The big questions are: ***How robust is this, based on barcodes and a central data repository***, at removing the risks of SF vaccines?; Are there ***ways to strengthen it that will work in resource-constrained settings (including those out of scope in the pilot) and not be overly onerous to enact?***; Can ***manufacturers and developers provide even more data prior to shipment*** of the product to make it easier to verify the product (the need for this is likely to grow in the face of updated generations of vaccines, ***spare-doses redistribution/reallocation, competing suppliers of different vaccines***)?; Can ***GSI tools help with location data?***; What are the ***training program needs*** so that quickly evolving 'how-to' knowledge can be spread?; Can ***automated data capture*** improve on errors of manual data capture?; Can it be ***scaled up*** so that others can follow Nigeria's example and, if so, what might be the necessary local modifications? How might it support countries within Africa to become ***producers of COVID-19 vaccines*** and not just be recipients of imported vaccines? ***If companies like AstraZeneca, BioNTech, Pfizer, and Moderna are to share knowhow and partner with low-income country manufacturers to build manufacturing hubs, they will need reassurance that the products of such facilities will be tracked and protected and their activities de-risked. Improved supply chains will work synergistically to encourage new supply of quality vaccines.***

Besides deploying cutting-edge technologies, NAFDAC has intensified ***institutional strengthening programs*** (e.g. attainment of ISO 9001 for the entire Agency's management system, ISO 17025 Accreditation in 5 of its 7 quality-control laboratories while undergoing WHO Pre-Qualification and WHO Global Benchmarking assessment). Before 2001, prevalence of counterfeit medicine in Nigeria was estimated at about 40%. This was brought down to about 16.7% in 2005. When NAFDAC, in collaboration with the USP Monitoring Quality of Medicines (MQM) project, conducted five rounds of surveys on the quality of antimalarials they found estimates of 3.6% (2014), 4.3% (2016). 1.6% (2017), 1.9% (2018) and 1.3% (2019).[7] ***There are useful lessons to be***

[5] Details on page 4 and 5 of https://www.nafdac.gov.ng/report-of-traceability-implementation-for-covid-19-vaccines-distribution-in-nigeria

[6] https://www.nafdac.gov.ng/report-of-traceability-implementation-for-covid-19-vaccines-distribution-in-nigeria

[7] https://www.nafdac.gov.ng/wp-content/uploads/Files/Resources/Pharmacovigilance_Newsletter/2019-Vol-12-No-2-Circulation-of-falsified-antimalaria-and-antibiotics-in-subsaharan-Africa.pdf

learned across Africa and low-resource settings from Nigeria's efforts to tackle the risks of SF COVID-19 vaccines and its growing technical leadership in supply chain management.

Use of new technologies have been proposed including ***distributed ledger technology (DLT)*** and other ***blockchain*** solutions, because of the way this ***improves traceability*** (all previous data entries, locations and timestamps can be used to trace products back to their origin) and ***makes immediately visible, to all authorized participants, any attempt to interfere with the data in the digital leger***, which those legitimate ***participants can reject***. Blockchain—a single record of truth—can assist with quick detection and identification of faulty, incorrectly stored, or counterfeit products, which can be recalled from the supply chain. However, a study performed in Nigeria[8] found "some ***barriers to blockchain adoption***, including the fact that the level of awareness of blockchain technology among stakeholders within the Nigerian pharmaceutical supply chain and the regulatory agencies is very low…that the ***supply chain's current structure needs more regulatory and structural interventions by the Nigerian government than blockchain technology***. In other words, ***with the current nature of the supply chain***, blockchain technology adoption would not be effective in delivering the said benefits reported." [9] For blockchain to be viable in resource-poor settings, we need to ask: what is the whole needed ***package of 'regulatory and structural interventions' needed for blockchain to work***? Is this achievable in the time-frame available to us, or are other innovations higher priority? Can the blockchain bit be ***used in low-resource settings even given lack of other structural interventions***, alongside the GS1 Global Traceability standard (GTS)? What are the funding and training needs?

Several groups in the 'Global Health Strategy Group for Digital Health and AI for Health' are operational across Africa. In addition, ***African digital and AI innovators have been very active***. For example, ***mPedigree***, a Ghanaian non-profit, deploys a simple text message code to help check the authenticity of medicines, to create end-to-end protection for pharmaceutical supply chains from manufacturers through to patients (by scratching a zebra-marked seal on the labeling to reveal a code that can be checked on a toll-free hotline, or by scanning a barcode with a phone camera). The ***Nigerian health-tech startup, Medsaf***, links manufacturers directly to hospitals and pharmacies to confirm authenticity. ***RxAll and True-Spec Africa*** use AI-powered scanners to cross-reference information on a product against a database to quickly check its veracity, and ***FD Detector*** is a mobile app, developed in ***Nigeria***, to detect fake medicines at point of sale. ***Nigeria*** also has a ***Safe Medicines Foundation***. Technological solutions have been developed 'on the ground' and they have, in a sense, already been piloted. Such private enterprise is an important part of the solution. Governments and regulators need to play their part by ***strengthening the frameworks and standards needed to deploy such technologies to create more visible supply chains***.

The workshop will provide an opportunity to also explore the following components of a package of interventions (and perhaps set up follow-on activity):

- ***Joined-up stakeholder data sharing*****,** across manufacturers, regulatory authorities, health ministries, enforcement, customs, donors, international organisations.
- ***Risk analysis*** – globally and for countries to identify and rank risks to inform risk-based post-market surveillance – prevent, detect & respond strategies.
- ***Authentication, e.g. as barcode systems*** – but is the infrastructure there, especially in countries that have not implemented such systems pre-pandemic? Again, can digital and AI tools be innovated to overcome lack of infrastructure and be made to work even with low

[8] Labaran MJ, Hamma-Adama M. View of The Nigerian Pharmaceutical Supply Chain: Blockchain Adoption, Counterfeit Drugs and Successful Deployment of COVID-19 Vaccine in Nigeria. J Sci Res Reports. 2021;27(2):20-36. doi:10.9734/jsrr/2021/v27i230356.
[9] Reported in the Medical Product Quality Report – COVID-19 Vaccines, Infectious Diseases Data Observatory - Medical Product Quality Report: COVID-19 vaccines, page 35.

resources? Would the use of such tools modify existing systems or need new systems from the ground up? What is the sequence of required innovation? What are the levels of investment and training needs?

- ***Reference labs for different vaccines***. Where are these? Which and how are samples submitted, which assays, who and when are data shared with, and what actions are taken?
- ***Devices readily available for screening vaccines in the supply chains*** – without which we are flying blind.
- ***Public engagement*** on SF risks in different communities. How will community engagement be conducted to reduce risk of vaccine hesitancy in SF 'outbreaks'?

If the world is to finally exit from the pandemic, like the successful development of the vaccines themselves, we need to apply the same can-do attitude and resources to concatenate the timeline for putting together a joined-up set of inventions, that work, from ten years to less than a year.

Intended audience?

The workshop will bring together the expertise of a large number of groups (all will be listed and logos entered on any final agenda). The following have been, or shortly will be, invited:

- Senior officials in ***NAFDAC***, the regulatory agency in ***Nigeria*** dealing with SF COVID-19 vaccines**.** Others*?* Ethiopia commenced the process earlier with an approved national pharmaceutical traceability strategic plan in 2018. However, Nigeria was first to leverage the pandemic to pilot the system with the COVID-19 vaccines. Others—Turkey, Argentina, and the EU—have implemented similar traceability systems.
- Members of the ***COVID-19 Clinical Research Coalition****;*
- The ***Medicine Quality Research Group,*** IDDO and MORU, University of Oxford;
- ***Africa Union/Africa CDC 'Trusted vaccines'*** https://africacdc.org/trusted-vaccines/ ***and US CDC team working on global vaccine access and supply chains;***
- Leading ***digital and AI experts***, including in the new ***'Global Health Strategy Group: Digital Health and AI for Health'***, set up by 'Oxford in Berlin' to create a critical mass of expertise from both the global north (***Berlin, Oxford, London***, etc.) and the global south (***Villgro Africa, minoHealth AI Labs and Runmila AI Institute, Aga Khan Development Network Digital Health Resource Centre, Centrale Humanitaire Médico-Pharmaceutique, Kenya***, with others joining), to tackle challenging global health problems such as this, drawing in further local expert knowledge as needed.[10]
- **Blockchain experts** from a number of organizations (e.g. https://www.molecule.to, Berlin);
- Members of the ***Market Dynamics; Medicine Quality Working Group***, and ***COVID-19 Clinical Research Coalition***;
- Representatives potentially from Foundations (***Gates Foundation*** and/or ***Fondation Botnar*** colleagues engaged as members or observers of the Global Health Strategy Group for Digital Health and AI for Health, and ***Clinton Foundation***);
- ***Vaccine developers and manufacturers****;*
- ***COVAX/CEPI/WHO/UNICEF/CEPI/GAVI*** (since heavily supply-constrained systems cause price spikes which incentivizes SF, efforts to ramp up supply and to tackle SF go hand in hand);
- ***Others, such as Nigerian/African digital and AI innovators mPedigree, Medsaf***, ***RxAll, True-Spec Africa***, ***FD Detector***, ***Safe Medicines Foundation, Nigeria, etc. and RAND Corporation.***

[10] The Global Health Strategy Group: 'Digital health and AI for Health' is planning a hackathon in late 2021, but that would be rather late in the day for this particular global health problem—hence this workshop now.

ORDER FOR 28 July meeting (minute-by-minute)

0.00-0.04: ***WELCOME AND INTRODUCTION***

0.04-0.16: **National Agency for Food and Drug Administration and Control (NAFDAC), Nigeria**: Professor Christianah Mojisola Adeyeye, Director-General and team
0.16-0.20: **Medicine Quality Research Group**, IDDO & MORU, University of Oxford: Professor Paul Newton, Head of Group
0.20-0.24: **mPedigree**, https://mpedigree.com Ghana, Nigeria, Kenya, India: Bright Simons, Founder and CEO
0.24-0.34: ***DISCUSSION***

0.34-0.38: **Oxford Vaccine Group**: Professor Sir Andy Pollard, Director
0.38-0.42: **COVAX:** Hamidreza Setayesh, Senior Country Manager, Country Support (currently in Nigeria)
0.42-0.46: **UNICEF**: Zabi Kamran, Immunization Specialist - Data Analytics
0.46-0.50: **Africa CDC:** Elvis Sedah, Trusted Vaccines Cluster Coordinator
0.50-1.00: ***DISCUSSION***

1.00-1.04: **Villgro Africa** https://villgroafrica.org: Deogratias Mzurikwao, AI sector lead
1.04-1.08: **Gavi, The Vaccine Alliance**: Moz Siddiqui, Head, Strategic Innovation and Partnerships
1.08-1.12: **Centrale Humanitaire Médico-Pharmaceutique,** Kenya: Paul Lotay, CEO
1.12-1.22: ***DISCUSSION***

1.22-1.26: **Gudra Studio,** https://www.gudra-studio.com, Ghana: Darlington Akogo, Founder and Director of AI
1.26-1.30: **Zenysis Technologies**: James Bolster, Manager, Growth Team, US/Australia
1.30-1.34: **Lancet-Financial Times commission on Governing Health Futures 2030** (co-chair) and **CSIR Institute of Genomics and Integrative Biology, Delhi** University (Director): Professor Anurag Aggarwal
1.34-1.38: **RAND Europe**: Harriet Teare, Research leader for science and emerging technologies, especially in health

1.38-2.00: ***DISCUSSION***

2.00 CLOSE