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Incessant threat of COVID-19 variants: Highlighting need for a mix of FDA-approved artificial intelligence tools and community pharmacy services

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A B S T R A C T

Seamless integration of artificial intelligence (AI) technology, especially FDA-approved AI tools, in community pharmacies can build increasingly effective and easy care pathways, thereby minimizing burden on healthcare system, and ensuring compliance to preventive measure through limiting hospital visits. In this regard, the WHO needs to enlist and provide guidance on most promising AI tools that can be implemented in community pharmacy settings.

Most recently, the World Health Organization (WHO) and the International Pharmaceutical Federation (FIP) have published a guidance and a survey report, respectively, in view of the emerging evidence-based potential of digital technologies, especially artificial intelligence (AI), in enhancing the delivery of quality health care and medicine, increasing patient safety and reducing healthcare costs.^{1,2} However, the WHO has also highlighted high implementation cost, several safety concerns, and has issued caution about the use of AI without expert supervision, robust technologies, and training. This clearly implies that the integration of AI in major patient-related decisions or specialty areas demand a lot of evidence and monetary resources. But we are of the opinion that easily available AI tools, especially approved by the US Food and Drug Administration (FDA),³ could be beneficial beyond expectations in strengthening collapsed healthcare system of developing countries,⁴ if employed wisely. This editorial is intended to highlight the urgent need for the push of AI in community pharmacies to deliver healthcare services in a more organized and timely manner in resource deprived nations, as pandemic is nowhere near finished and community pharmacies are the only healthcare entities that can empower patients and communities to undertake control of their healthcare while maintain social distancing protocols.

The Delta variant of SARS-CoV-2, classified as variant of concern (VOC) by the WHO, and COVID-19 associated opportunistic infections among patients with co-morbidities have highlighted the importance of

management of chronic disease patients, such as diabetes, hypertension and cardiovascular diseases. Under such catastrophic conditions, community pharmacies can be upgraded using AI tools. For instance, improved accuracy of cardiovascular risk prediction among patients with heart disease was reported in clinical settings using EHR data.⁵ Likewise, FDA-approved AI tools, such as DreaMed AdvisorPro (analyzes blood glucose and insulin pump data), and the guardian™ connect system (predicting blood glucose changes) can be used to manage diabetic patients, as they are vulnerable to COVID-19 associated mucormycosis and other complications.

Treatment adherence is a cornerstone of patient health outcomes management. However, the World Health Organization has deemed medication non-adherence an epidemic and has called for effective, patient-specific approaches.⁶ The COVID-19 lockdown has further suppressed healthcare consultations, thereby potentially hindering patient-centered care. With the integration of computer implemented patient medication review system, community pharmacists can assess the patient compliance to the prescribed treatment and nudge patient practices. According to reports, the incidence of non-adherence to treatment was lowered considerably with the aid of Express Scripts, “Vik” (chatbot), and intervention of community pharmacist using big data analysis techniques.^{7,8}

Given the fact that immunization and vaccination programs around the globe have been greatly influenced due to ongoing bleak situation,

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Table 1
List of FDA approved and other artificial intelligence (AI) tools for community pharmacies.

Artificial Intelligence tool	Description	Benefit of implementation in community pharmacy
FDA approved AI tools		
AI-ECG Platform ^a	<ul style="list-style-type: none"> This AI-ECG Platform is designed to assist healthcare professionals in measuring and interpreting ECG 	<ul style="list-style-type: none"> Easy routine monitoring of cardiac patients Minimize hospital referrals Useful in home-base pharmacy services, especially in case of emergency situations
RhythmAnalytics by Biofourmis Singapore Pte. Ltd ^b	<ul style="list-style-type: none"> RhythmAnalytics platform helps healthcare professionals to detect cardiac arrhythmia, or irregular heartbeat 	<ul style="list-style-type: none"> Easy routine monitoring of cardiac patients Minimize hospital referrals Useful in home-base pharmacy services, especially in case of emergency situations
Steth IO by Stratoscientific, Inc. ^a	<ul style="list-style-type: none"> Steth IO is a smartphone-powered stethoscope that captures heart and lung sounds. The hardware resides in a smartphone case that modernizes centuries old stethoscope technology into a handheld device. 	<ul style="list-style-type: none"> Can help community pharmacist deal emergency patients and seek physician advice if required
Current Wearable Health Monitoring System by Current Health Ltd ^a	<ul style="list-style-type: none"> Current Health is all-in-one wireless wearable which sits on the upper arm of patients and continuously measures a patient's respiration rate, oxygen saturation, heart rate, temperature and movement with intensive care unit accuracy. 	<ul style="list-style-type: none"> Can be used by community pharmacist to monitor patients discharged from hospitals by home visits Can be used for determining parameters in COVID-19 suspected patients
FerriSmart Analysis System ^c	<ul style="list-style-type: none"> This automated system is for measuring liver iron concentration. 	<ul style="list-style-type: none"> Can help community pharmacist detect anemia in children, pregnant, lactating and women with child-bearing age. Avoid complications due to early detection of low iron levels. Risk prediction in diabetic patients, especially COVID-19 survivors
Guardian™ connect system ^a	<ul style="list-style-type: none"> This system predicts blood glucose changes 	<ul style="list-style-type: none"> Aid in better management of diabetic patients, especially COVID-19 survivors, and prevent opportunistic infections Modified form can be used in community pharmacies to identify potentially life-threatening cases and avoid complications, for example, mucormycosis and diabetic foot etc.
DreaMed Advisor Pro ^c	<ul style="list-style-type: none"> Analyzes blood glucose and insulin pump data to generate recommendations for optimizing insulin pump dose ratios. 	
BriefCase by Aidoc ^a	<ul style="list-style-type: none"> This assists radiologist with prioritization of time-sensitive and potentially life-threatening cases through analyzing scanned images. 	
Other AI tools		
Development of tool for prescription approval & prospective audit and feedback system ^d	<ul style="list-style-type: none"> Help to seek approval from a general physician before prescribing or dispensing medicine, provide feedback and also help monitor patient entire antibiotic treatment regimen. 	<ul style="list-style-type: none"> Rational use of antibiotics Antibiotic stewardship
Express Scripts ^e	<ul style="list-style-type: none"> Used to improve adherence and compliance to treatment. 	<ul style="list-style-type: none"> Aid in improving adherence and compliance among patients with communicable and non-communicable diseases
Vik ^f	<ul style="list-style-type: none"> It is a chatbot and proven to improve treatment adherence and compliance via personalized text messages 	<ul style="list-style-type: none"> Aid in improving adherence and compliance among patients with communicable and non-communicable diseases. Vaccination and immunization services
mPulse™ Mobile ^b	<ul style="list-style-type: none"> A tool used to improve higher medication refill rate and reduce emergency hospital visits 	<ul style="list-style-type: none"> Aid in improving adherence and compliance among patients with communicable and non-communicable diseases.
A virtual pharmacy review program (ViPRx) ¹	<ul style="list-style-type: none"> Leverages electronic medical record (EMR) to maximizes the patient-centered skills of community pharmacist 	<ul style="list-style-type: none"> Enables better patient outcomes and reduced costs.
The Pharmaceutical Record (DP) (Dossier Pharmaceutique) ¹	<ul style="list-style-type: none"> The DP lists all the medicinal products provided to each patient over the last four months (21 years for vaccines, 3 years for biological drugs). This includes both medicinal products prescribed by a doctor and those advised by a pharmacist. It is handled by community pharmacists, and authorized physicians. 	<ul style="list-style-type: none"> For improving the safety of dispensing medicinal products and assisting with vaccination monitoring Helps deter drug- and disease-related problems
Everion ^k	<ul style="list-style-type: none"> It is a device, which is a multi-sensor platform, worn on the arm capable of measuring 22 parameters in real time. Collected physiological data can include heart rate, inter-beat interval, respiratory rate, blood oxygenation, skin temperature and actigraphy (rest/activity cycles)—all gathered non-invasively. 	<ul style="list-style-type: none"> Aid in monitoring cardiac patients Can be used in COVID-19 confirmed and suspected patients Useful tool for home based pharmacy services
Electronic health record (EHR) data ^{g,h}	<ul style="list-style-type: none"> Up-skill community pharmacists in terms of clinical decision making 	<ul style="list-style-type: none"> Help select better treatment strategies and promote appropriate medication use Improved accuracy of risk prediction among patients with chronic diseases Help in risk-benefit analysis and decision-making about whether to treat a person with a specific drug or not.

^a The Medical Futurist. FDA-approved A.I.-based algorithms. 2021alg2021; <https://medicalfuturist.com/fda-approved-ai-based-algorithms/>.

^b Brar Prayaga R JE, Feger E, Noble HK, Kmiec M, Prayaga, RS. Improving refill adherence in medicare patients with tailored and interactive mobile text messaging: pilot study. JMIR Mhealth Uhealth. 2018; 6:e30.

^c Lyell D, Coiera E, Chen J, Shah P, Magrabi F. How machine learning is embedded to support clinician decision making: an analysis of FDA-approved medical devices. BMJ Health Care Inform. 2021; 28 (1):e100301.

^d Ying W, Qian Y, Kun Z. Drugs supply and pharmaceutical care management practices at a designated hospital during the COVID-19 epidemic. Research in Social and Administrative Pharmacy. 2020.

^e See HQ, Chan JN, Ling SJ, Gan SC, Leong CO, Mai CW. Advancing Pharmacy Service using Big Data - Are We Fully Utilising the Big Data's Potential Yet? Journal of pharmacy & pharmaceutical sciences: a publication of the Canadian Society for Pharmaceutical Sciences, Societe canadienne des sciences pharmaceutiques. 2018; 21 (1):217–221.

^f Chaix B, Guillemassé A, Nectoux P, Delamon G, Brouard BJH. Vik: A Chatbot to Support Patients with Chronic Diseases. 2020; 12 (07):804.

^g Flynn A. Using artificial intelligence in health-system pharmacy practice: Finding new patterns that matter. American journal of health-system pharmacy: AJHP: official journal of the American Society of Health-System Pharmacists. 2019; 76 (9):622–627.

^h Weng SF, Reys J, Kai J, Garibaldi JM, Qureshi N. Can machine-learning improve cardiovascular risk prediction using routine clinical data? PloS one. 2017; 12 (4): e0174944-e0174944.

ⁱ Murraywid B, Butkievich LE, Myers B. Effect of a Virtual Pharmacy Review Program: A Population Health Case Study. Journal of managed care & specialty pharmacy. 2020; 26 (1):24–29.

^j Trinh-Duc A, Painbeni T, Byzcko A, Fort P-A, editors. Le dossier pharmaceutique dans un service d'accueil des urgences: évaluation de son accessibilité et de son impact sur le niveau de connaissance du traitement du patient. *Annales Pharmaceutiques Françaises*; 2016: Elsevier.

^k de Ree R, Willemsen J, te Grotenhuis G, de Ree R, Kolkert J, Peppelman M. Continuous monitoring in COVID-19 care: a retrospective study in time of crisis. *JAMIA Open*. 2021; 4 (2).

the utilization of AI equipped community pharmacies seems extremely value-added in preventing other public health crisis. In addition, lack of vaccine acceptance and non-compliance to complete course of vaccination are major challenges due to cultural, psychological and poor self-care behaviors. This makes the populations vulnerable to increased morbidity and mortality. For instance, partial vaccination with a single dose of the COVID-19 vaccine has been reported to cause an outbreak of a more complex SARS-CoV-2 Delta in the United Kingdom. In this regard, community pharmacists can use AI tools to convince through sharing information and ensuring administration of complete course of COVID-19 vaccine as well as track any adverse drug event followed by administration of COVID-19 vaccine.

Imposed lockdowns as well as public anxiety about COVID-19 have results in fewer visits to healthcare facilities. As a result, self-medication and inappropriate use of medicines have escalated to threatening levels in developing nations with low health literacy.^{9,10} As such, AI can help up-skill community pharmacists and help them play role in prevention, documentation and alleviation of medication errors, and deterring drug-and disease-related problems.⁷ There are also reports that the consumption of antibiotic has increased manifold in the wake of COVID-19, which is well-known to contribute to disquieting high rates of antimicrobial resistance. The prescription approval & prospective audit and feedback have been recommended as most promising antibiotic stewardship interventions to halt the irrational use of antibiotics. A community pharmacist can use an AI tool not only to seek approval from a general physician before prescribing or dispensing antibiotics for self-medication, but can also monitor patient treatment course.

In sum, bearing in mind the emerging variants of COVID-19 and deadly opportunistic infections, there is a need to revamp healthcare systems of developing nations with collapsed healthcare systems.⁴ Seamless integration of AI technologies, especially FDA approved AI tools in community pharmacies can build increasingly effective and easy care pathways, thereby minimizing burden on healthcare system and ensuring compliance to preventive measure through limiting hospital visits. In this regard, the WHO needs to enlist and provide guidance on most promising AI tools that can be implemented in community pharmacy settings. Thereafter, they will need to compel governments to

provide monetary support required to address a number of barriers to establishment of community pharmacy services in developing nations¹⁰ and AI technologies on priority basis. A list of AI tools along with their benefits has been provided in [Table 1](#).

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We declare no competing interests.

References

1. International Pharmaceutical Federation. *FIP Digital Health in Pharmacy Education*. The Hague, Netherlands: International Pharmaceutical Federation; 2021.
2. World Health Organization. Ethics and governance of artificial intelligence for health: WHO guidance. *World Health Organization*. 2021.
3. Lyell D, Coiera E, Chen J, Shah P, Magrabi F. How machine learning is embedded to support clinician decision making: an analysis of FDA-approved medical devices. *BMJ Health Care Inform*. 2021;28(1), e100301.
4. Atif M, Malik I. Why is Pakistan vulnerable to COVID-19 associated morbidity and mortality? A scoping review. *Int J Health Plann Manag*. 2020;35(5):1041–1054. <https://doi.org/10.1002/hpm.3016>, 32700410.
5. Weng SF, Reys J, Kai J, Garibaldi JM, Qureshi N. Can machine-learning improve cardiovascular risk prediction using routine clinical data? *PLoS One*. 2017;12(4), e0174944. e0174944.
6. World Health Organization. *Adherence to Long-Term Therapies- Evidence for Action*. Switzerland World Health Organization; 2003.
7. See HQ, Chan JN, Ling SJ, Gan SC, Leong CO, Mai CW. Advancing pharmacy service using big data - are we fully utilising the big Data's potential yet? *J Pharm Pharmaceut Sci : a publication of the Canadian Society for Pharmaceutical Sciences, Societe canadienne des sciences pharmaceutiques*. 2018;21(1):217–221.
8. Torres-Robles A, Wiecek E, Cutler R, et al. Using dispensing data to evaluate adherence implementation rates in community pharmacy. *Front Pharmacol*. 2019;10: 130.
9. Atif M, Malik I, Asif M, Qamar-Uz-Zaman M, Ahmad N, scahill S. Drug safety in Pakistan. In: Al-Worafi Y, ed. *Drug Safety in Developing Countries: Achievements and Challenges*. India: Elsevier; 2020:287–316.
10. Atif M, Malik I. COVID-19 and community pharmacy services in Pakistan: challenges, barriers and solution for progress. *Journal of Pharmaceutical Policy and Practice*. 2020;13:33, 33.