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THE UKRAINIAN WAR AND THE PANDEMIC: THE IMPACT ON PUBLIC HEALTH AND THE NEED FOR NEW HEALTH DIGITAL TOOLS AND THE NEXT LEVEL OF INTELLIGENCE

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Ключові слова: *дослідження цифрової системи охорони здоров'я, моніторинг соціальних мереж, геноміка громадського здоров'я, поведінка, війна, Україна, COVID-19*

Abstract. The Ukrainian war and the pandemic: the impact on public health and the need for new health digital tools and the next level of intelligence. Geanta M., Cucos B., Boata A., Nuta A.C., Nuta F.M., Semenov V.V. *Against the background of the war in Ukraine, the COVID-19 pandemic has waned from public consciousness as the threat of the virus to health is outweighed by safety concerns during the war. Pandemic restrictions in the European region are being lifted despite low vaccination rates in Central and Eastern European countries and a lack of effective containment strategies. However, Central and Eastern European countries are influenced most by the flow of refugees from neighboring Ukraine where a triple health crisis occurs: an overloaded health system, an ongoing COVID-19 pandemic, and the war. The aim: to review the progress regarding viral surveillance technologies that use genomics, digital, and informational tools, to find the gap in the literature and formulate policy recommendations for continuing surveillance in the context of permacrisis. Unstructured search was conducted through scientific (PubMed and Google Scholar databases) and grey literature using the keywords. The paper highlights aspects of war-related problems of infectious diseases control in Europe, new challenges in healthcare connected with COVID-19 pandemic and war in Ukraine and provides discussion on the role of innovative surveillance systems in tackling infection outbreaks (with COVID-19* *pandemic as an example). The paper overviews perspectives of the implementation of the discussed measures. Future COVID-19 outbreaks and new variants are possible. Complex adaptive system models, new tools, and the next level of health and digital intelligence are needed to provide timely and valuable insights. Combining lessons learned from the COVID-19 pandemic, the threat of war, and the need for continuous outbreaks surveillance, new public health and digital intelligence tools must be designed and implemented at regional, European, and global levels.*

Реферат. Війна в Україні та пандемія: вплив на громадське здоров'я та потреба в нових цифрових інструментах охорони здоров'я і наступному рівні дослідження. Джеанта М., Кукош Б., Боата А., Нута А.К., Нута Ф.М, Семенов В.В. *На тлі війни в Україні увага суспільства до пандемії COVID-19 знизилась, оскільки питання безпеки під час війни є важливішими від загрози вірусу. Пандемічні обмеження в європейському регіоні знімаються, незважаючи на низький рівень вакцинації в країнах Центральної та Східної Європи та відсутність ефективних стратегій стримування. Однак на країни Центральної та Східної Європи найбільше впливає потік біженців із сусідньої України, де відбувається потрійна криза в галузі охорони здоров'я: перевантаження системи охорони здоров'я, пандемія COVID-19, що триває, та війна. Мета дослідження – проаналізувати прогрес щодо технологій вірусного спостереження, які використовують геноміку, цифрові та інформаційні інструменти, виявити прогалини в літературі та сформулювати політичні рекомендації щодо продовження нагляду в умовах пермакризи. Неструктурований пошук проводився через наукову (бази даних PubMed та Google Scholar) та "сіру" літературу за ключовими словами. У статті висвітлено аспекти пов'язаних з війною проблем контролю за інфекційними хворобами в Європі, нові виклики в охороні здоров'я, пов'язані з пандемією COVID-19 та війною в Україні, а також обговорено роль інноваційних систем епіднагляду в боротьбі зі спалахами інфекцій (на прикладі пандемії COVID-19). У роботі розглядаються перспективи впровадження обговорюваних заходів. Нові спалахи COVID-19 та його нових варіантів можливі в майбутньому. Для надання своєчасної та цінної інформації потрібні складні адаптивні моделі систем, нові інструменти та наступний рівень медичної та цифрової розвідки. Поєднуючи уроки, винесені з пандемії COVID-19, загрозу війни і необхідність безперервного спостереження за спалахами, нові інструменти громадського здоров'я і цифрової розвідки повинні бути розроблені і впроваджені на регіональному, європейському і глобальному рівнях.*

History has taught us that overlapping a war and a pandemic often leads to disastrous social and economic impacts, e.g., a decline in GDP, consumption, and increased inflation with critical implications on social life [1, 2, 3]. Infectious diseases have historically acquired the "third army" reputation in war [4]. The autumn of 1918 announced the First World War's end and marked the Great Influenza pandemic's beginning [5]. The pandemic is estimated to have killed over 50 million people, double the number of those killed in the war [6].

Armed conflicts greatly impact public health, even outside the conflict zone. The rapid spread of the Great Influenza Pandemic could be contributed to massive migration when soldiers were sent home from the frontline [7]. The indirect consequences of war from the forced migration of the populations may persist for several years after a conflict ends, impacting infant and maternal mortality rates outside conflict zones [8, 9].

During the war, public awareness is naturally turned to the problem of individual survival, which leaves the epidemiological situation out of focus. Nevertheless, a lack of information can weaken efforts to control a pandemic. Misinformation (intended or unintended) about the nature of a disease, its ways of transmission, or other aspects hampers effective pandemic management and endangers both individual and population health. Examples of that could be found in the history of the Great Influenza Pandemic, HIV/AIDS pandemic, and the current COVID-19 pandemic [10, 11]. Lack of information or misinformation have a proven impact on the likelihood of someone getting a COVID-19 vaccine. In 2020, WHO introduced the term 'infodemic' - an overabundance of information, including false or misleading, during a disease outbreak, making finding trustworthy information difficult [12].

The ongoing war in Ukraine has been an unprecedented military crisis in Europe since the Second World War (WWII), which overlapped with one of the most disastrous pandemics of the 21st century [13]. The last waves of the Great Influenza Pandemic a century ago were caused precisely by the movement of troops from one country to another [14]. A similar dynamics of the pandemic may be expected today due to the massive forced migration from Ukraine, especially given the relaxed SARS-CoV-2 surveillance measures in many European countries and beyond [15, 16]. In Eastern European countries, where COVID-19 vaccination coverage is a little over 30% [17], health systems are already challenged, and mis-/disinformation has become a threat to the population's health; the emergence of new viral variants, even new outbreaks, is imminent [18].

In the modern globalized world, where people can easily travel long distances, predicting a pandemic's development may be more complicated than during The Great Influenza Pandemic. Traditional public health surveillance, which relies on post hoc

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observations of identified cases, proved inadequate during the COVID-19 pandemic, except for several examples of good practice, such as Taiwan or New Zealand [19, 20]. Newer, hybrid surveillance systems may produce the next level of health intelligence by merging traditional surveillance data with multidimensional data from search patterns, de-identified human movements, passive behavioral data tracking, social intelligence, and crowdsourcing [21]. Wilson et al. described how smart hybrid health intelligence layers (Health Intelligence Atlas – HI-Atlas) enabled the extraction of the most relevant information to support real-time proactive planning and monitoring for COVID-19 vaccine preparedness and distribution [22]. A new global public health system supported by novel surveillance technologies and connected databases is needed to address the current and future challenges caused by infectious diseases.

MATERIALS AND METHODS OF RESEARCH

For the completion of the study aims an unstructured literature search was conducted with the usage of the keywords “digital health intelligence”, “social media surveillance”, “public health genomics”, “behavior”, “war”, “Ukraine”, and “COVID-19”. Scientific (PubMed and Google Scholar databases) and grey literature was interrogated. The paper includes the unpublished data from Ipsos study that were used for the Figures 2 and 3. For creation of the figures was used R software (version 4.1.2) [23]. The study was approved by the Ethical Committee of Dnipro State Medical University (protocol No. 10 from 21.06.2023).

Literature review: pandemic control in Europe

The first case of COVID-19 in Europe was reported on January 24, 2020 [24]. On January 31, 2020, the Director-General of WHO declared COVID-19 a public health emergency of international concern [25]. An analysis from February 2021 showed that only 13 countries in the WHO European area had plans to prepare for the pandemic, 4 were updated, but none referred to the use of innovations such as data or *omics* sciences [26].

Between January 24, 2020, and December 31, 2021, more than 102 million people were infected with SARS-CoV-2 in the WHO European Region [15], but the impact could be much higher. A substantial proportion of people who fall ill still experience severe health problems weeks or even months after being infected [27].

While COVID-19 can affect everyone, it does not affect everyone equally. Some European countries managed to use good viral surveillance systems and secondary data to predict viral outbreaks. Western European countries faced significant challenges in the first pandemic wave, with Italy, Belgium, Spain, and the U.K. experiencing significant cases and deaths [28]. However, until the second wave, the Western states, severely affected at the beginning, began to take adequate measures and improve the efficiency of their healthcare systems [28]. Instead, Central and Eastern European countries were hit hard by the inefficiency of health systems and continued to face serious challenges in each pandemic wavev [28].

Eastern European countries fatality and mortality rates follow the same trend over time and are high above the European average rates [17]. Currently, COVID-19 vaccination rates vary across Europe, with relatively low coverage in Central and Eastern Europe, compared to Western and Northern Europe. For instance, only 35% of the Ukrainians got the COVID-19 vaccine, with very few getting booster doses before the war began [17]. While many European countries imposed strict non-pharmaceutical interventions on gatherings, schools, business, and domestic traveling, with some having multiple lockdowns, some had only the first lockdown (like Romania in March 2020) [29].

The line of geographical division between countries with high (above 70%) and low vaccination coverage follows the border between Warsaw Pact countries and the West during the Cold War – the Iron Curtain [30]. It seems that this subdivision persists, but now in the form of beliefs, perceptions, and legislative regulations that lead to inefficient vaccination campaigns in Eastern European countries – so-called the "iron curtain of vaccination" [31]. To ensure preparedness on multiple levels, including increasing vaccination and boosting, setting up integrated surveillance systems, testing and sequencing, and intensifying the actions against disinformation, the European Commission called on the Member States to take action [32]. According to the official statement of the President of the European Commission, we are entering a new phase of the pandemic, which requires more sustainable management of COVID-19 [32].

Ukrainian healthcare during COVID-19 and war overlap

Ukraine is the second-largest country by area in Europe after Russia and shares borders with Belarus to the north; Poland, Slovakia, and Hungary to the west; Romania and Moldova to the south. In its current borders, Ukraine was formed in 1991 after the fall of the Soviet Union. Due to corruption and a fragmented, under-resourced health system inherited from the Soviet Union, many of the population distrusted health workers [33, 34]. A significant number of unsolved problems in the healthcare system resulted in suboptimal responses to the challenges of the COVID-19 outbreak. Measures taken by the Ukrainian government to cope with the outbreak were associated with numerous misunderstandings, lack of organization, and scandals [35]. The capacity of hospitals to take care of an avalanche of new cases and the accessibility of medical help were the most pressing problems in the Ukrainian healthcare system [35]. Figure 1 shows that initial measures (lockdown, obligatory mask-wearing, shutdown of all activities except the critical ones) introduced by the Ukrainian government prevented the dramatic early increase in mortality as it happened in the European Union [17]. Despite timely measures to control COVID-19, Ukraine's health system was inadequately prepared for a surge in new cases resulting in increased mortality due to COVID-19. Starting from the second half of 2021, mortality in Ukraine began to increase, especially compared to the European Union, which had a higher COVID-19 incidence [17].

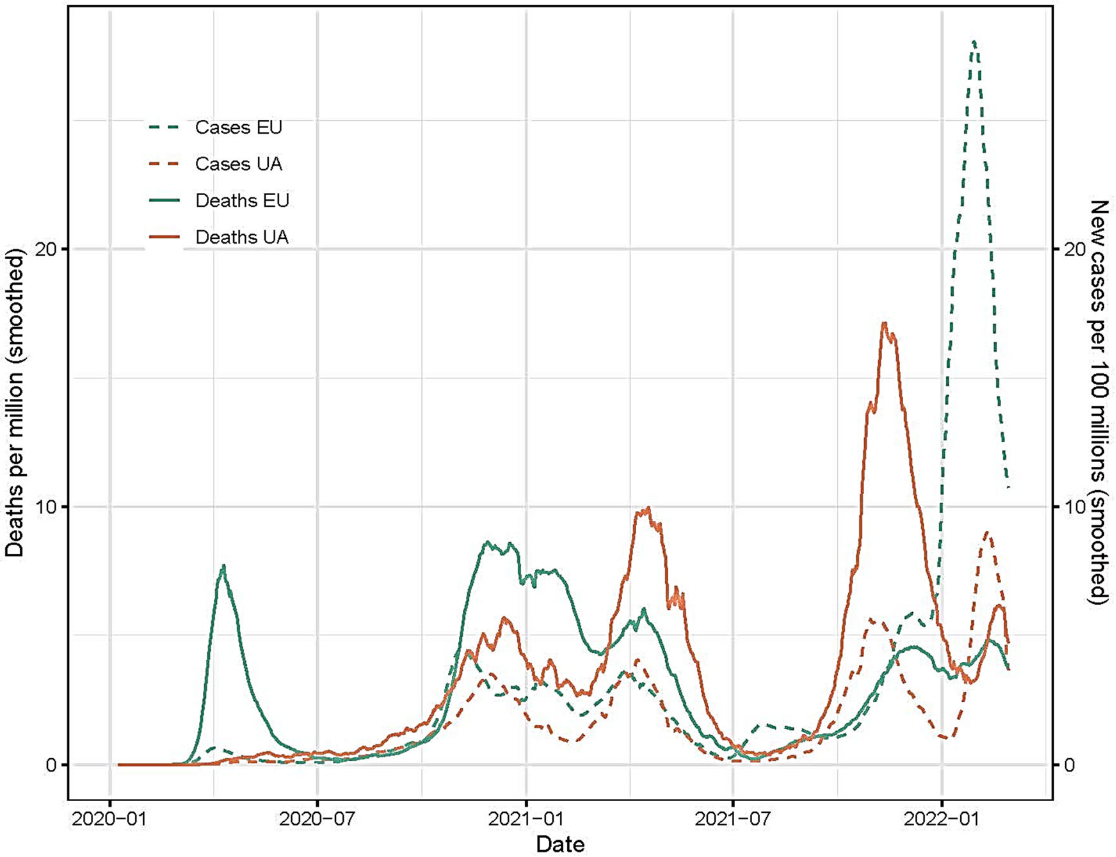

Fig. 1. COVID-19 incidence and mortality in European Union and Ukraine Data from Ritchie et al. [17]

One of the possible causes of the increased mortality in Ukraine is the failure of the vaccination campaign. As of February 27, 2022, approximately 36% of the population of Ukraine was vaccinated with at least one dose [17]. Low COVID-19 vaccination coverage in Ukraine among the general population and healthcare workers may stem from mistrust of vaccination due to insufficient transparency of vaccination policy (36). There was a significant increase in vaccinations by the end of 2021 [17]. It could be speculated that the short-term goal of 50% vaccine coverage in 2021-2022, announced by the government, could have been achieved if the war had not begun [37].

Rates of COVID-19 vaccination in Ukraine varied by geography. While Ritchie et al. report 36% of vaccination coverage [17], the study conducted in Ukraine by Ipsos between December 2020-December 2021 shows that 60% of the urban population was vaccinated with at least one dose [38, 39]. Nearly 30% of the Ukrainian population lives in a rural area, where attitudes to vaccination may differ [39]. This study was representative of gender, age, and geographical location.

According to the Ipsos study, most respondents suggested that the pandemic is not going to end soon and had negative feelings concerning the pandemic (worried about their safety or the safety of their nearest, worried about their work, craving to return to normal life) [38] (Fig. 2). Nevertheless, 53% of those who were not vaccinated did not want to receive the vaccine, and their attitude to COVID-19 vaccination did not change significantly from the beginning of the pandemic [38] (Fig. 3).

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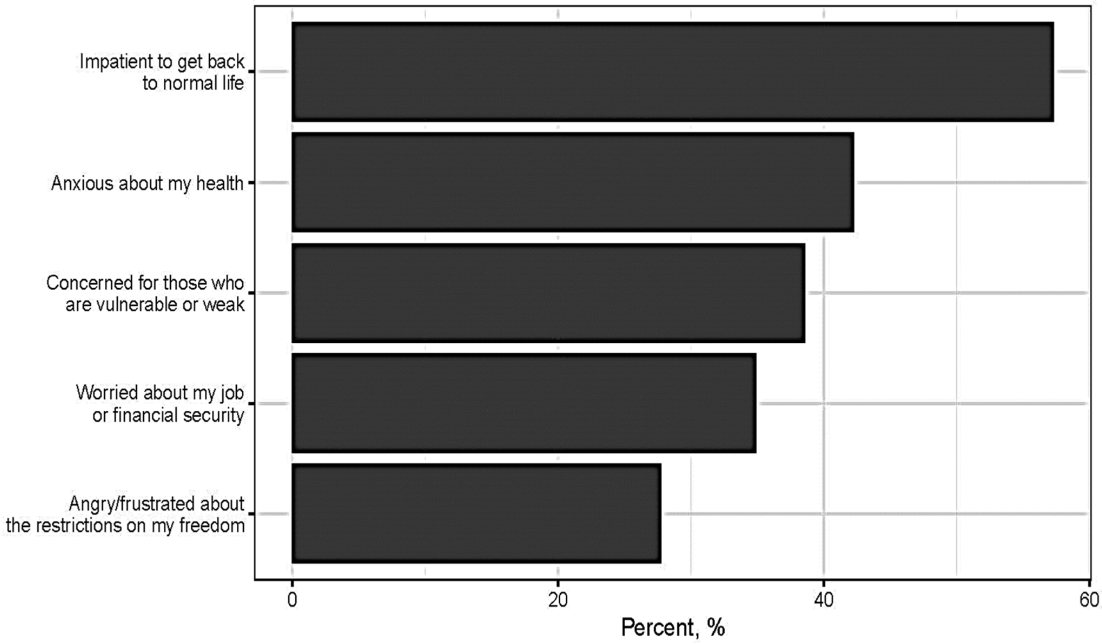

Fig. 2. Self-perception during the COVID-19 pandemic. Original data from Ipsos study [39]

The general hesitancy of the Ukrainian population to get vaccinated may be explained by low trust in vaccinations and the asymmetric depiction of vaccination consequences in the media [41]. UNICEF data suggest that a decrease in child vaccination coverage from around 80% to 50% in the five year-period happened after the high-profile case of death of a child preceded by the MMR (measles, mumps, and rubella) vaccine [41].

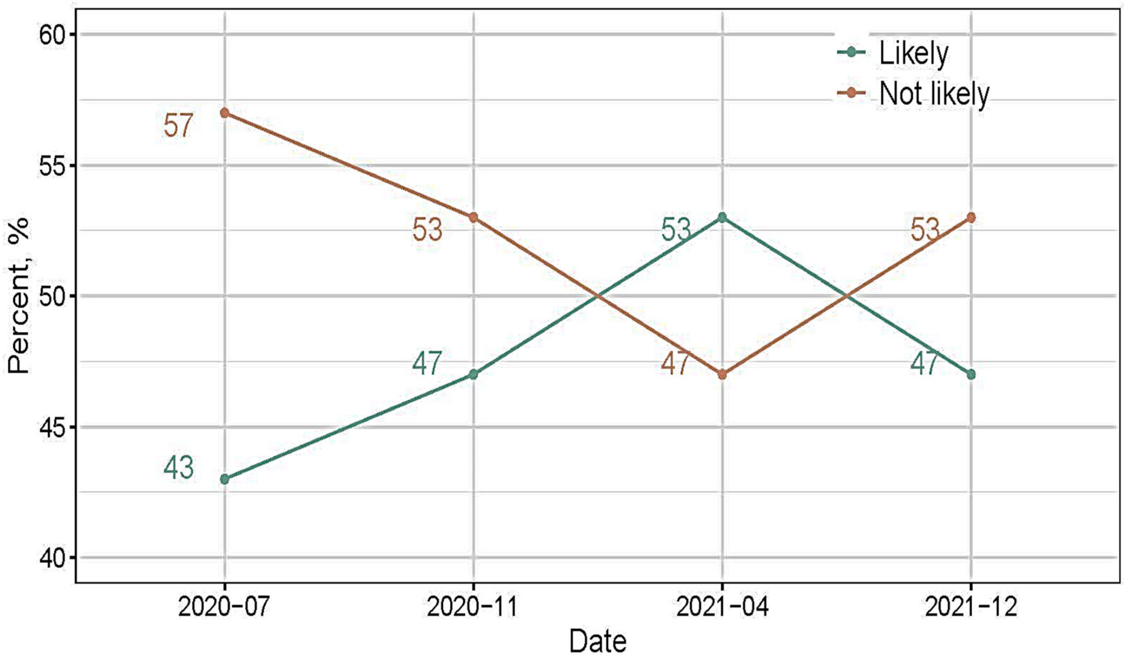

Fig. 3. Likelihood of vaccination against COVID-19. Data from [38] and original data from Ipsos study [39]

The Ukrainian-Russian war that started on February 20, 2014, mainly in the east of the country, was followed by a Russian invasion on February 24, 2022. Russian Federation troops invaded vast territories of Ukraine and created a massive military, political, and the healthcare crisis in Ukraine [42]. Problems that arose in Ukrainian healthcare include, but are not limited to, destroyed healthcare facilities, a massive number of inner migrants, an overload of remaining healthcare infrastructure with militaries and migrants, and disruption of public transport work [42]. The healthcare facilities are overloaded with patients who require acute trauma care, and there is a concern that communicable diseases will not get appropriate attention [43]. With the beginning of the massive military invasion, Ukraine faced a triple healthcare crisis: an overloaded health system, an ongoing COVID-19 pandemic, and the war.

Since the independence of Ukraine in 1991, Ukrainian society has been largely polarized; fierce debates have taken place between supporters of European integration of Ukraine and supporters of closer cooperation with Russia [44]. However, attitudes towards Russians in Ukraine have been getting worse in recent years, with a rapid deterioration after the new phase of the war [45]. Therefore, it was expected that refugees would choose to flee to European countries (Fig. 4). As of September 20, 2022, more than 7 million people fled Ukraine [46]. As shown in Figure 4, Ukrainian citizens emigrated all over Europe [46], creating what can be described as a new country inside the European Union.

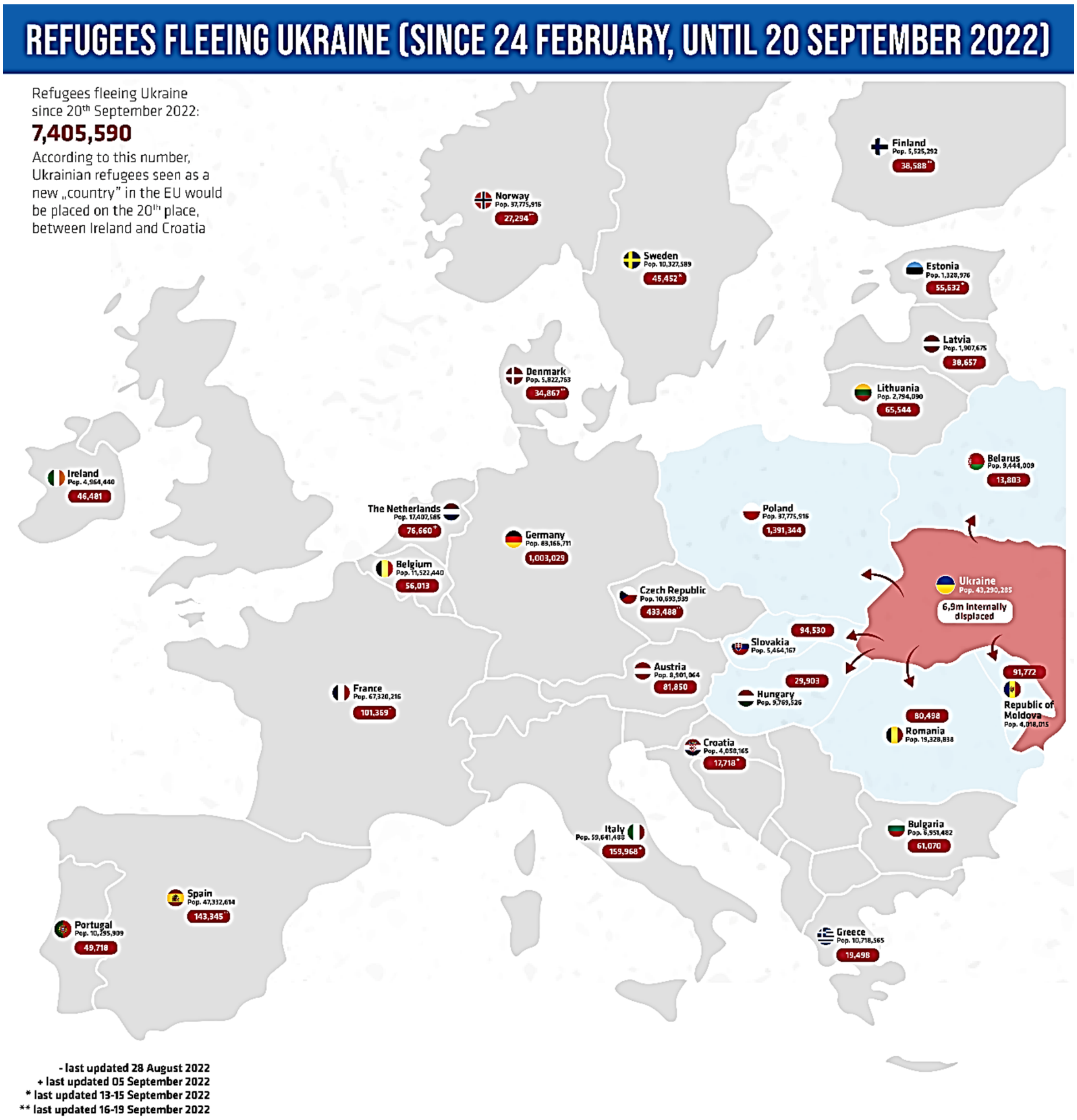

Fig. 4. The migration of Ukrainian citizens in Europe.
With more than 7 million of refugees the community may be seen as a new country inside the European Union.
Data from Ukraine Refugee Situation [45]

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The importance of innovative surveillance systems

The rapid displacement of Ukrainian residents can accelerate the spread of SARS-CoV-2 and other infectious diseases across Europe. Innovative surveillance systems might be helpful as they facilitate tracking vaccination coverage and make possible early identification of outbreaks and timely interventions [47]. Importantly, refugees from Ukraine (36% vaccination coverage) enter the European Union mainly through Eastern European countries, where the vaccination coverage is similar, and non-pharmaceutical interventions are missing [29]. This creates the risk of new outbreaks, which might be dangerous for all countries, as it increases the risk of emerging new virus variants [48].

According to WHO, increasing cases occurred after measures were lifted, even with high vaccination coverage [48]. In Western Europe, where non-pharmaceutical interventions were lifted earlier, there is an increase in COVID-19 cases, despite high vaccination coverage rates. Denmark, the first country to eliminate restrictions, has a vaccination coverage of over 80%, reported, in early March 2022, the highest mortality rate since the beginning of the pandemic [49]. Therefore, in the fourth year of the pandemic, we need to learn that enhancing the surveillance systems is essential, not eliminating them.

Genome sequencing

The pandemic has brought important opportunities to evaluate various medical interventions (from decisions to medicines and vaccines) in real life and on real people (considering everyone's knowledge, fears, and emotions). The current coronavirus disease 2019 (COVID-19) pandemic is the first to apply whole-genome sequencing in real-time. The genome of the SARS-CoV-2 coronavirus was sequenced within a month of the first case of COVID-19 disease being reported [50]. The international scientific community responded with unprecedented speed to the public health emergency. This response was made possible by massively parallel sequencing technologies, digital tools, and real-time data sharing. The costs and turnaround time of these state-of-the-art technologies have dropped significantly, and they are already routinely used in certain countries to guide public health measures [51].

The technologies we have today show great promise for the future of global health; however, it involves crucial system reforms in public health policies. According to the most recent European Centre for Disease Prevention and Control (ECDC) recommendation, whole genome sequencing, or at least complete or partial S-gene sequencing, is the best method for characterizing viral variants [52]. In a new study published in Science, a new machine learning algorithm is proposed to predict variants that have the potential to become dominant and cause outbreaks. It also allows the identification of the components of the viral genome that are most likely to mutate and thus facilitate the development of vaccines [53]. The amount of data available today and advanced processing methods allow capturing a real-time image of viral evolution in different parts of the world, which was not possible in previous pandemics and epidemics. Genomics applications are increasingly diverse, with new approaches such as wastewater surveillance [54]. These models could also be applied to monitor other viruses for which enough genetic data exists.

One of the most important lessons gained from the pandemic is bridging the gap between research and the application/development component. Testing strategies should be flexible and rapidly adaptable to changes in the epidemiological situation across the WHO European Region [55]. However, no matter how many SARS-CoV-2 genome sequences are generated, they will positively impact public health only if strategies are defined for producing and communicating usable and timely results [55]. While high-income countries could meet whole genomic sequencing targets for cases and priority groups (e.g., breakthrough infections), most low- and middle-income countries have lagged. According to a ECDC report from 2021, most E.U. countries sequenced under 1% of positive cases, below the standard required by the European Commission of 5-10% [56]. In contrast to the expected dynamics of SARS-CoV-2 evolution towards milder variants in the public perception, scientific evidence suggests that there is no guarantee that the coronavirus will evolve into less virulent variants [57]. Unfortunately, these technologies and systems will only remain in place with engagement and collaboration from all stakeholders.

The COVID-19 pandemic has accelerated digital transformation at a global scale. Genomic surveillance of the SARS-CoV-2 should become a key part of the pandemic response allowing the tracking of the new variants. In this context, in February 2021, the Romanian Centre for Innovation in Medicine published a position paper advocating for "Surveillance of SARS-CoV-2 virus through Genomic sequencing – proposal to establish the National Center for Data and Genomic Analysis for Public Health" [58]. The national or regional public health authorities or other healthcare decision-makers never discussed the proposal.

The COVID-19 pandemic has proved the importance of genomic surveillance of viral variants for public health and, at the same time, has highlighted the value of improving the infrastructure to carry out genomic sequencing, the value of expertise in genomic epidemiology and development of appropriate health policies. In this context, there is a moment of opportunity to build global genomic surveillance network dedicated to endemic or epidemic viruses. In March 2022, WHO released a a strategy to strengthen and scale up genomic surveillance around the world, which is not specific to a single pathogen or disease threat. The recommendations highlight the importance of using such technology to improve the management and surveillance of diseases that could constitute public health emergencies including cholera, Ebola virus disease, bacterial meningitis and polio [53].

Digital Intelligence

The COVID-19 infodemic has shown the magnitude of social media's impact on population health and the importance of providing relevant and timely information by authorities. Several studies from South Korea prove the benefits of using social network sites by health officials to cope with public health crises [59]. A study conducted by the University of Potsdam and the Institute of Migration (IOM) shows that multilingual social media communication campaigns can be a cost-effective method for increasing vaccination rates in marginalized populations, such as migrants [60]. The research shows that campaigns should be tailored based on understanding the characteristics of migrant groups and considering other demographic factors [60]. Analyzing how people search and navigate the Internet for health-related information and how they communicate and share it can provide valuable insights into the health-related behavior of populations (Infoveillance) [61]. If taken into consideration, social media can be a complementary surveillance system for monitoring epidemics and informing the decisions of public health officials and experts [21].

In addition, opt-in passive behavioral data measurement panels hold promise for combining surveys of affected and exposed populations with their digital behavioral footprint, including app behavior, reading, and visual consumption patterns, search patterns, and information discovery and purchase journeys. This approach has been systematically used in marketing research for the last three years. It is estimated that up to $50 billion is projected to be spent on understanding consumer digital signals by 2023 [61].

Creating or utilizing behavioral data panels will allow decision-makers to measure the effectiveness of their public health communication campaigns, understand how information, including misinformation on vaccination treatment options, is disseminated digitally, and understand information-seeking behavior across multiple demographic groups, including Internally Displaced Persons.

RESULTS AND DISCUSSION

Two major technological breakthroughs have powered our global response to COVID-19. First, advances in biomedical technologies, especially genomics, enabled the rapid detection and characterization of SARS-CoV-2 and the rapid development of different applications such as vaccines and therapies. Second, information technologies have matured, allowing real-time viral surveillance at the national, regional, and global levels.

COVID-19 has brought unique opportunities to confront long-standing issues underlying public health. Public health data systems should enable cross-sector and real-time data-sharing. Current decision-making management systems are insufficient and “only pass the baton to the next unwary generation” [1]. It is essential to re-think the role of public health and include social sciences along with medical innovation and data science. Public health should reflect the progress of the Fourth Industrial Revolution.

Given the ongoing conflict in Ukraine, ensuring the continuity of routine vaccinations and addressing gaps in prior vaccination histories is essential to public health support for displaced people. They must benefit from the same level of protection as the host country's population in terms of infectious disease prevention and control measures, including those diseases which routine vaccinations can prevent. Vaccination coverage against poliomyelitis, measles, HPV, and COVID-19 should be a priority, as well as the implementation of syndromic surveillance, mostly in reception centers in the first phase of migration [63]. As stated by Lee Jong-Wook, former Director-General of the World Health Organization (WHO), *“pandemics do not respect international borders”* [64]. Nevertheless, the limitations of this study consist in the use of the narrative framework that can be associated with relatively limited capacity to conduct to comprehensive conclusions and should be replaced with a more relevant scooping review framework.

CONCLUSIONS

1. Future COVID-19 outbreaks and new variants are anticipated. The viral genomic surveillance systems, as useful as they are and proved to be when implemented, seem to be left behind in this double new reality and permacrisis.
2. Nevertheless, under the heavy burden of migration imposed by the war, leaving communicable diseases uncontrolled would be a grave mistake. Complex adaptive system models, new tools, and the next level of health and digital intelligence are needed to provide timely and valuable insights.
3. These insights need to be drawn from diverse and rapidly expanding data sources, such as digital and passive behavioral data, social media, anonymized

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financial, mobility, and Internet of Things data. Standardized data sources and an interoperable suite of tools and response actions are critical, so decision-makers can access timely health and digital intelligence insights to support their response.

4. Combining lessons learned from the COVID-19 pandemic, the threat of war, and the need for continuous outbreaks surveillance, new public health and digital intelligence tools must be designed and implemented at regional, European, and global levels.

Contributors:

Geanta M. – conceptualization, methodology,writing – review & editing;

Cucos B. – methodology, writing – original draft;

Boata A. – writing – original draft, review & editing, project administration, supervision;

Nuta A.C., Nuta F.M. – investigation, writing – review & editing;

Semenov V.V. – formal analysis, visualisation, writing – review & editing.

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