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Authors

Fieldhouse, Jane
Nakiire, Lydia
Kayiwa, Joshua
et al.

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How feasible or useful are timeliness metrics as a tool to optimise One Health outbreak responses?

Jane Fieldhouse ,[1,2] Lydia Nakiire,[3,4] Joshua Kayiwa,[3] Claire D Brindis,[2,5] Ashley Mitchell,[2] Issa Makumbi,[3] Alex Riolexus Ario ,[6] Elizabeth Fair,[2,7] Jonna A K Mazet ,[1,2,8] Mohammed Lamorde[4]

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For numbered affiliations see end of article.

Correspondence to
Dr Jonna A K Mazet;
jkmazet@ucdavis.edu

ABSTRACT

Introduction As timeliness metrics gain traction to assess and optimise outbreak detection and response performance, implementation and scale-up require insight into the perspectives of stakeholders adopting these tools. This study sought to characterise the feasibility and utility of tracking One Health outbreak milestones across relevant human, animal, plant, and environmental sectors to systematically quantify timeliness metrics in Uganda, a country prone to outbreaks of WHO priority diseases.

Methods A database of outbreak events occurring in Uganda between 2018 and 2022 was compiled. Outbreak reports meeting our inclusion criteria were reviewed to quantify the frequency of milestone reporting. Key informant interviews were conducted with expert stakeholders to explore the feasibility and utility of tracking metrics using a framework analysis. Quantitative and qualitative data were collected and analysed concurrently.

Results Of the 282 public health emergencies occurring between 2018 and 2022, 129 events met our inclusion criteria, and complete data were available for 82 outbreaks. For our qualitative portion, 10 informants were interviewed from 7 institutions, representing the human, animal and environmental sectors. Informants agreed most One Health milestones are feasible to track, which was supported by the frequency of milestone reporting; however, there was a demonstrated need for increased reporting of after-action reviews, as well as outbreak start and end dates. Predictive alerts signalling potential outbreaks and preventive responses to alerts are seen as challenging to routinely capture, reflecting the lack of public health action for these domains.

Conclusion Despite consensus among stakeholders that timeliness metrics are a beneficial tool to assess outbreak performance, not all One Health metrics are being tracked consistently, thereby missing opportunities to optimise epidemic intelligence, preparedness and prevention. The feasibility of tracking these metrics depends on the integration of reporting channels, enhanced documentation of milestones and development of guidance for early adopters, recognising country-specific on-the-ground realities and challenges to national scaling efforts.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Studies have demonstrated that timeliness metrics can be calculated to assess speed in outbreak detection and response times, as well as inform targets for improved performance.

⇒ However, it was not well understood how feasible or useful stakeholders perceive tracking all One Health timeliness metrics to be, which has implications for the adoption of this integrated and collaborative approach.

WHAT THIS STUDY ADDS

⇒ There is consensus among stakeholders in Uganda that timeliness metrics are a beneficial tool to assess past performance in outbreak detection and response; however, predictive alerts, preventive responses and after-action review meetings are not yet being tracked.

⇒ Timeliness metrics have not yet been fully embraced as part of an integrated One Health approach, and therefore, there are missed opportunities not just to predict and possibly prevent outbreaks, but to also mount fully coordinated responses.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These real-life, real-time insights from Uganda help document that sustainable adoption of One Health timeliness metrics will depend on the integration of outbreak reporting channels and the development of guidance and capacity building to formally engage front-line workers. This effort will also require incorporating a response to the full context and realities of countries seeking to strengthen their outbreak performance efforts.

INTRODUCTION

As the threat from viral spillover and other emerging infectious diseases grows increasingly evident, countries are ramping up efforts to develop and implement innovative tools for pandemic preparedness and response. Towards this objective, the WHO developed a Research and Development (R&D) Blueprint

for Action to Prevent Epidemics to strengthen the global capacity to curb emerging epidemics faster.[1] During a 2017 R&D prioritisation exercise, the WHO added 'Disease X' to the shortlist of diseases with the highest epidemic potential and greatest public health risk. While this placeholder name represents a pathogen currently unknown to cause disease among humans, the likelihood that the disease will be zoonotic[2] reinforces that cross-cutting R&D efforts must focus on integrated and flexible pathogen-agnostic tools.

Timeliness metrics, or the analysis of speed in detection and response during health events, have been proposed as one such tool to promote monitoring and evaluation of performance during outbreaks and other health emergencies in order to optimise future outbreak surveillance and response.[3 4] In addition to studies of timeliness metrics to assess progress and identify bottlenecks in disease surveillance and response performance,[5–9] several stakeholders have proposed evaluative frameworks for timeliness metrics. Resolve to Save Lives, the New York City-based not-for-profit organisation, has proposed the '7-1-7' targets, to identify an outbreak within seven days of emergence, notify health authorities within one day and complete the initial response within seven additional days, as a timeliness framework and implementation tool.[10] The WHO Regional Office for Africa (WHO AFRO) has formally adopted the 7-1-7 indicators as a target for timeliness in their 2022–2030 Regional Strategy for Health Security and Emergencies.[11]

The same 2022–2030 WHO AFRO strategy report also calls for the adoption of a One Health preparedness and response plan informed by multidisciplinary teams across the public and private sectors.[11] Recognising that a collaborative approach across environmental, human, animal and plant health is optimal for detecting and mounting coordinated responses to outbreaks, experts convened in 2019 to expand on human health timeliness metrics by proposing a set of One Health outbreak milestones.[12] The 11 milestones outlined in the Salzburg Statement on Metrics for One Health Surveillance include response components similar to those set forth by other timeliness frameworks while also proposing several additional metrics, reflecting the importance of a multisectoral approach. The One Health timeliness metrics framework specifically proposes that (where possible) dates be captured for predictive alerts of potential outbreaks, preventive responses to early signals and joint after-action reviews among relevant stakeholders (figure 1). Adoption of these additional metrics would necessitate a truly integrated, cross-sectoral approach to disease surveillance, implemented at the national, regional, district and community levels. As a tool for pandemic preparedness, it is essential that timeliness metrics use an integrated One Health approach if they are to support the ongoing effort to anticipate and respond to Disease X.[13]

Figure 1 The One Health outbreak milestones defined by the Salzburg Global Seminar.[12] Milestones do not necessarily occur in this order or for every outbreak.

Uganda: an opportunity to assess One Health metrics

While previous studies have sought to evaluate how One Health timeliness metrics are being reported at the global level, it is not well understood how feasible it is to track these outbreak milestones and metrics at the country level. As one of the countries currently implementing the 7-1-7 targets,[14] Uganda is an ideal setting in which to study One Health timeliness metrics. In addition to stakeholders' familiarity with the objectives of timeliness metrics, the Government of Uganda (GoU) has embraced a One Health approach for epidemic preparedness, given the prevalent risk of emerging infectious diseases in the country.[15 16] Uganda's growing population combined with increased demand for agricultural practices has resulted in encroachment into wildlife and other naturally existing ecosystem habitats. Such human behaviours ultimately lead to an increased risk of spillover events, a challenge compounded by globalisation and environmental drivers of infectious diseases.[17]

As timeliness metrics continue to attract the attention of international organisations as a viable tool and framework for global health security, insights into the perspectives of the stakeholders adopting these frameworks will help provide the critical feedback needed to optimise these approaches for implementation and scale-up. We, therefore, sought to describe how the One Health outbreak timeliness milestones have been reported during recent multisectoral outbreaks in Uganda, as well as to characterise the perceived feasibility and utility of a more integrated, collaborative approach to tracking timeliness metrics as a tool to systematically and quantifiably assess outbreak performance.

METHODS

As described by Fieldhouse,[18] this study followed a convergent parallel mixed methods study design, with quantitative and qualitative data collection and analysis occurring concurrently. Quantitative analyses were conducted using outbreak reports to assess reporting frequency of One Health outbreak milestones, and qualitative interviews were conducted to explore the perceived feasibility and utility of tracking the One Health milestones and timeliness metrics among expert stakeholders. The

analysis focused on areas of convergence and divergence between findings.[19]

Quantitative study

Data sources

Investigators from Uganda's Public Health Emergency Operations Centre (PHEOC) and the Infectious Diseases Institute (IDI) at Makerere University collaborated with researchers from the University of California in the USA to develop a database of documented outbreak events in Uganda that began or were ongoing between January 2018 and December 2022. We created an electronic folder for each event as a repository for all available Situation Reports, outbreak investigation reports, and Spot Reports. Reports were provided by the Ministry of Health's (MoH) PHEOC, the coordinating body responsible for managing all information, resources and operations related to public health emergency response within Uganda.[20] Other formal GoU documentation was also compiled for review, including press releases from ministries and agencies such as the Uganda Wildlife Authority or the Ministry of Agriculture Animal Industries and Fisheries (MAAIF), International Health Regulations Notification reports, and National Task Force (NTF) meeting presentations. Our database was cross-checked against records of all PHEOC activations between 2018 and 2022 to assess completeness.

Inclusion and exclusion criteria

This study aimed to include health events which prompted PHEOC activation and were documented by the responsible government body. PHEOC activation is determined on an event-by-event basis by the Director General of Health Services based on the existing guidelines on Integrated Diseases Surveillance and Response (IDSR) thresholds.[21] These activations could occur at the alert or response level, depending on the perceived severity and magnitude of the public health event. Outbreaks had to be multisectoral, defined as involving two or more of the One Health sectors, namely humans, animals, plants or the environment. In accordance with Uganda's IDSR guidelines, an outbreak was defined as the occurrence of disease beyond normal expectancy with epidemiologically related cases within a confined period of time and space.

Given these inclusion criteria, non-multisectoral outbreaks of diseases, such as those arising from a human reservoir, including surges in measles cases, were excluded from our analysis. Disease preparedness activities for Ebola virus disease and mpox were excluded, as were natural disasters, given these events did not meet our definition of an outbreak.

Data management and analysis

A study team member reviewed all records available to find the earliest date for each of the 11 One Health outbreak milestones (figure 1).[12] In addition to recording the milestone date, we documented if a milestone was described without a date or was not mentioned at all. If different sources reported conflicting dates for a milestone, we deferred to the date recorded in the latest available PHEOC-provided report.

Other variables captured included the district and region in which the outbreak occurred, if Uganda had experience with similar outbreaks in the past and, if so, the relative frequency of the occurrence, defined as 'frequent' (>10 in the past decade) or 'infrequent' (≤10 in the past decade). Transmission route, pathogen type and status as an IDSR priority disease were recorded.[21] Data were exported to STATA V.16.0 (StataCorp) for descriptive analysis to determine the frequency of reporting of the 11 milestones as well as a bivariate screening to assess the association between covariates of interest and the outcome of a milestone date being reported. χ^2 and Fisher's exact tests of independence were conducted, followed by logistic regression to assess predictors of milestone reporting.

Qualitative study

Sampling and participants

Informants with expertise in public health emergencies in Uganda were identified and invited via email for a key informant interview from a list of professionals who previously participated in 7-1-7 timeliness workshops, convened by IDI. Purposive sampling was applied to ensure informants represented the human, animal and environmental sectors and had knowledge of different levels of the health system. Participants were contacted directly by email by a study team member. Invited contacts who agreed provided written consent to participate in a recorded interview with a trained researcher. No compensation was provided to participants.

Public involvement

Stakeholders, beyond those represented by the coauthors and anonymous interviewees, were not involved in setting the research question or data development; however, results will be disseminated to the expert participants and additional stakeholders during a PHEOC-led NTF meeting.

Interview content

30–45 min interviews were conducted and transcribed in English, using a semistructured interview guide. Topic domains included feasibility and utility of tracking One Health milestones and timeliness metrics. Interviews were conducted either in-person or remotely via teleconferencing software, depending on the preference of the informant. Mid-way through each interview, informants were shown the 11 One Health outbreak milestones with definitions and a description of timeliness metrics calculations. Participants were asked to comment from their professional perspective: '[H]ow feasible would it be to report a specific date for these milestones during an outbreak?' and 'Do you think tracking the timeliness of different outbreak steps or events could be useful in

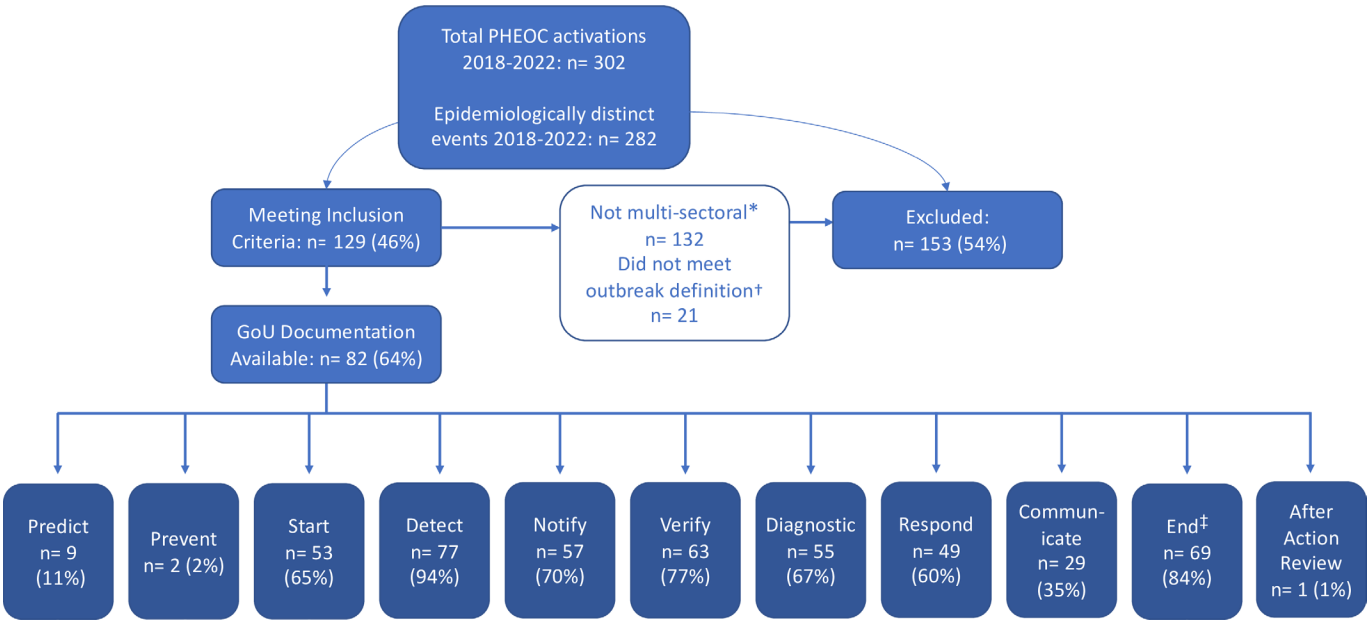

Figure 2 Flow diagram of the Uganda Ministry of Health Public Health Emergency Operations Centre (PHEOC) activations, by frequency of reporting One Health outbreak milestones. *Outbreaks involving one sector included outbreaks of measles (unless nosocomial), surges in tuberculosis, etc. †PHEOC activations for events not meeting study definition of an outbreak included natural disasters such as landslides, upsurges in endemic diseases such as malaria, elimination of mother-to-child transmission of HIV activities, and emergency preparedness activities for outbreaks that did not occur, such as mpox in 2022. ‡Three outbreaks ended in 2023. GoU, Government of Uganda.

improving outbreak responses in the long term?' (online supplemental appendix).

Framework analysis

Following familiarisation with interviews, two study team members developed a working analytical framework based on open coding of the first four interview transcripts. We then compared, revised and recoded all transcripts using a cyclical approach. In addition to inductive coding, several deductive codes were predefined based on interview questions about feasibility and utility. Codes, grouped by category, were applied to all interviews using Dedoose V.9.0.90 (SocioCultural Research Consultants, Los Angeles, California, USA, 2023). Data were charted into a framework matrix for each transcript, summarised by category along with noteworthy quotes. Data were mapped and interpreted using the framework table in Microsoft Excel, and memos were generated to describe codes of particular interest and highlight deviant cases.

RESULTS

Quantitative results

Outbreak events

Between 2018 and 2022, the PHEOC was activated 302 times for 282 epidemiologically distinct public health emergencies. Of these activations, 129 events met our inclusion criteria, constituting 21 types of health emergencies (figure 2); however, complete documentation was unavailable for 47 events (online supplemental table 1). Thus, we analysed One Health outbreak milestones for 82 outbreak events occurring in Uganda between 2018 and 2022 (figure 2). 13 different types of disease events were represented, including undiagnosed illnesses (n=5). Cholera was the most frequent outbreak, with n=22 reports included in the analysis, followed by anthrax (n=14), Crimean-Congo haemorrhagic fever (n=12) and Rift Valley fever (n=12).

Reporting of outbreak milestones

Among the documented events, the three milestone dates reported most consistently were *Detect*, with 94% of reports providing the milestone date; *Outbreak End*, with 84%; and *Verify*, with 77%. Of the dates captured for *Outbreak End*, only five were documented in the outbreak reports themselves while 93% of these dates came from the PHEOC activation database. *Respond*, *Start*, *Notify* and *Diagnostic Confirmation* milestones were all reported with an approximate frequency of 60%–70%. 35% (n=29) of reports provided a specific date of official communication to the public about the outbreak, though 33 additional outbreaks mentioned this milestone without a date, highlighting that this step is being executed but reported with low frequency (table 1).

The least reported milestones were *After-Action Review* and *Prevent*, with one report describing a date when a review meeting took place and two reports describing a date that a preventive action in response to a predictive alert occurred (table 1). *Predict* was also infrequently reported, with 11% of reports from the GoU providing a specific date of an alert signalling a potential outbreak. Of the 82 outbreaks analysed, approximately 80% (n=65) of events could have theoretically had a predictive alert based on epidemiological

Table 1 Analysis of feasibility of capturing specific dates and tracking timeliness metrics for One Health outbreak milestones as reported by ten key informants

Milestone	Reporting frequency (Total n=82)	Cross-cutting themes of perceived feasibility	Illustrative quotes
Detect: symptom onset, death or evidence of circulation observed or suspected in humans or animals	Specific date n=77 (94%) Mentioned, no date n=3 (4%) Not mentioned n=2 (2%)	Existing infrastructure facilitates capturing the date of detection, including the 6767 SMS alert notification platform under eIDSR; however, additional digitalization of reporting forms may increase tracking of this date.	*'First of all, it is feasible and doable [to report a specific date]. The way we've been doing it here, is in such a way that once there's an alert that comes from the community, whether it is an animal health alert or a human health alert, or a community disaster… These are events that are reported through our eIDSR channels, especially the 6767 SMS platform.' (KII 11)* *'Detect, of course that is something to do with how the system was able to say, 'You know what? This is something'. You can put a date on that.' (KII 7)*
Notify: outbreak reported to relevant authorities	Specific date n=57 (70%) Mentioned, no date n=3 (4%) Not mentioned n=22 (27%)	As relevant authorities must be informed to prompt a response, the *Notify* milestone necessarily always occurs and should be recordable. Several factors have improved the ease of notification and documentation, including the advent of new technology (eg, mobile phones, network accessibility, email).	*'Notification, I must say that one has been occurring faster enough, because as soon as get to know about [the outbreak] then the notification has always been first because people have access to phones, people have access to emails. So that [milestone], notification, has always not been an issue.' (KII 1)*
Verify: outbreak confirmed by field investigation or other valid method	Specific date n=63 (77%) Mentioned, no date n=10 (12%) Not mentioned n=9 (11%)	Existing infrastructure including regional EOCs and rapid deployment of District Task Forces to investigate rumours facilitates verification and consistent tracking of this milestone, among others through the reporting mechanisms of spot reports and situation reports.	*'One of the things that has helped us in tracking of the dates, or the duration of these events, is the existence of the original public health emergency operations center in West Nile which sits in Arua. And the center is able to have all this information, sieve them out… 'Spot reports' are written if the event has been verified and teams have been sent to go and respond… And thereafter, a situation report is written as the event is being contained. So that the durations or the dates in between there from when the alert came and up to when response teams go to the ground or intervening, are all tracked.' (KII 11)*
Diagnostic Confirmation*: outbreak confirmed by diagnostic test or laboratory confirmation	Specific date n=55 (67%) Mentioned, no date n=20 (24%) Not mentioned n=4 (5%)	Existing infrastructure facilitated tracking dates for diagnostic confirmation through the hub system, which requires documentation at every step of transportation and delivery of specimens to laboratories.	*'There is now…chain of custody tools around. Almost at every step a sample goes though, somebody signs. Handing over the sample, okay, picking the sample, somebody signs. Handing it over to the transport, somebody signs. You bring it to Kampala you hand it to somebody else? Sign. Until it reaches the gate.' (KII 7)*
Respond: intervention enacted in response	Specific date n=49 (60%) Mentioned, no date n=25 (30%) Not mentioned n=8 (10%)	Though the response is dependent on type of intervention required, this milestone date is considered feasible to routinely track.	*'Respond, that deserves a date because our SOPs is that people respond with… in coordination with the public health administration, so the time they say yes to something is the date.' (KII 7)*

Continued

Table 1 Continued

Milestone	Reporting frequency (Total n=82)	Cross-cutting themes of perceived feasibility	Illustrative quotes
Communication: official release of information to the public	Specific date n=29 (35%) Mentioned, no date n=33 (40%) Not mentioned n=20 (24%)	Government press releases and readily available radio airtime facilitate this milestone and easy tracking of the date for public communication.	*'You can write a date for these public communications. You write a date, because there will be a press release.' (KII 7*)
Outbreak Start: earliest epidemiologically linked symptom onset or death	Specific date n=53 (65%) Mentioned, no date n=4 (5%) Not mentioned n=25 (30%)	Reporting for this milestone could be increased if front-line workers, especially those at the facility or clinic, are trained to ask and record date of symptom onset.	*'If a health worker at facility X is informed that, actually, if you have a suspect measles patient in front of you, please note for me the date when they first showed symptoms or something like that. If that is part what the data piece they have to collect, and angle it into the system, I think that will go a long way in helping us to capture these data pieces.' (KII 4*)
Outbreak End: date that outbreak is declared closed by a responsible authority	Specific date n=69 (84%) Mentioned, no date n=1 (1%) Not mentioned n=12 (15%)	Formal declaration of the *End* date occurs more often for outbreaks perceived as high consequence (eg, VHFs declared over in a press release). The end date may be more difficult to capture for other outbreaks of diseases which are perceived as less urgent, due to some ambiguity as to when the outbreak is declared closed.	*'Many of the outbreaks, at least they normally declare the end of the outbreak, especially the VHFs, but other diseases they have ben not so much declaring the outbreak end…(W)hen you're still in that very first phase in that outbreak you find that you're meeting daily, eventually that meeting after a few days may be weekly, then monthly, then you find that the risk is no longer there or whatever, then you find… the NTF is deactivated… that seems, that marks the end.' (KII 1) 'Outbreak end - it will be on paper, even though that is on paper, but it doesn't really mean the end of outbreak in the field. Let's call it outbreak end for logistic reasons.' (KII 7*)
After-Action Review: joint review of outbreak by relevant One Health authorities	Specific date n=1 (1%) Mentioned, no date n=2 (2%) Not mentioned n=79 (96%)	To date, *After-Action Review* is an inconsistent practice which is therefore a difficult date to capture; however, international involvement has recently facilitated reviews.	*'(W)e can follow [milestones] chronologically until the outbreak ends and even take the After-Action Review. But we have not in fact been doing this one, we have been now like, it is just coming up. (KII 5)' 'So at least but at least the issue of AAR we've been doing it. Even last year…through facilitation and from TDDAP and FAO, were able to do after-action review of RVF or anthrax.' (KII 1*)
Predict: a valid predictive alert of a potential outbreak	Specific date n=9 (11%) Mentioned, no date n=8 (10%) Not mentioned n=65 (79%)	Difficult to capture dates of predictive alerts of outbreaks but increasingly possible with geographical and seasonal mapping. The feasibility of capturing this milestone will differ from outbreak to outbreak depending on context.	*'Like these predict milestones, you know there are particular disease outbreaks for which this can be applied, like the cholera outbreak which often come along with heavy rain and flooding in some parts of the country. But for a couple other outbreak conditions… it's a little difficult to track… So for the more often incidents like cholera, maybe yes, but for the vast majority of the other diseases, no.' (KII 6*)

Continued

Table 1 Continued

Milestone	Reporting frequency (Total n=82)	Cross-cutting themes of perceived feasibility	Illustrative quotes
Prevent: date that preventive action is initiated in response to the predictive alert	Specific date n=2 (2%) Mentioned, no date n=0 (0%) Not mentioned n=80 (98%)	Informants describe that it is not always possible to capture a date because dependent on *Predict* milestone, which is also not possible to consistently record a date for.	*'Yeah you can [ensure the date is reported]. Always. Except the first two. Predict and Prevent, you can't put a date, you can't put a consistent date.' (KII 2) '(T)he same for prevention, the milestone to prevent. Well, to be able to have surveillance after a predictive alert, that's in line with my first response that for the vast majority of outbreaks you don't have all that information, you know, available to facilitate such a decision.' (KII 6)*
Key. Outbreak milestones were described by participants based on feasibility of capturing a specific date as:			
Easy and feasible to routinely capture			
Easy and usually feasible to capture			
Feasible but more difficult to routinely capture			
Challenging to routinely capture			

*Dates of unsuccessful diagnostic tests were additionally described for three of the unknown illness.
AAR, After-Action Review; eIDSR, electronic Integrated Disease Surveillance and Response; EOC, Emergency Operations Centre; FAO, Food and Agriculture Organization; NTF, National Task Force; RVF, Rift Valley fever; SMS, short message service; SOP, standard operating procedure; TDDAP, Tackling Deadly Diseases in Africa Project; VHF, viral haemorrhagic fever.

considerations (eg, climate-related predictors for cholera, anthrax and vectorborne illnesses). Eight additional PHEOC reports described predictive alerts of outbreaks without providing a specific date, though none described any additional preventive actions.

Tests of association between covariates of interest and reporting of outbreak milestone dates found that outbreaks of viral haemorrhagic fevers (VHFs) had 5.3 times the odds of reporting the *Diagnostic* milestone date compared with outbreaks of non-VHFs (95% CI 1.4 to 20.9, p=0.02), 3.4 times the odds of reporting the *Start* date (95% CI 0.98 to 11.69, p=0.05) and 4.7 times the odds of reporting the *Verify* date (95% CI 1.1 to 20.3, p=0.04).

Qualitative results

Key informant interviews

Of the 23 experts invited to participate in interviews, 15 agreed to an interview and 11 scheduled one. Half of the individuals who did not respond to our request were senior ministerial officials; however, several senior officials from other institutions participated. One remote interview was interrupted due to internet connectivity and was not rescheduled. Therefore, 10 informants, 1 female and 9 males, were interviewed from 7 institutions at the regional, national and international levels of the Ugandan health system. Four informants worked primarily with the human health sector, two primarily with the animal health sector, two in laboratory sciences, one at the human-environmental health interface and one explicitly in One Health. Findings across the expert informants were highly consistent with very few deviant cases, helping to assure data saturation given the range of expertise and responsibilities captured (online supplemental appendix). In the following section, we present the results of our framework analyses by feasibility and utility.

Feasibility

Capturing specific dates for the One Health outbreak milestones was perceived as desirable across participants; however, certain milestones were described as more easily captured than others. Broadly, participants generalised it to be very feasible to capture a specific date for the *Detect*, *Notify*, *Verify*, *Diagnostic Confirmation*, *Respond* and *Public Communication* milestones. *Outbreak Start* was perceived by some as feasible and by others as challenging to identify the date of emergence. *Outbreak End* and *After-Action Review* were generally described as less feasible to capture, but possible in theory. The *Predict* and *Prevent* milestones were perceived as difficult to capture. Still, participants described ongoing efforts by the GoU to actively build the capacity to capture these two milestones, namely through tracking seasonal, weather and geographical patterns of diseases.

Table 1 describes the feasibility of capturing the specific One Health outbreak milestones, beginning with those milestones that are described by informants as easy and feasible to routinely capture (shaded green) and ending with those milestones perceived as challenging to routinely capture (shaded red).

Utility

Unanimously, participants characterised timeliness metrics as a useful tool to inform and optimise future outbreak detection and response. Descriptions of how timeliness metrics are useful fell into three broad categories: (1) learning from past outbreaks to be more prepared for future outbreaks; (2) improving communication and accountability and (3) serving as a motivator and educational tool (table 2).

While timeliness metrics are seen as a useful long-term investment in outbreak preparedness, the benefits of tracking milestones may not be immediately evident.

Table 2 Thematic analysis of the perceived utility of One Health timeliness metrics by ten key informants

Theme	Subtheme	Illustrative quotes
Learning from past outbreaks to position the health system to be more prepared for future events	Allowing stakeholders to identify gaps, barriers and enablers in the current system	*'We're able to also note what were the gaps between vet and also the human health side… So, we noticed that there had been actually a training on community-based surveillance that involved both the vet and also the human health rapid response teams that enabled them to share information promptly. So, looking at the timeliness, it actually helps us to track our enablers, the enabling factors for us to be able to detect the outbreak and also respond.'(KII 9*)
	Providing evidence on how to best allocate and mobilise resources	*'(T)imeliness is key to response. And the earlier you respond, the less the cases, or the faster you take action when you know what is happening. So, it will also help us mobilizing resources where we need them. And maybe in case we need extra support we can always use the data that we have as evidence.' (KII 10*)
	Generating data for comparative studies and evaluation of implementation projects	*'(W)e will learn from it and then… say, 'Hey, in 2018 this is what happened, in 2019 this is what happened, and then we make this kind of comparative research and findings to make us better." (KII 2*) *'Then it will also help us to be able to track the progress in terms of implementing the proposed recommendations because at the end of the day, we are able to look back and know what has been proposed… So, timeliness will actually be very key to help us track our successes in terms of our detection, tracking the different remediations that we have proposed, and also to be able to appreciate how fast we are.' (KII 9*)
Improving communication and accountability	Providing a platform to elevate messages between levels of the health system and internationally	*'Those at the national level [messages] often reach because we often have a platform to present and share with them… So maybe something that you could probably include at the national level, is often a follow-up meeting with the district staff that's where the outbreak has occurred, so that they can take on some of the response, understand what have been their weaknesses, to be able to now prepare for the next outbreak.' (KII 9*) *'Uganda is what I want to call a hub because so many countries are learning from us.' (KII 2*) Stated in the context of how timeliness metrics can contribute to the outbreak landscape.
	Increasing communication and coordination between health sectors	*'(T)he issue of the mandates will come in. If I am from the animal side, I am mandated to report mainly on them. I might keep a blind eye [to the human side]… But now with this open One Health approach, we need to report on similar issues. And even share the findings.' (KII 5*)
	Serving as a mechanism for increased accountability, including accountability in reporting	*'[Tracking timeliness is] very, very, very, very useful. Why? Because if you do not have as a system, you don't have monitoring, you can't monitor yourself that I took so many days before responding to signals A, B, C, then there's no accountability. So, if the question is usefulness, then the actual answer is a very big plus. It's very useful.' (KII 4*) *'It's supposed to flag what has not been done within the timelines, so in a sense it kind of begins to enforce or help people get used to the need to routinely report certain types of information in a timely manner.' (KII 8*)
Serving as a motivator and educational tool	Providing a learning opportunity for investigators and the next generation of health leaders	*'Yeah, people or the responders really need to see the reason why you know certain action needs to be taken when events are detected. So keeping track of those timelines targets and metrics is vital to ultimately contributing or even turning around, implicating better response in terms of timeliness.' (KII 6*) *'There are those learners who are still in school, studying their master's in public health, doing PhD programs. Now [timeliness metrics] will give them an opportunity also to come and learn.' (KII 2*)

One informant cited that the implementation of these metrics will also add work for investigators:

> In the short term a benefit may not be seen…Because it's kind of adding work onto the reporter's side. But in the long term if we want to improve our system, this will be very, very handy… So short term might not be very visible, but long term the benefits are enormous. (Public Health Information Analyst)

Additionally, informants cautioned that steps to improve timeliness during outbreaks ultimately depend on a multitude of other on-the-ground priorities:

> Even if you tracked [timeliness] there are so many barriers… If you've planned and you say that the team will leave for the field tomorrow, the team cannot leave without resources and the process to receive the money… So, I mean it is important to set the timeliness tracker and see how things are done but you need to be cognizant of the reality. (Epidemiologist)

Participants also described a perceived need for integrated reporting channels. One informant described that, at present, reporting channels are not yet designed to streamline data for use or analysis across sectors:

> I think the major thing is how feasible is it for us to match all these reporting channels. So there is what you might consider as inoperability of the different channels for reporting…Already there are two parallel channels, but can we have interoperability of the two or three…So that in the end there's somewhere they're amassed, and everyone sees the events as they come in. (Medical Lab Scientific Officer)

Despite the perceived ease of capturing seven of the eleven milestones (table 1), participants also acknowledged that routine tracking of timeliness data is not yet happening. As such, timeliness metrics are not yet being measured or analysed:

> What has been happening, is that [timeliness] is something that we have not been focusing much on, about. When an outbreak happens, we just swing into action to go and support investigating, responding, but not trying to measure the timeliness for each of the key components. (Public Health Officer)

DISCUSSION

Feasibility

The consensus among expert informants from the human, animal and environmental sectors that most One Health outbreak milestones are feasible to track is supported by the frequency of milestones documented in reports of the 82 events in this study.

Given the relatively new focus on the use of the One Health milestones, there were some reporting variations. There was a similar reporting frequency on the *Notify*, *Diagnostic* and *Respond* milestones and their perceived ease of being routinely documented. In contrast, although *Outbreak Start* was described as usually feasible to capture, participants felt slightly less confident in their documentation. If countries want to assess whether efforts to shorten the duration of an outbreak translate to better outcomes, then the *Start* and *End* outbreak milestones are two of the more critical dates to capture.

However, most informants expressed that the *Outbreak End* milestone is difficult to document. As an example, the end date for the 2022 outbreak of Ebola virus disease caused by *Sudan ebolavirus* was formally announced 42 days after the last admitted case tested negative and the last confirmed death was buried.[22] This date follows objective criteria per WHO recommendations for declaring the end of an outbreak based on interrupted human-to-human transmission.[23] Conversely, the end date for outbreaks of other diseases, including cholera and anthrax, is linked to deactivation of the response, a date not often described in outbreak reports. Even if identified retrospectively, if both *Start* and *End* dates are defined per symptomology (onset and last observed), these standardised metrics could be consistently used by countries to track their own progress in the duration of outbreaks.

A few participants expressed uncertainty about the definitions of several other milestones, including *Public Communication*, given that this step will likely occur more than once during an outbreak.

Concern regarding the subjective interpretation of milestone dates reflects the possibility of measurement bias in timeliness analyses. Indeed, the quantitative data review for this study was performed by one study member from the University of California, increasing the risk that our milestone reporting frequency is subject to measurement bias. However, the study member had previously reviewed thousands of outbreak reports for a scoping review on One Health timeliness metrics for which validation exercises for interpretation of milestone reporting and dates took place.[8] As timeliness metrics continue to be adopted globally, implementation tools such as the 7-1-7 toolkit should provide guidance and examples of milestone definitions.[24]

Descriptions ofafter-action review meetings during two interviews suggests that this milestone has taken place more than it was reported in the past 5 years. It is possible that when outbreaks slowly subside without formally being declared over, it is more difficult to set a date to convene for a review meeting. The infrequent reporting of *After-Action Review* dates may also reflect observations by informants that they are often overwhelmed by the ever-present, and sometimes concurrent, threat of outbreaks, which keep responders too busy to take advantage of calm periods (if they exist) between outbreaks to fully learn from previous crises. Globally, after-action reviews often face barriers related to concerns over cultural sensitivity, perceived finger-pointing and political response, as well as personnel constraints such as time or analytical expertise.[25] These lost opportunities for quality improvement may result in the same performance patterns being repeated over time.

As reflected in both our qualitative and quantitative findings, dates for the newer One Health *Predict* and

Prevent milestones are not yet being documented. Most informants described these milestones as challenging or not possible to capture, or only possible for certain outbreaks. Though participants describe steps in Uganda to increase tracking disease seasonality, the non-reporting of these metrics reflects the absence of documented dates due to a lack of public health action for these domains. This challenge is not unique to Uganda. Globally, we have seen insufficient political and fiscal investments in outbreak prevention, reflecting a short-term focus and failure to recognise the complex drivers of disease such as climate change, land use change and sociopolitical conflict. Together, these realities result in a heightened risk of spillover events occurring and outbreaks quickly evolving into costly epidemics and pandemics. For all countries, *Predict* and *Prevent* actions provide an opportunity to minimise human, animal and economic losses arising from outbreaks and other hazards. Greater efforts to strengthen work in this area are needed, particularly due to climate change. A 2022 study investigating transmission pathways of climate hazards found that nearly 60% of pathogenic diseases that affect humans are or can be exacerbated by climate change.[26]

In Uganda, increased rain, floods, landslides, mudslides and changes in seasonality and drought, may serve as predictors of outbreaks and can be tracked as such. The advantage of this One Health approach for timeliness was demonstrated in October 2023, when Uganda was prepared to quickly detect and respond to earlier-than-usual outbreaks of anthrax, caused by a spore-forming bacterium occurring naturally in soil, which typically peaks in January and February after heavy rains.[27] Using data from 2022, the GoU had developed seasonal calendars to identify disease patterns using weather and climate data from the Ministry of Water and Environment; soil and animal disease data from the MAAIF and the Uganda Wildlife Authority; and human outbreaks data from the MoH.[28] Observed patterns from this compiled data led to preventive action ahead of the anticipated anthrax season, including risk communication with local communities and livestock vaccination conducted by the MoH and MAAIF, respectively. Additionally, timeliness in detecting outbreaks of anthrax in the Mbale region greatly improved from 64 days in 2022 to 2 days in 2023.[28]

While this case study illustrates what can be achieved when data is triangulated across sectors, informants in our study highlighted that the feasibility of using data for timeliness metrics analysis is dependent on integrated health information systems. If reporting channels are to be integrated, these systems must be easy to operate and accessible 'on-the-go', with training opportunities and clear instructions for system users.

Lastly, despite the perceived importance of tracking timeliness metrics and feasibility of documenting milestones dates, participants cited on-the-ground realities that pose practical challenges to tracking and improving timeliness. Our findings of increased odds of reporting *Start*, *Diagnostic* and *Verify* milestone dates for outbreaks of VHFs may reflect one such country-specific reality: certain outbreaks may receive heightened attention compared with others given their perceived threat. VHFs are highly fatal and most have no known treatments. Past experience has also illustrated difficulties in bringing these outbreaks under control. We believe that contextual influences such as these warrant further investigation, as do additional factors influencing reporting on and response to multisectoral outbreaks, such as sector-specific access to funding and resources, diagnostic and laboratory considerations, health infrastructure and international or political engagement.

Utility

Several categories of utility that emerged in our framework analysis align with the general objectives of the 7-1-7 targets. Necessarily, we recognise that informants may have a biased perspective of the utility of timeliness metrics, given that we recruited participants who had previously been invited to participate in 7-1-7 workshops. Key informants interviewed for this study also did not represent all levels of the health system. However, the study participants were heterogeneous across different sectors. Their responses may be more transparent than those of senior leaders, and their perspectives may represent individuals better positioned to report on perceived strengths and limits of the framework given their first-hand experience. Due to their understanding of the proposed framework, these individuals are most likely to be early adopters of timeliness metrics, representing the best-case scenario for implementation. Those not yet exposed to the timeliness metrics framework may be less quick to embrace this change opportunity. Additional considerations for capacity building and training should consider how to incorporate evidence illustrating the effectiveness of these metrics. By naming the metrics of interest as 'One Health' during the interview, it is also possible that participants were more inclined to describe timeliness metrics in terms of coordination between health sectors.

Indeed, informants invariably expressed an interest in and appreciation for the One Health approach to both timeliness metrics and outbreak investigations more broadly. In particular, the integrated approach was described as an opportunity for increased communication and collaboration across sectors. As a tool, One Health timeliness metrics can serve as a platform to elevate messages not only between levels of the health system but also between disciplines and the public and private sectors. The *After-Action Review* milestone seems the ideal opportunity to convene stakeholders across relevant sectors and the national, regional and district levels. While beyond the scope of this assessment, the WHO has also encouraged countries to conduct intra-action reviews for protracted outbreaks when significant changes to response plans could be needed.[29]

Other timeliness metrics frameworks similarly consider review meetings as an essential component of the

implementation of timeliness metrics. By incorporating the *Predict* and *Prevent* milestones into the framework, we believe that stakeholders are more likely to approach the investigation and response with a coordinated approach in mind across environmental, animal and human sectors from the outset, rather than identifying missed opportunities for collaboration after the fact.

With data available for only 64% of the outbreak events meeting our inclusion criteria, we recognise that more robust and complete data on milestone dates will result in richer and more accurate understandings of timeliness trends. Uganda recently established a compendium of public health emergencies to address gaps in data related to these health events.[30] The compendium seeks to track the One Health outbreak milestone dates, which will allow prospective analysis of these data in the future.

Our study relied on data from a country with a great deal of experience in responding to public health emergencies and one that has already adopted timeliness targets as a monitoring and evaluation tool. Generalisability to other settings may, therefore, not be feasible. However, Uganda's experience makes it an ideal context in which to test the feasibility and explore the perceived utility of the One Health timeliness metrics. Additional testing and piloting of the framework is necessary to understand if information is captured consistently and how adaptable it is to other localities with different contexts.

This study provides evidence of consensus among a group of key stakeholders in Uganda that timeliness metrics are recognised as a beneficial tool to assess past performance in outbreak detection and response. It also points to the importance of such data for quality improvement initiatives that engage each level of outbreak responder, from community members and 'on-the-ground' front-line workers to policy-makers and health leaders at the national and international levels. Additionally, several outbreak milestones need to be reported on more frequently to allow optimal utility of these metrics, including quality improvement efforts.

IMPLICATIONS AND CONCLUSIONS

These initial results hold promise for a variety of future steps. First, with consideration within the country where the study was conducted: Uganda is prone to WHO R&D priority diseases including Crimean-Congo haemorrhagic fever, Ebola and Marburg virus diseases, and Rift Valley fever. It is also at risk for Disease X being an animal-sourced virus.[31] Consequently, Uganda would benefit from leveraging a One Health approach to address future epidemic and pandemic threats, as well as the impacts of climate change, and continuously monitor its performance in predicting, preventing, detecting and responding to these threats.

Second, findings from this study have led us to make the following recommendations regarding timeliness metrics in Uganda and more broadly for other countries positioned to adopt timeliness into existing surveillance and response frameworks:

- Timeliness metrics frameworks would potentially benefit from a collaborative and transdisciplinary One Health approach that is inclusive of animal, environmental, and human sectors, and cross-cutting in both scope and implementation.
- Global actors need to identify additional ways by which to develop guidance and toolkits that formally engage eventual consumers of these tools to help advance a coherent strategy. This implies that such resources incorporate the context and realities of countries which seek to strengthen their country-wide efforts in predictive alerts and preventive action of outbreaks.
- Using principles of community-engaged research, stakeholder trainings and other capacity-building opportunities, for example, virtual or in-person technical assistance on how best to incorporate these metrics, will need to be developed and implemented. Over time, this infrastructure can help assess, capture and share best practices for wider distribution among countries using such frameworks.
- Reminders, in the form of field prompts or reporting templates to capture timeliness milestones, can be introduced to enhance documentation of relevant metrics.
- To ensure metrics are standardised, stakeholders should agree on the most appropriate proxy dates to use for the *Start* and *End* milestones. The date of symptom onset is the most reliable available proxy date for *Outbreak Start*, and therefore, we recommend that this milestone date, as well as *Outbreak End*, be based on symptomology.
- Current outbreak reporting channels are siloed, posing challenges to tracking timeliness during outbreaks involving multiple sectors. By integrating reporting channels to create a single repository for milestone dates, which is easily accessible to all possible investigators across all ministries, agencies and institutions, may result in more complete data and facilitate analysis and use of these metrics.
- To ensure dates are reported transparently and in every instance possible, timeliness targets must be feasible to investigators given on-the-ground realities. Therefore, we recommend targets be flexible given contextual factors which may vary on a country-by-country basis.
- Beyond capturing data, planning for how to incorporate system oriented, quality-improvement initiatives, where the individual is not blamed for a particular action, but rather seen within the broader context is also necessary to fulfil the 'last mile' of implementation.

Recognising the increased training and work required on behalf of outbreak investigators to implement this framework, additional engagement with expert stakeholders at the district level will be useful in implementing the next set of programmatic efforts. Furthermore, given

that community-based surveillance is a cornerstone of rapid outbreak detection, community engagement (eg, trainings and efforts to build trust and channels of communication with volunteer community members and village health teams) will bolster timeliness and the reporting of metrics.

As shown in this study, Uganda has exemplified how timeliness metrics can be used during outbreaks through the implementation of the 7-1-7 targets. However, to achieve these targets, relevant milestones must first be routinely tracked. Furthermore, we believe that Uganda is well positioned to incorporate surveillance for One Health predictive alerts into these efforts. There is also a need to continue to support staff in their efforts to assure that they have the time to devote to incorporating the lessons learnt and to build quality improvement efforts based on these local lessons. Given the expertise of coordinating bodies, such as the National One Health Platform and the PHEOC, Uganda is likely to continue to play a leadership role as an early adopter of these additional metrics, which are critically important to a global model needed to prepare for and prevent pandemics.

Author affiliations
[1]One Health Institute, University of California Davis School of Veterinary Medicine, Davis, California, USA
[2]Institute for Global Health Sciences, University of California San Francisco Graduate Division, San Francisco, California, USA
[3]Public Health Emergency Operations Centre, Ministry of Health, Kampala, Uganda
[4]Infectious Diseases Institute, Makerere University, Kampala, Uganda
[5]Philip R. Lee Institute for Health Policy Studies, University of California San Francisco, San Francisco, California, USA
[6]Uganda National Institute of Public Health, Ministry of Health, Kampala, Uganda
[7]Division of Pulmonary and Critical Care Medicine, Department of Medicine, University of California San Francisco, San Francisco, California, USA
[8]Office of Grand Challenges, University of California Davis, Davis, California, USA

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ORCID iDs
Jane Fieldhouse http://orcid.org/0000-0002-5450-0970
Alex Riolexus Ario http://orcid.org/0000-0002-3560-1952
Jonna A K Mazet http://orcid.org/0000-0002-8712-5951

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