Family Medicine and Community Health

Setting up an epidemiological surveillance system for vaccine hesitancy outbreaks and illustration of its steps of investigation

Dewesh Kumar ,[1] Medha Mathur ,[2] Tanya Tanu,[1] Mahendra Singh,[3] Neelanjali Kumari,[1] Mansi Mathur,[4] Chandrakant Lahariya,[5] Neelesh Kapoor,[6] Archisman Mohapatra,[7] Rishabh Kumar Rana,[8] Prerna Anand,[1] Pankaj Bhardwaj[9]

To cite: Kumar D, Mathur M, Tanu T, *et al*. Setting up an epidemiological surveillance system for vaccine hesitancy outbreaks and illustration of its steps of investigation. *Fam Med Com Health* 2021;**9**:e001080. doi:10.1136/fmch-2021-001080

Received 06 May 2021
Accepted 13 July 2021

For numbered affiliations see end of article.

Correspondence to
Dr Dewesh Kumar;
dr.dewesh@gmail.com

INTRODUCTION

Vaccines are indispensable agents of the quintessential healthcare delivery system in the contemporary world and have played an unprecedented role in effectively combating vaccine preventable diseases (VPDs) in past few decades. The vehement use and advocacy of some vaccines, such as small pox and polio vaccines, has even led to the eradication of such diseases which used to wreak havoc back in their hey days. Such are the success stories of vaccination and mass immunisations that scientific experiments have taken a more biased approach towards the study of vaccines rather than studying the risk factors that cause VPDs. Even the new-age vaccinees know little about the ways of preventing the occurrence and spread of these diseases and depend entirely on immunogenic products to fight them. This in turn has led to scaling up of studies, discussions and debates on the use or misuse of vaccines and has brought vaccination programmes under the magnifying glass of the critics and the laymen alike. Thus vaccines are facing the aftermath of their own success.[1]

In context to vaccination, two groups of people were recognised earlier, the pro-vaxxers and the anti-vaxxers.[2–4] The pro-vaxxers were of the idea that vaccination for preventable diseases is imperative to curb their spread while anti-vaxxers held a stringent belief against the use of vaccines due to various religious, cultural or political determinants. Opposition to vaccination is not a new phenomenon. Since the advent of vaccines, there have been people who objected their use for various reasons across the world. The first episode of such refusal occurred in 1800s when people objected to the use of small pox vaccines. The idea of injecting someone with a vial of cow pox immunogens faced criticism on the basis of sanitary, religious and political beliefs.[5] With time, it was realised that the above concept was a continuum ranging from ardent supporters of vaccination to staunch rejecters of the same, that is, from full acceptance to outright refusal. In the middle of this continuum, a cohort of people is found which are hesitant to the use of vaccines rather than being totally pro or against it. This new phenomenon was named 'vaccine hesitancy'. Vaccine hesitancy can be of varying degrees ranging from indecision regarding specific vaccines to absolute rejection of vaccination in general.[6 7]

Such is the impact of vaccine hesitancy on our health system, that WHO has declared it as one of the 10 biggest threats to global health.[8] Vaccine hesitancy can bring all the historical achievements made in reducing the burden of VPDs down to their knees. There are various examples in literature which shows that vaccine hesitancy is quite prevalent in the communities irrespective of nature of population, ethnicity and nation boundaries.[9–17] This phenomenon has been observed in all types of vaccines regardless of route of administration, doses, make of vaccines or its side effects. This led to frequent outbreaks of various diseases in areas of low immunisation coverage and adversely affected the immunisation programme by undermining its success. Some quasi-scientific studies have also led to misinformation and scepticism, adversely influencing vaccine-seeking behaviour, which in turn ruthlessly subdues decade's worth of hard work in limiting the spread of VPDs.[18] This is most often due to assumed biological plausibility and temporal association which is

often misleading and is a unique variant of the 'post hoc ergo propter hoc fallacy'.[19] Local vaccination cultures and beliefs can also influence vaccine acceptance as was the case in a low coverage village of Pauri-Garhwal in India.[9] Another important factor determining vaccine uptake is the quality of vaccine services and their convenience viz physical availability, geographical accessibility and affordability.[20]

The three major determinants that contribute to vaccine hesitancy included complacency, convenience and confidence as per WHO Strategic Advisory Group of Experts on Immunization (SAGE) report.[21] Further various models came into being by different researchers which validated different measures to assess vaccine hesitancy.[22] Chen *et al* described the four stages of vaccine acceptance in the evolution of an immunisation programme viz, phase of increasing coverage, phase of loss of confidence, phase of redemption of confidence and finally the phase of eradication.[23] These potential stages need to be understood in the context of dynamics of the interaction of disease incidence, vaccine coverage and incidence of vaccine adverse events. And as per the stages, different mechanisms to counter vaccine hesitancy have to be formulated with focused approach.

Addressing vaccine hesitancy becomes especially mandatory in the present scenario when the world is in midst of a pandemic and incessant efforts are being made to successfully roll out the vaccination programme against COVID-19.[24] Studies in France, Israel and the USA have already predicted opposition to the vaccine even before the vaccine was launched.[25–28] One of the most important factors influencing vaccine acceptance is the level of trust the study group places in the health sector, pharmaceutical companies and the government in terms of reliability and competence. This influences vaccine-seeking behaviour.[6] The distrust was especially high in people belonging to lower socioeconomic classes, young women and senior citizens, which basically forms the high risk community.[9] Evidences over the years have underlined the influence of the political dimension of health on vaccine-seeking behaviour with people siding up with the words and notions of the political party of their choice while completely ignoring scientific explanations.[29]

Recognising the detrimental effects of vaccine hesitancy on global immunisation strategies, the WHO recommends all countries to monitor vaccine hesitancy and its proxies. This entails development of tools to detect vaccine hesitancy. Since this is a highly complex, contextual and multifactorial entity and its effect vary among populations and geographical locations, so the detection and measurement becomes quite a herculean task. Tools such as Parent Attitudes and Childhood Vaccine Survey, Vaccine Confidence Scale, Global Vaccine Confidence Index, Vaccine Hesitancy Scale, Vaccine Confidence Index, Vaccine Acceptance Scale and so on have been developed. These are more specific to high-income countries.[22 30–34] Wallace *et al* developed the Caregiver Vaccine Acceptance Scale in Ghana,[35] a low/middle-income countries but more context-specific indices which can be used for generalised comparison all over the world with uniformity and ease are need of the hour.[36]

Until, we have not been able to reliably quantify the vaccine hesitancy in the community as the degree of hesitancy varies from time to time and depends on the efforts by the community and government to curb vaccine refusal in the area. It is generally observed that a person or family is vaccine hesitant for any vaccine may develop hesitancy towards other vaccines also. The environment, political scenario and media also get influenced with the idea or rumours mongering in the community and become sensational talk for the population even without any scientific evidence or rationale behind it. This further fuels up the matters and controversies regarding vaccines and vaccination programme propagate and thus giving a blow to the adequate implementation of its roll out. Considering vaccine hesitancy as one health event in a single beneficiary family, it may further lead to outbreak in a small community, epidemic at bigger scale encompassing more areas/population and even pandemic involving two or more regions of world. The health system in coordination with public health experts may work to develop surveillance system for vaccine hesitancy in the country. So, that health system may identify the initial triggers of vaccine hesitancy in communities and take appropriate steps of communication to prevent its spread in becoming epidemic. In addition to devising tools for measurement of vaccine hesitancy, the various steps that will need to be followed while investigating a vaccine hesitancy outbreak have to be laid out before hand, so that the entire process becomes both simplified and efficient. The steps in investigating the vaccine hesitancy outbreak are illustrated in the below sections.

Verification of vaccine-hesitant population

Authenticating the information received that certain pockets are manifesting vaccine-hesitant behaviour should be the first and foremost step towards investigation. It is necessary to authenticate the information received regarding hesitancy and not to just believe the media reports or lay reports. At times it has been observed that social media is used by vaccine-hesitant lobby to spread the wrong word and influence the non-hesitant cohort. It is not mandatory to assess whole population reported to be hesitant, rather a minor sample showing hesitancy on preliminary interview would be sufficient for verification or some qualitative research methods for example, in-depth interviews with influential persons of the defined population may be applied.

Confirmation of the existence of a vaccine hesitancy epidemic

The next step is to confirm if epidemic really exists. An epidemic is said to exist when the observed frequency is in excess of the expected frequency of vaccine hesitant for that population, based on past experience. Usually statistical confirmation is not required for vaccine hesitancy as it may devour time. Vaccine coverage in that

particular geographic region based on previous immunisation records will give a direct impression of emergence of vaccine hesitancy for any particular vaccine or for overall vaccination per se. While investigating vaccine hesitancy outbreaks, we must keep in mind the two types of vaccine hesitancy that is, 'Base line vaccine hesitancy' and 'Reactive vaccine hesitancy' and accordingly we may proceed in it .[37]

Defining population at risk

Those adults/parents who are showing vaccine hesitancy and resisting the vaccination of their own/children comprise the population at risk.

To begin the investigation of such epidemic following prerequisites are essential.

Obtaining a map of the area

A recent and detailed map of the area should be procured. Usually such maps are available at the local health/nutrition centres. In case they are unavailable, a working outline of the map should be prepared. It should contain information of all vaccination sites, location of potential vaccinees' houses like houses having antenatal mothers, under 5 children and adolescents (eligible for vaccination), concerning natural landmarks and roads. Any hard to reach and isolated areas should be marked on the map. Specific segmentations of dwellings and labelling using numbers can be done.

Counting the hesitant population

The eligible population for vaccination will comprise the denominator in this case and the population showing hesitancy for vaccination will comprise the numerator of equation. Such data have to be meticulously obtained with the help of trained health workers and a proper line list of all involved is the best approach.

Rapid search and further mapping of the population in various communities

Intense finding of vaccine resistant communities and their detailed analysis needs to be done. After analysis, we need to understand the predictors for such behaviours.

Finding vaccine-hesitant cases

This can be done by analysing and comparing previous data regarding immunisation. Vaccinees who did not turn up for vaccination showed absenteeism quite often or got vaccinated only for mandates while overlooking routine immunisations will form the potential vaccine-hesitant lobby. Village or community heads can play a major role in influencing the ideas of the sections they lead. They can also help identify groups that show low vaccine uptake.

Vaccine Hesitancy Survey

This can be done using the 'Questions related to SAGE Vaccine Hesitancy Questionnaire'.[38] It is a validated and structured questionnaire and has been made to analyse the degree of vaccine hesitancy in the population under survey. The preliminary signs and symptoms of vaccine hesitancy can also be observed. These include getting vaccinated under resistance, showing up for vaccination under compulsion, disinterest in routine immunisation, condemning inconsequential side effects or affirming vaccination as unreasonable practice. Lay workers must be trained to administer such surveys and collect relevant data.

The 'Questions related to SAGE Vaccine Hesitancy Questionnaire' contains questions that are (1) context specific, such as, historic, socio cultural, environmental, health system/institutional, economic or political influences; (2) individual or group specific, such as those arising from personal experiences or those occurring in the social/peer environment; (3) vaccine/vaccination specific. If the surveyor wants to build a situation specific questionnaire which focuses better on specific deficiencies and statistics, she/he can do that too.

Deeper search

This can be done by asking the known hesitant about the people, who support, share or are influenced by their ideas of avoiding vaccination. Snowballing will help percolate the investigation deeper into the society, reaching out to such segments of the population that show vaccine refusal but have not been discovered yet. For such survey village head or community head/stakeholders can also be approached as their hesitant viewpoints may be the cause of similar attitude of other members of that community.

Data analysis and understanding the epidemiological triad of vaccine hesitancy

The data collected should be analysed so that the root cause can be meticulously identified and classified under the epidemiological triad: agent, host and environmental factors.

Agent/vaccine-specific factors

These can include vaccine efficacy perception (vaccine is not effective in limiting the disease), vaccine safety perception (vaccine is not safe enough to be administered to children, pregnant women or old age individuals) or disease susceptibility perception (vaccine increases disease susceptibility).

Host/vaccinees' specific factors

This may include education status, income status, cultural, ethnic or racial factors and the individual's personal immunisation experiences in the past. They may have been subject to rare cases of adverse effects following immunisation (AEFI) in the past which negatively influenced their vaccine-seeking behaviour.

Environmental/external factors

Unfavourable experiences with the vaccine providers, relaxed government policies, collective community behaviour of not getting vaccinated and media influences which present the vaccine in bad light through negative articles, social media posts and forwards and biased media

trials can all lead to scepticism regarding vaccine uptake thereby decreasing compliance.

The purpose of data analysis is to identify common event or experience, and to delineate the group involved in the common experience.

Formulation of hypothesis

On the basis of time, place and person distribution or the agent–host–environment model, formulate hypotheses to explain the epidemic in terms of (a) vaccine-specific factors, (b) parent-specific factors, (c) possible modes of spread of hesitancy (media and so on) and (d) the environmental or external factors which enabled it to occur. These hypotheses should be placed in order of relative likelihood. Formulation of a tentative hypothesis should guide further investigation.

Testing of hypothesis

The formulated hypothesis cannot be tested using routine procedures because vaccine hesitancy is multifactorial in causation. So, all plausible theories need to be laid down and tested schematically.

Evaluation of ecological factors

An investigation of the circumstances involved should be carried out to undertake appropriate measures to prevent further emergence and spread of hesitancy among the parents. All the factors which lead to vaccine hesitancy epidemic should be investigated and their conceivable solutions should be provided to the community. Primary causes like fear of side effects, cost of vaccines, religious causes, influence of social media and other sources emphasising the non-acceptance of vaccines should be dealt.

Further investigation and formulation of communication plan

A detailed assessment of the population at risk including those who are in support of getting vaccinated should be done. These groups should be encouraged and appreciated. Discussions should be held with such groups to come up with innovative ideas to promote vaccine compliance among the vaccine-hesitant groups. All findings should be charted while laying special emphasis on the major challenges that need addressal.

DISCUSSION

Having deftly outlined the steps involved in investigation of a vaccine hesitancy outbreak (box 1), the next important step will be to appoint or establish a committee that shall monitor these investigations. A Vaccine Hesitancy Technical Group should be established at national level with involvement of all major stakeholders (eg, representatives from beneficiary, subject experts, researchers, administration, media, human rights, law and the government) in all countries to promote and support effective surveillance. To promote vaccination and counter vaccine hesitancy, a vaccine portal should be started in all countries which will serve as a repository for vaccine related information and research on various vaccine preventable diseases. Also the regional technical advisory groups may be formed to help identify specific regional challenges of vaccine hesitancy and define priorities.

Box 1 Steps of investigation of vaccine hesitancy outbreaks

- Verification of vaccine-hesitant population.
- Confirmation of the existence of a vaccine hesitancy epidemic.
- Defining the population at risk.
- Rapid search and further mapping the population in various communities.
- Data analysis and understanding the epidemiological triad of vaccine hesitancy.
- Formulation of hypothesis.
- Testing of hypothesis.
- Evaluation of ecological factors.
- Further investigation and formulation of communication plan.

With more and more vaccines being included in the National Immunisation Schedule, the overall distrust towards vaccines has increased in various parts of world. Once vaccine hesitancy creeps into the population, it takes considerable time and effort to gain back confidence of the community to that particular vaccine. Rare and coincidental episodes of AEFI prove to be the icing on the cake with prejudiced media coverage serving as the cherry on top. Country like India which is the biggest supplier of vaccines in the world needs to focus largely on eliminating vaccine hesitancy because if not checked this can largely effect vaccine economy as well. To combat vaccine hesitancy, interdisciplinary approach is needed where public health specialists, communication experts, social scientists, policy makers, clinicians may come to a common platform and devise an effective, efficient and robust tool.[39] Furthermore, research is definitely needed in developing proper physician communication skills especially in primary healthcare settings.[2] Keeping the above discussion in mind, we understand that we cannot stress enough on the importance of addressing vaccine hesitancy as it is a sensitive and complex domain and requires great care and precision. With great success, comes great responsibility. The global success of vaccination in the contemporary world is commendable and like everything else, vaccination has brought along the baggage of vaccine hesitancy and this uninvited baggage needs skillful negotiation. As long as the concept of vaccination exists, the concept of vaccine hesitancy shall persist. We can limit its spread through proper measures and healthy balance. This shall help health of humanity flourish.

Author affiliations
[1]Department of Preventive and Social Medicine, Rajendra Institute of Medical Sciences, Ranchi, Jharkhand, India
[2]Department of Community Medicine, Geetanjali Medical College and Hospital, Udaipur, Rajasthan, India
[3]Community Medicine and Family Medicine, All India Institute of Medical Sciences-Rishikesh, Rishikesh, Uttarakhand, India
[4]Surveillance, Immunization Technical Support Unit, New Delhi, India
[5]Foundation for People-centric-Health Systems, New Delhi, India
[6]Orbi Health, New Delhi, Delhi, India

[7]Generating Research Insights for Development (GRID) Council, Noida, Uttar Pradesh, India
[8]Preventive and Social Medicine, Shaheed Nirmal Mahto Medical College, Dhanbad, Jharkhand, India
[9]Community Medicine and Family Medicine, AIIMS Jodphur, Jodhpur, Rajasthan, India

Twitter Chandrakant Lahariya lahariyac Chandrakant lahariya@DrLahariya and Rishabh Kumar Rana @Ran1kr

Acknowledgements We acknowledge the previous works on vaccine hesitancy of all researchers of world.

Contributors DK conceived and conceptualised the intellectual content of the paper. MeM, TT and NKu performed literature search and reviewed them. MS, PB, NKa and MaM contributed to the design and drafted the manuscript. CL, AM, RKR, PA and MeM critically analysed the content. All authors read, revised and approved the final version of the manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Disclaimer The opinions expressed in this paper are solely attributable to the author and should not be attributed to any institution/organisation he has been affiliated in the past or at present.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

ORCID iDs
Dewesh Kumar http://orcid.org/0000-0001-5356-801X
Medha Mathur http://orcid.org/0000-0001-9539-5890

REFERENCES

1 Shen SC, Dubey V. Addressing vaccine hesitancy: clinical guidance for primary care physicians working with parents. *Can Fam Physician* 2019;65:175–81.
2 Reuben R, Aitken D, Freedman JL, *et al*. Mistrust of the medical profession and higher disgust sensitivity predict parental vaccine hesitancy. *PLoS One* 2020;15:e0237755.
3 Omer SB, Salmon DA, Orenstein WA, *et al*. Vaccine refusal, mandatory immunization, and the risks of vaccine-preventable diseases. *N Engl J Med* 2009;360:1981–8.
4 Betsch C. Innovations in communication: the Internet and the psychology of vaccination decisions. *Euro Surveill* 2011;16:pii=19849.
5 Saint-Victor DS, Omer SB. Vaccine refusal and the endgame: walking the last mile first. *Philos Trans R Soc Lond B Biol Sci* 2013;368:20120148.
6 Kumar D, Chandra R, Mathur M, *et al*. Vaccine hesitancy: understanding better to address better. *Isr J Health Policy Res* 2016;5:2.
7 World Health Organization. Improving vaccine demand and addressing vaccine hesitancy. Available: http://www.who.int/immunization/programmes_systems/vaccine_hesitancy/en/ [Accessed 29 Sep 2020].
8 The Lancet Child Adolescent Health. Vaccine hesitancy: a generation at risk. *Lancet Child Adolesc Health* 2019;3:281.
9 Krishnamoorthy Y, Kannusamy S, Sarveswaran G, *et al*. Factors related to vaccine hesitancy during the implementation of Measles-Rubella campaign 2017 in rural Puducherry-A mixed-method study. *J Family Med Prim Care* 2019;8:3962–70.
10 Giambi C, Fabiani M, D'Ancona F, *et al*. Parental vaccine hesitancy in Italy - Results from a national survey. *Vaccine* 2018;36:779–87.
11 Cunningham RM, Minard CG, Guffey D, *et al*. Prevalence of vaccine Hesitancy among expectant mothers in Houston, Texas. *Acad Pediatr* 2018;18:154–60.
12 Sankaranarayanan S, Jayaraman A, Gopichandran V. Assessment of vaccine Hesitancy among parents of children between 1 and 5 years of age at a tertiary care hospital in Chennai. *Indian J Community Med* 2019;44:394–6.
13 Mohd Azizi FS, Kew Y, Moy FM. Vaccine hesitancy among parents in a multi-ethnic country, Malaysia. *Vaccine* 2017;35:2955–61.
14 Alabbad AA, Alsaad AK, Al Shaalan MA, *et al*. Prevalence of influenza vaccine hesitancy at a tertiary care hospital in Riyadh, Saudi Arabia. *J Infect Public Health* 2018;11:491–9.
15 Agrawal A, Kolhapure S, Di Pasquale A, *et al*. Vaccine Hesitancy as a challenge or vaccine confidence as an opportunity for childhood immunisation in India. *Infect Dis Ther* 2020;9:421–32.
16 Miko D, Costache C, Colosi HA, *et al*. Qualitative assessment of vaccine Hesitancy in Romania. *Medicina* 2019;55:282.
17 Alsuwaidi AR, Elbarazi I, Al-Hamad S, *et al*. Vaccine hesitancy and its determinants among Arab parents: a cross-sectional survey in the United Arab Emirates. *Hum Vaccin Immunother* 2020;16:3163–9.
18 Rao TSS, Andrade C. The MMR vaccine and autism: sensation, refutation, retraction, and fraud. *Indian J Psychiatry* 2011;53:95–6.
19 Stolle LB, Nalamasu R, Pergolizzi JV, *et al*. Fact vs fallacy: the Anti-Vaccine discussion Reloaded. *Adv Ther* 2020;37:4481–90.
20 Kumar D, Noor N, Kashyap V. Vaccine hesitancy - Issues and possible solutions. *J Med Allied Sci* 2018;8:55–8.
21 World Health Organization. Report of the SAGE Working group on vaccine Hesitancy, 2014. Available: http://www.who.int/immunization/sage/meetings/2014/october/1_Report_WORKING_GROUP_vaccine_hesitancy_final.pdf [Accessed 30 Sep 2020].
22 Betsch C, Schmid P, Heinemeier D, *et al*. Beyond confidence: development of a measure assessing the 5C psychological antecedents of vaccination. *PLoS One* 2018;13:e0208601.
23 Chen RT, Rastogi SC, Mullen JR, *et al*. The vaccine adverse event reporting system (VAERS). *Vaccine* 1994;12:542–50.
24 World Health Organization. The push for COVID-19 vaccine. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines [Accessed 15 Sep 2020].
25 COCONEL Group. A future vaccination campaign against COVID-19 at risk of vaccine hesitancy and politicisation. *Lancet Infect Dis* 2020;20:769–70.
26 Harrison EA, Wu JW, Julia WW. Vaccine confidence in the time of COVID-19. *Eur J Epidemiol* 2020;35:325–30.
27 Dror AA, Eisenbach N, Taiber S, *et al*. Vaccine hesitancy: the next challenge in the fight against COVID-19. *Eur J Epidemiol* 2020;35:775–9.
28 Sprengholz P, Betsch C. Herd immunity communication counters detrimental effects of selective vaccination mandates: experimental evidence. *EClinicalMedicine* 2020;22:100352.
29 Power LE. The politics of vaccination: a global history. *Emerg Infect Dis* 2018;24:2135.
30 Thomson A, Robinson K, Vallée-Tourangeau G. The 5As: a practical taxonomy for the determinants of vaccine uptake. *Vaccine* 2016;34:1018–24.
31 Opel DJ, Taylor JA, Zhou C, *et al*. The relationship between parent attitudes about childhood vaccines survey scores and future child immunization status: a validation study. *JAMA Pediatr* 2013;167:1065–71.
32 Gilkey MB, Reiter PL, Magnus BE, *et al*. Validation of the vaccination confidence scale: a brief measure to identify parents at risk for refusing adolescent vaccines. *Acad Pediatr* 2016;16:42–9.
33 Shapiro GK, Holding A, Perez S, *et al*. Validation of the vaccine conspiracy beliefs scale. *Papillomavirus Res* 2016;2:167–72.
34 Sarathchandra D, Navin MC, Largent MA, *et al*. A survey instrument for measuring vaccine acceptance. *Prev Med* 2018;109:1–7.
35 Wallace AS, Wannemuehler K, Bonsu G, *et al*. Development of a valid and reliable scale to assess parents' beliefs and attitudes about childhood vaccines and their association with vaccination uptake and delay in Ghana. *Vaccine* 2019;37:848–56.
36 Oduwole EO, Pienaar ED, Mahomed H, *et al*. Current tools available for investigating vaccine hesitancy: a scoping review protocol. *BMJ Open* 2019;9:e033245.
37 World Health organization. Vaccine Hesitancy survey questions related to SAGE vaccine Hesitancy matrix. Available: https://www.who.int/immunization/programmes_systems/Survey_Questions_Hesitancy.pdf [Accessed 30 Sep 2020].
38 Wiyeh AB, Cooper S, Nnaji CA, *et al*. Vaccine hesitancy 'outbreaks': using epidemiological modeling of the spread of ideas to understand the effects of vaccine related events on vaccine hesitancy. *Expert Rev Vaccines* 2018;17:1063–70.
39 Harrison EA, Wu JW. Vaccine confidence in the time of COVID-19. *Eur J Epidemiol* 2020;35:325–30.