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Perspective

Ebola Vaccine — An Urgent International Priority

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With the Ebola epidemic in West Africa continuing to grow, the World Health Organization (WHO) convened an urgent meeting on September 29 and 30 to assess the efforts under way to evaluate and produce safe and effective Ebola vaccines as soon as possible.[1] The 70 scientists, public health officials, and representatives from industry and regulatory bodies who gathered in Geneva discussed two vaccine candidates at length — cAd3-EBOV (cAd3), from GlaxoSmithKline (GSK) and the U.S. National Institute of Allergy and Infectious Diseases (NIAID), and rVSVΔG-EBOV-GP (rVSV), from NewLink Genetics and the Public Health Agency of Canada. Several other vaccine candidates are at earlier, preclinical stages in the development pipeline.

Phase 1 studies of cAd3 have begun in the United States and the United Kingdom, and researchers plan to begin enrollment for trials of rVSV soon. Both vaccine candidates have demonstrated 100% efficacy in studies in nonhuman primates,[2,3] but how that will translate to human subjects remains unknown. The phase 1 trials of both vaccines use dose–response designs structured to determine the level of humoral and cellular immunity that can be induced. The minimum antibody titer needed to confer protection in humans is unknown. Because of the small numbers of participants in these trials, they will provide data only on common adverse events.

The cAd3 vaccine is being tested in both bivalent (ClinicalTrials.gov number, NCT02231866) and monovalent (NCT02240875) forms; the monovalent form is based on the Zaire strain of Ebola virus, which is the cause of the current West African epidemic, and the bivalent form includes the Sudan strain of the virus as well (see Fig. 1). The monovalent form will be evaluated in a nonrandomized, open-label study involving 60 adult volunteers who will receive the vaccine at three different doses (1×10^{10} vp, 2.5×10^{10} vp, and 5×10^{10} vp). The bivalent form will be evaluated in a nonrandomized, open-label study involving 20 adult volunteers who will receive the vaccine at two different doses ($2\text{x}10^{10}$PU and $2\text{x}10^{11}$PU). Both studies will assess safety, side effects, and immunogenicity, including antibody responses as measured by enzyme-linked immunosorbent assay (ELISA) and neutralization assays and T-cell immune responses as measured by intracellular cytokine staining. Investigators anticipate that pre-

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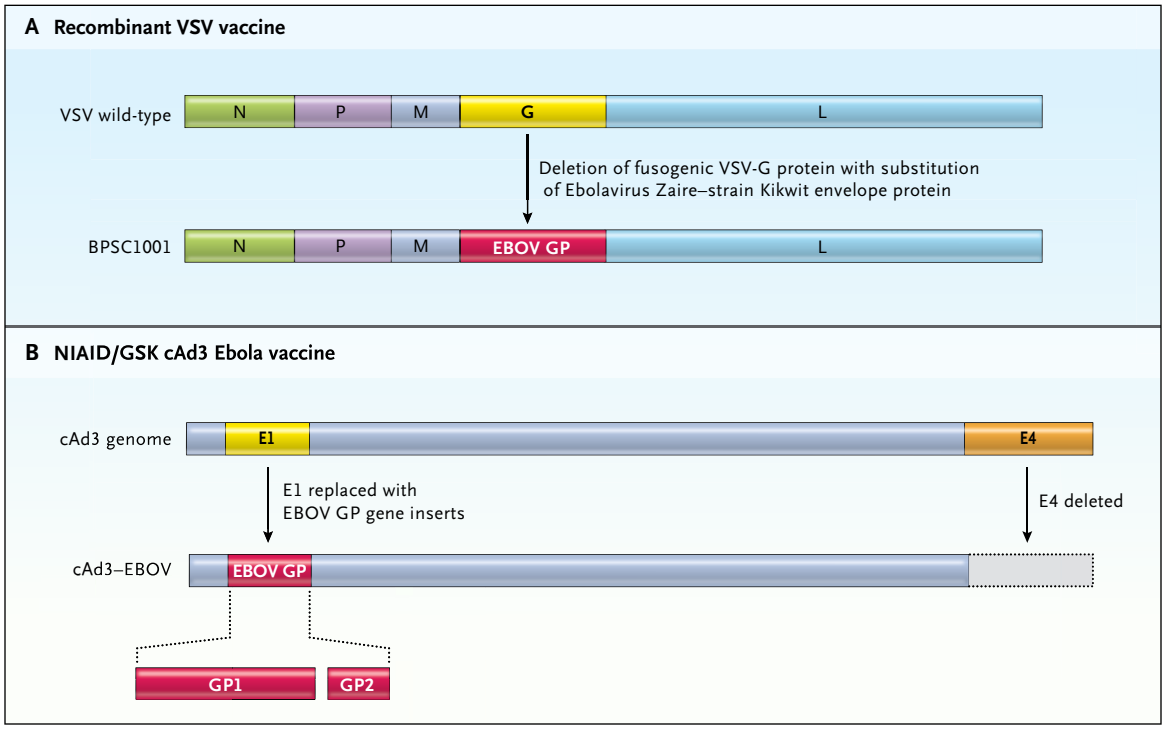

Figure 1. Structures of Ebola Vaccine Candidates rVSV (Panel A) and cAd3 (Panel B).

liminary immunogenicity and safety data will be available by November.

The first phase 1 trial of the rVSV vaccine is slated to begin soon in the United States. Ideally, the immunogenicity outcomes in this trial will be compared with those obtained with the GSK–NIAID vaccine. The government of Canada has donated 800 vials of rVSV to the WHO, and discussions about expanding phase 1 trials to European and sub-Saharan African sites are at an advanced stage.

Participants in the Geneva meeting stressed that phase 1 trials should be expedited and their results shared broadly in order to facilitate rapid progression to phase 2. If the results in phase 1 are favorable, the consensus was that phase 2a studies should be conducted in Africa but outside the current Ebola outbreak zone and should proceed in parallel with phase 2b studies conducted in exposed populations. This approach will provide robust efficacy and safety data as quickly as possible. Results from phase 2a trials in unexposed populations would inform the use of these vaccines in expanded populations, including children and people who are HIV-positive. The phase 2b trials in exposed populations would enroll people who are at the highest risk for Ebola virus disease, including frontline workers at Ebola treatment facilities.

The design of these proposed trials in exposed populations raises many complex questions that pit issues of scientific rigor against feasibility and acceptability. Since there are no data on the efficacy of Ebola vaccines in humans, equipoise justifies the use of a randomized, controlled trial. Yet though it's clear that well-designed randomized, controlled trials would generate the most reliable and robust data regarding vaccine efficacy, the feasibility of such studies may be affected by the same fear and resistance to interventions that communities have evinced in the West African epidemic to date. The trials therefore need to be designed with participation from local governments and communities so that they can proceed in a manner that is acceptable to the affected populations. The consensus at the Geneva meeting was that there are reasonable alternatives if individually randomized, controlled trials are not acceptable in some settings — for example, studies using a stepped-wedge design (see Fig. 2). A basic principle of every study design should be that all participants will receive Ebola vaccine at some point. There was also agreement that health care workers who care for patients with Ebola or are otherwise exposed to patients' body fluids in hospitals and clinics, family members

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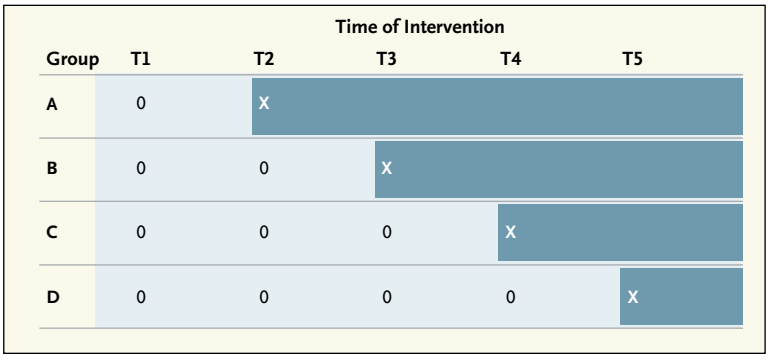

Figure 2. Stepped-Wedge Study Design Schematic.

Participants are randomly assigned to receive the intervention at one of several times. Outcomes in each group are measured at each step. X denotes the intervention, and O control treatment.

caring for patients with Ebola at home, and people who cleanse and bury deceased patients should be among those given the opportunity to participate in the early phase 2 trials.

Representatives of regulators and ethics committees in Africa as well as of the U.S. Food and Drug Administration and the European Medicines Agency were at the meeting and agreed to work with industry and researchers to accelerate the evaluation, licensure, and availability of the candidate vaccines. The regulators stressed that rigorous standards for clinical safety and efficacy will be applied. Another WHO-arranged meeting is planned for November to reevaluate the next necessary steps once preliminary results from the phase 1 trials are available.

Even if adequate safety and immunogenicity are demonstrated in the phase 1 studies, vaccines will not be available in substantial quantity until the first quarter of 2015 at the earliest. For that to occur, funding must be secured for production. Even if an effective vaccine can be produced, it is not likely to be 100% effective, so to succeed in stemming the current outbreak, a coordinated effort to improve capacity and provide clinical care in affected countries needs to be scaled up urgently.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

Dr. Kanapathipillai is an editorial fellow at the *Journal*. Other authors are from the World Health Organization, Geneva.

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1. Experimental Ebola vaccines: WHO consultation on Ebola vaccines. Geneva: World Health Organization, October 1, 2014 (http://who.int/mediacentre/news/ebola/01-october-2014/en/).
2. Stanley DA, Honko AN, Asiedu C, et al. Chimpanzee adenovirus vaccine generates acute and durable protective immunity against Ebolavirus challenge. Nat Med 2014 September 7 (Epub ahead of print).
3. Geisbert TW, Geisbert JB, Leung A, et al. Single-injection vaccine protects nonhuman primates against infection with Marburg virus and three species of Ebola virus. J Virol 2009;83:7296-304.

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