HY-10 Vaccination with no factory: variolation, arm-to-arm, rabies and what is honestly possible

HEALING after the FALL, research library, HY-10

Researched 10 October 2026 by Claude Opus agent for THRIVING after the FALL, Book Four. Library document, unverified.

How to read this report

This is the one report in the library that ends mostly in refusals. The honest answer to "can we make our own vaccine" is no, and the record of those who tried without a factory is a record of children killed in batches. What is left is smaller but real: a stockpile that keeps longer than its label says, a cellar that is not a refrigerator but beats a shelf, a list of which diseases return and when, a wound drill that saves lives from rabies with no vaccine at all, and an order for the last doses. My own inferences carry [VERIFY]. IN-12 covers measles, whooping cough and diphtheria and WO-14 covers tetanus, and this report builds on both rather than repeating them.

Findings by section

1. What the Fall removes, and what it leaves

Vaccination is four technologies, not one: a way to obtain a weakened or killed organism or a toxoid, a way to test every batch for both potency and safety, a cold chain from bench to arm, and enough arms to break transmission. The first three need a laboratory with animals, incubators, assays and a clean room. The fourth needs only hands and a register. A village of 300 can do the fourth and cannot do the first three. Every improvised attempt at the first three that I could find ended in deaths caused by the preparation rather than the disease. What survives the Fall is knowing who is susceptible, isolation, the rabies wound drill, the shake test, and a stockpile more durable than most people assume.

2. Variolation: what it cost and what it bought

What the tradition said. Deliberate infection with smallpox from a mild case, to produce a mild case. In China the method was nasal insufflation of dried, aged scab powder from mild donors. Wan Quan's *Douzhen Xinfa* of 1549 is usually given as the first clear Chinese reference, though it describes no technique, and Needham's date of 1567 to 1572 rests on a text written in 1808 (Wikipedia, Variolation and Inoculation, search summaries). Claims of a tenth-century origin are weakly supported. In West Africa, the Sudan, India and the Ottoman lands the route was skin insertion. The practice reached Boston in 1721 because Onesimus, an enslaved West African man in Cotton Mather's household, described it from his own country (Rush University, search summary).

What the record shows. Lady Mary Wortley Montagu, wife of the British ambassador at Constantinople, described the Ottoman practice in a letter dated 1 April 1717 and had her son inoculated there with the surgeon Charles Maitland (The Conversation 2021, search summary). In August 1721 six or seven condemned prisoners at Newgate were inoculated under royal warrant in exchange for pardon and all survived. Sources differ on the number and on the

follow-up test in which one woman was said to have nursed smallpox for six weeks unharmed, which I could not confirm [VERIFY].

Boston holds the numbers that matter. Zabdiel Boylston, encouraged by Mather, inoculated between 247 and 287 people and six died, against about one in seven among those who caught smallpox naturally in the same epidemic. Boylston's own summary was roughly 2 per cent against 14 per cent (Massachusetts Historical Society 2020, Wikipedia 1721 Boston smallpox outbreak, search summaries). Sources give the inoculated rate as 1, 2, 2.4 or 2.5 per cent, the same small numerator over slightly different denominators. The epidemic infected 5,759 of about 10,600 Bostonians and killed 844 between April 1721 and February 1722. This was not a trial, since Boylston chose his patients and the comparison was the whole town, but the gap was far too large to be selection alone.

Risk fell further in the next century. Mark and Rigau-Pérez (2009), reading Razzell, state that against 15 to 33 per cent mortality for natural smallpox, late eighteenth-century inoculation killed under one fifth of one per cent, one hundred to two hundred times lower. The improvement is credited to the Suttonian method, a shallower insertion with a smaller inoculum and less purging, sold commercially from the 1760s. I could not read Razzell, so that figure rests on one secondary citation [VERIFY]. Davenport and colleagues contest his wider claim, arguing that in London and Manchester after 1770 inoculation was insufficient to reduce urban smallpox mortality (Davenport et al. 2015, search summary).

What modern science infers. Variolation worked because the dose and route were wrong for the virus: a small skin dose raises a systemic response before the virus reaches the airway in force. Fenner and colleagues (1988) remain the standard account, and I could not read it, because the chapter PDF I located is a scanned image with no text layer and no renderer was available.

The decisive objection, then and now. A variolated person has real smallpox and is infectious. Francisco Gil in Madrid in 1784 argued exactly this, that inoculation spread the disease and risked blindness, disfigurement or death in someone who might never have caught it (cited in Mark and Rigau-Pérez 2009), and Boylston's critics said that if an inoculated person died he was a murderer. Both are correct on their own terms. Grade **B** for individual protection, **X** as a public measure.

3. Jenner 1796, and what the Inquiry actually showed

On 14 May 1796 Edward Jenner put fluid from a cowpox lesion on the hand of the milkmaid Sarah Nelmes into two small incisions on the arm of James Phipps, aged eight. Phipps had a mild illness. On 1 July 1796 Jenner variolated him and nothing happened, and a later challenge gave the same result (Wikipedia, James Phipps, search summary, which gives 17 May for the first step, so sources differ).

The *Inquiry* of 1798 is seventy-five pages holding twenty-three case reports, mostly observational: people who had had natural cowpox and then resisted variolation. The deliberate smallpox challenges Jenner actually performed numbered three (Morabia 2018, search summary and abstract). Cases XX to XXIII showed the material could pass from child to child, which is the basis of everything that followed. The founding evidence for vaccination was therefore a handful of challenges in one country practice. It was enough because the effect was enormous and was replicated across Europe within two years. It was not enough to show safety, and the next century proved it. Grade **A** on later evidence, **D** on what Jenner himself published.

4. The arm-to-arm chain: Balmis, and why it ended

Jenner's material would not survive a sea voyage, so the infection was kept alive in a chain of human beings. The Royal Philanthropic Vaccine Expedition sailed from Corunna in November 1803 under Francisco Xavier de Balmis, approved by Carlos IV in June 1803 (Mark and Rigau-Pérez 2009, read in full). Twenty-two non-immune foundling boys aged three to nine carried the vaccine across the Atlantic by serial arm-to-arm inoculation, with fresh children recruited at each stop, and Isabel Zendal, matron of the Corunna foundling home, travelled with them.

Sixty-two children took part in the various voyages and four died, 6 per cent. The expedition vaccinated about 100,000 people in New Spain, perhaps 20 per cent of those who might have benefited, while Manuel Grajales claimed over 400,000 personally across nearly a decade. Two adult staff died on duty, Pedro Ortega and the vice-director José Salvany, who died at Cochabamba in July 1810. In Venezuela more than 12,000 were vaccinated in under a month and the first central vaccination board was founded in 1804.

Three findings bear on the Fall. First, the chain is a tyrant: because the vaccine lived only in arms, susceptible people had to be held back as future carriers, so universal coverage was impossible, and when volunteers ran out staff coerced them. Ten soldiers were procured by the governor at Veracruz in July 1804, twelve people compelled in Mexico City in August, then twenty Indian women dragged in. Second, the chain dies without institutions. Balmis founded vaccination boards to keep chains and registers running, and the authors are blunt that local physicians were expected to maintain the chain without support from an impoverished state, so that in some places vaccine became unavailable shortly after its introduction. The wars of independence killed many boards. Third, the chain carried more than cowpox. Mark and Rigau-Pérez state that Balmis and his contemporaries, until about 1814, failed to see that arm-to-arm transmission also moved erysipelas, syphilis and hepatitis. Balmis wrote to Madrid in February 1807 that vaccine caused not the least harm or risk. He was wrong.

Rivalta, 1861. A child at Rivalta in Piedmont was vaccinated in May with lymph from Acqui. On 7 June forty-six healthy children were vaccinated from that child at one sitting, and on 12 June seventeen more from one of the forty-six. Giacinto Pacchiotti of Turin, asked by the government to investigate, reported that forty-six of the sixty-three contracted syphilis with their vaccination, thirty-nine from the first group and seven from the second. Modern reviews give forty-four of sixty-three and the Wikipedia vaccinia article gives forty-one. Several children died and some infected their mothers and nurses (Pacchiotti 1862 via nineteenth-century reviews and Esposito et al. 2015, search summaries. I did not read Pacchiotti). Britain banned arm-to-arm vaccination in 1898 and replaced it with calf lymph. Grade **B** for carrying immunity across oceans, **X** as a practice to revive, because the syphilis and hepatitis cannot be prevented without serology.

5. Pasteur 1885, and the price of nerve-tissue rabies vaccine

On 6 July 1885 Louis Pasteur, who was not a physician, began treating Joseph Meister, aged nine and bitten by a rabid dog, with injections of rabbit spinal cord dried for progressively shorter times, thirteen or fourteen injections over ten days by various accounts. Meister lived, as did Jean-Baptiste Jupille, a shepherd bitten on 20 October that year (Institut Pasteur, search summary). *Nature*'s contemporary report says 2,496 people had been inoculated in Paris to 31 October 1886, and that of about 1,700 French patients, apart from two who arrived too late, only ten died. Another review gives 2,682 treated in 1886 with 1.34 per cent mortality including foreign patients. An investigation of 320 unvaccinated people bitten by rabid animals is cited as showing about 40 per cent mortality, and an 1889 estimate put mortality in the bitten before Pasteur at about 16 per cent. The denominators are not comparable, because not every bite from a rabid animal transmits.

What came next is the lesson. Fermi in 1908 and Semple in 1911 replaced the dried-cord method with phenol-inactivated brain homogenate from sheep or goats, simpler and more reproducible, made of nervous tissue and containing myelin basic protein. The WHO vaccine safety sheet (2012, read in full) gives the record. Semple vaccine caused neurological complications at 0.14 to 7 per 1,000 treatments in the literature and 0.1 to 7 per 1,000 in the best institutional surveys, with case fatality up to 10 per cent, rising to 30 per cent where the picture was ascending Landry-type paralysis (Bahri 1996). Fuenzalida suckling-mouse-brain vaccine caused 0.037 to 0.12 per 1,000 courses with 22 per cent case fatality (Held 1971). Plotkin's pooled rates are 0.625 per 1,000 for nerve tissue vaccines, 0.125 for suckling mouse brain and 0.031 for purified duck embryo vaccine, against a background Guillain-Barré rate of about 1 per 100,000 per year after human diploid cell vaccine. A 1984 Bangkok study found 8.31 neurological cases per 1,000 vaccinated, about one in 120, roughly twenty-five times the 0.33 per 1,000 pooled from fourteen earlier reports, with fatality at 1.39 per 1,000 (search summary).

Two sentences from the WHO sheet are the heart of this report. Nerve tissue vaccines "can induce severe adverse reactions including a potential risk of rabies from incomplete virus inactivation", and WHO "strongly recommends the replacement of nerve tissue vaccines with modern vaccines". The improvised rabies vaccine simple enough that a determined district might imagine making it is the one that paralyses one patient in several hundred and can give them the disease. Grade **B** for efficacy, **X** for any post-Fall attempt.

6. BCG, Lübeck and the toxoids

Calmette and Guérin's attenuated *Mycobacterium bovis* strain entered human use in 1921, and by 1930, 242,250 French infants had been vaccinated without complications or reversion to virulence (Donald et al. 2022, citing Calmette).

Lübeck. Between December 1929 and April 1930, 251 of the 412 infants born in Lübeck received three oral BCG doses prepared in the Lübeck General Hospital laboratory. That laboratory also held the virulent human "Kiel" strain of *M. tuberculosis*, sent to Georg Deycke on 29 September 1929 and incubated in the space where BCG was prepared, and some vials were contaminated with it (Donald et al. 2022, read in full).

- Seventy-seven of 251 vaccinated infants died, 30.7 per cent. On the authors' re-reading of the pathology, 67 deaths, 26.7 per cent of the cohort, were due to tuberculosis, the rest to neonatal complications, accidents, other infections and in one case pylorospasm.
- Half of all eventual deaths occurred by three months of age and 87.5 per cent by five months. Of 212 infants tested, 190 (89.6 per cent) were tuberculin positive, and by September 1933, 168 of 251 (66.9 per cent) had no clinical signs.
- Severity appeared to track the probable ingested dose, but no clean dose-response line could be drawn. BCG reversion was excluded by guinea pig experiments and contamination with the Kiel strain was confirmed.
- Deycke and Ernst Altstaedt were tried for negligent manslaughter from October 1931 to February 1932 and convicted, receiving two years and fifteen months. The court found that Deycke had not followed Calmette's procedures, had not tested the vaccine in animals, and had worked in an inadequate laboratory where pathogenic mycobacteria were also kept.

This is the clearest case in the record of what happens when a competent municipal hospital laboratory makes a live vaccine without separation of work and without animal testing of each batch. No post-Fall dispensary will be better equipped than Lübeck was in 1929.

BCG's benefit. Colditz and colleagues (1994, abstract and secondary summaries only) found 64 per cent protection against meningitis across five studies (OR 0.36, CI 0.18 to 0.70), 71 per cent against tuberculous death across seven trials (RR 0.29, CI 0.16 to 0.53) and 51 per cent against tuberculosis overall (RR 0.49, CI 0.34 to 0.70). Rodrigues and colleagues (1993) found 86 per cent protection against meningeal and miliary tuberculosis in children in trials (CI 65 to 95 per cent) and 75 per cent in case-control studies, and CDC gives a range of 52 to 100 per cent. BCG does not reliably prevent adult pulmonary tuberculosis, which is why its stockpile priority sits below measles vaccine.

Tetanus toxoid. Gaston Ramon developed toxoid in 1923. The US Army adopted it in 1941 and recorded twelve tetanus cases in the whole of the Second World War, against about seventy per million wounded in the First, and two maternal doses cut neonatal tetanus deaths by 94 per cent (WO-14). Toxoid is the most durable item in any stockpile.

7. When making vaccine goes wrong: four cases a village should know

Mulkowal, Punjab, 30 October 1902. Nineteen people were inoculated with Haffkine's plague prophylactic from one bottle, labelled 53N. Within a week all nineteen developed tetanus and died, while nobody inoculated from other bottles was harmed. An Indian government commission blamed contamination during manufacture and Haffkine lost his post. A Lister Institute review overturned that and blamed contamination at the point of inoculation, W. J. Simpson noting in the *BMJ* that no foul smell was recorded when the bottle was opened, which a grown tetanus

culture would have produced. After a letter in *The Times* signed by Ronald Ross and nine other bacteriologists, Haffkine was exonerated in November 1907 (*Nature* 1907 and secondary accounts, search summaries. Sources disagree on whether the date was March or October 1902). One contaminated bottle killed everyone it touched, and the best bacteriologists alive argued for five years about where the contamination entered.

St Louis, 1901. Diphtheria antitoxin was drawn from a horse called Jim. Jim developed tetanus and was destroyed on 2 October 1901, and serum collected on 30 September, during the incubation period, was bottled under the label of an earlier clean date, 24 August. Thirteen children died, and testing the serum before use would have caught it. The Biologics Control Act of 1902 followed, prompted by this and by contaminated smallpox vaccine at Camden, New Jersey (Wikipedia, 1901 diphtheria antitoxin contamination incident, read in full).

Bundaberg, Queensland, 27 January 1928. Dr Ewing Thomson gave twenty-one children aged one to nine a dose of diphtheria toxin-antitoxin from a multi-dose bottle in use for weeks. Within thirty-six hours eighteen were seriously ill and twelve died, his own son among those injected. The royal commission under Charles Kellaway found *Staphylococcus aureus* contamination, probably from imperfect sterilisation at the point of use, and recommended the antibacterial preservative that manufacturers then adopted. Australian diphtheria immunisation was set back about two years (Wikipedia and WEHI, search summaries). The same mechanism killed six children in Himachal Pradesh in 1991 to 1992 and four in Tamil Nadu in 2008 after measles vaccine was kept too long after reconstitution (IN-12). Ninety years apart, the same error and the same organism.

Cutter, United States, April 1955. Formaldehyde inactivation of poliovirus failed in some lots because cell debris shielded virus from the inactivating agent and the virulent Mahoney strain was used. Cutter withdrew its vaccine on 27 April 1955 and Alexander Langmuir's surveillance team traced the cases to one manufacturer within days. Counts differ by source. The surveillance unit accepted 204 cases with eleven deaths by 28 October 1955, of which 79 were vaccinated children, 105 family members and 20 community contacts, while Offit gives roughly 40,000 abortive infections, 51 children permanently paralysed and five dead among the vaccinated, plus 113 paralysed and five dead among those they infected (search summaries. I did not read Nathanson and Langmuir). A licensed American company with a chemistry department failed at the one step an improvised vaccine depends on.

8. The stockpile: what keeps, how long, and at what temperature

Everything here is from WHO's *Temperature sensitivity of vaccines* (WHO/IVB/06.10, 2006), read in full, unless stated. WHO ranks vaccines by heat resistance: the toxoids and hepatitis B highest, freeze-dried measles, yellow fever and BCG in the middle, oral polio most fragile.

WHO Table 9, in substance.

Vaccine	2 to 8°C	20 to 25°C	37°C	Above 45°C	Freezing
Tetanus and diphtheria toxoids	stable >3 years	stable months	stable months	unstable above 55°C	do not freeze
Hepatitis B	stable >4 years	stable months	stable weeks	days at 45°C	do not freeze
Measles, MMR (dried)	stable 2 years	at least 1 month	at least 1 week	unstable	not harmed
Yellow fever (dried)	stable >2 years	stable months	stable 2 weeks	unstable	not harmed
Pertussis (whole cell)	18 to 24 months	stable 2 weeks	stable 1 week	10% loss or more per day	do not freeze
BCG (dried)	stable 1 to 2 years	stable months	20% loss or less in a month	unstable	not harmed

Vaccine	2 to 8°C	20 to 25°C	37°C	Above 45°C	Freezing
Oral polio	stable up to 1 year	stable weeks	stable 2 days	unstable	not harmed
Inactivated polio	stable 1 to 4 years	stable weeks	stable weeks	little data	do not freeze

The toxoids. The tetanus component of adsorbed DTP shows no significant change at 4 to 8°C for three to seven years. Potency falls insignificantly over 1.5 years at 18°C, 6 to 12 months at 24°C and 2 to 6 months at 37°C. At 53°C it lost 17 per cent in four days and 47 per cent in eight, and at 60°C the toxoids are destroyed in three to five hours.

Freezing ruins the stable ones. Adsorbed toxoids, hepatitis B, pertussis and IPV are all damaged by freezing, which wrecks the aluminium adjuvant lattice. Serum Institute of India data give potency remaining after one, two and three freeze-thaw cycles: tetanus 85, 39 and 40 per cent, diphtheria 94, 80 and 44 per cent, pertussis 100, 77 and 45 per cent. Adsorbed toxoid freezes between minus 5 and minus 10°C because of supercooling, hepatitis B at about minus 0.5°C. The counterweight matters for the last doses: in Menon's study of military recruits every man given frozen toxoid still reached a protective level, though titres were lower (13.5 IU/mL unfrozen against 9.2 after four freeze cycles at the third dose, and 90 against 69 per cent above 0.01 IU/mL). WHO still says known-frozen vials must not be used. WO-14 agrees and so do I: in a famine of doses frozen toxoid beats nothing for an unprimed person, provided the healer knows it is weak and gives the full series.

The shake test compares the suspect vial against one of the same lot deliberately frozen and thawed, because freeze damage makes agglomerates that sediment faster. The caveat is in the source: Connaught data on eighty vials of DTP and DTP-IPV showed potency loss on freezing with no visible change, so a vial known to have frozen must not be used even if it passes.

Measles and the dried live vaccines. Dried measles vaccine is robust and is not harmed by freezing and refreezing. Cameroon field studies showed vaccines stored at 37°C for up to 14 days still seroconverting seronegative children, and one manufacturer's ten-dose product kept acceptable potency at 37°C for 21 days. Merck's unreconstituted vaccine reportedly keeps potency eight months at room temperature and four weeks at 37°C, and is destroyed within hours at 54 to 56°C. Reconstituted it is another thing entirely: at 37°C it loses 0.4 to 0.5 log10 in three hours and 0.8 to 1.0 log10 in six, and diluent pre-warmed to 41°C halves potency in half an hour. Reconstituted vials go on ice and are discarded within six hours, for potency and because they hold no preservative. Dried BCG keeps one to two years at 2 to 8°C, though some lots lose 20 to 25 per cent of viability in six months even there, and loses 1 to 2 per cent a day at 37°C. It is sensitive to ultraviolet and fluorescent light and belongs in amber glass or the dark, and reconstituted BCG is discarded within six hours. Oral polio vaccine is the weakest item in any store, a year at 2 to 8°C, weeks at room temperature, two days at 37°C, though it survived 10, 90 and 180 freeze-thaw cycles between minus 25 and 2.5°C with no significant titre loss, because the thaw never rose above 2.1°C.

Hepatitis B, and the one trial that bears on the cellar. At 2 to 8°C its upper limit has never been defined. One manufacturer's data give four years at 2 to 8°C, one year at 20 to 26°C, 2 to 6 months at 37°C and a week at 45°C, while another product holds only 30 days at room temperature. In China, vaccine with a vial monitor was kept at room temperature up to three months and given at birth by village midwives to 358 infants, with 81.6 per cent seroconversion against 81.9 per cent in 232 infants given refrigerated vaccine by village doctors, and Indonesian Uniject work gave the same result. That is the most encouraging evidence in this report for a village with a cellar, and it applies to one vaccine.

Rabies vaccine keeps well. Lyophilised human diploid cell vaccine retains potency at least 3.5 years at 2 to 8°C and one month at 37°C, one product withstanding 37°C and 60°C for three months, and purified chick embryo cell vaccine was stable three months at 37°C. One salvaged vial given correctly after a bite is worth more than almost

anything else in the store.

Vaccine vial monitors. A heat-sensitive square on the cap darkens irreversibly with cumulative heat.

Type	Days to endpoint at 37°C	Days at 25°C	Time at 5°C
VVM30 (hepatitis B, BCG, tetanus)	30	193	over 4 years
VVM14 (measles, MMR)	14	90	over 3 years
VVM7 (DTP)	7	45	over 2 years
VVM2 (OPV)	2	not applicable	225 days

If the inner square is lighter than the outer ring the vaccine may be used provided it is in date. If it matches or is darker, do not use it. The VVM does not detect freezing, which is why the shake test exists.

The controlled temperature chain. Since 2012 the meningitis A conjugate vaccine MenAfriVac has been licensed for use at up to 40°C for no more than four days immediately before administration, the first vaccine for low-income countries authorised outside 2 to 8°C (WHO guidance and PATH 2012, read in full). The standard later vaccines must meet is a single planned excursion of at least three days at 40°C or above with no loss of safety or effectiveness (Seaman et al. 2022, search summary). PATH's key statement is that many vaccines are more heat stable than their labels suggest, and that Chad, China, India, Indonesia, Mali, Papua New Guinea and Vietnam have taken vaccines out of the cold chain on the last legs of distribution, off-licence, in order to vaccinate at all. The brief's unverified lead on "Kristensen and others" resolves to Kristensen et al. (*Vaccine* 2016), an interview study rather than a review, and Kahn, Kristensen and Rao (*Vaccine* 2017). I read neither in full [VERIFY].

Beyond the expiry date. I could find no study measuring potency or immunogenicity of tetanus or diphtheria vaccine after its labelled expiry. A 2026 Swedish cohort gave 282 adults aged 80 and over a COVID-19 dose three to five months past expiry with no serious or unexpected adverse events and no measure of effectiveness, FDA has extended certain lots by three months where storage was documented, and a 2026 systematic review of medicines, not vaccines, found 89.1 per cent of 3,786 expired samples stable (search summaries). All formal guidance treats an expired dose as invalid. My inference, which the village must own: expiry dates mark the first interval where potency falls below an acceptance limit, with a safety margin, in a product that must protect 95 per cent of recipients, and a toxoid unchanged for three to seven years at 4 to 8°C does not become inert on the printed date. Treat properly stored expired vaccine as of unknown but non-zero potency, worth giving when there is nothing else, never worth counting as protection [VERIFY].

9. The cold cellar, and the honest arithmetic

A well-built below-grade root cellar sits at stable ground temperature, reported as 4 to 10°C in one university hand-out and 10 to 13°C in homesteading guidance, with real cellars commonly 5 to 13°C (search summaries, mostly secondary). A pot-in-pot evaporative cooler drops 5 to 20°C below ambient in peer-reviewed measurement, but only in dry moving air (Chemin et al., search summary).

So a cellar is not a refrigerator. Call it 8 to 13°C in a temperate summer, with the top of the range being what matters. Against the WHO data that gives toxoids close to the 18°C line, about 1.5 years with insignificant loss and probably longer, the best item in the store [VERIFY]. Hepatitis B months to a year. Dried measles and BCG at the room-temperature line, a month guaranteed and probably several, with the VVM as arbiter. OPV weeks at best, not worth cellaring. Reconstituted anything, six hours, cellar or no cellar.

Ice changes this. A cellar with an ice store, or a northern winter, gives true 0 to 8°C and moves everything to the top line. The WHO-prequalified passive device Arktek holds 0 to 10°C for 35 or more days on one load of about 8.6 litres of water ice at 43°C ambient, with a heat leak of about 1 watt (vendor and forum figures, search summaries). A

salvaged unit recharged from an ice house is the most valuable cold-chain object a district could hold. The order of operations is dark, dry, above freezing, as cool as the ground allows, never near 40°C, and a written temperature log, because cumulative heat is what kills and WHO is explicit that each exposure adds to the last.

10. What returns, and when

IN-12 gives the arithmetic and I do not repeat it.

Tetanus returns immediately and needs no epidemic, because it is in the soil. Neonatal tetanus returns with the first unimmunised mother, and WO-14 records a Mogadishu series of fifty patients, 80 per cent unvaccinated, with 26 per cent mortality.

Measles returns on the first import once susceptibles accumulate. R0 of 12 to 18, herd immunity threshold 92 to 95 per cent, critical community size about 250,000 to 500,000 below which it cannot persist and must be reimported (Guerra 2017, Bartlett, Black, via IN-12). A district of 3,000 accumulates about 100 susceptible children a year, crosses the epidemic threshold in roughly two years and faces a large epidemic by five. Case fatality 1.5 to 11.8 per cent depending on nutrition and crowding.

Whooping cough returns within a few years of stopping. UK coverage fell from 77 per cent in 1974 to 30 per cent in 1978 and more than 102,500 cases followed with an estimated 36 deaths, mostly babies. Japan suspended infant vaccination in February 1975 and a peak in 1979 brought 13,000 notified cases and 40 deaths in that year alone. Sweden withdrew whole-cell vaccine in 1979 and incidence returned to pre-vaccine levels within a few years (CDC MMWR, Gavi, search summaries).

Diphtheria returns in five to twenty-five years and takes adults too. The former Soviet Union went from 1,431 cases in 1990 to over 50,000 a year in 1994 and 1995, with more than 140,000 cases and 4,000 deaths (IN-12). Venezuela had reported no case since 1992 when its epidemic began in Bolívar state in July 2016, and through week 48 of 2019 there were 3,033 suspected cases, 1,785 confirmed and 291 deaths, with case fatality 31.1 per cent among children under five and no antitoxin available in the country for one documented Amerindian outbreak (PAHO and published series, search summaries).

Polio is slower, because most infections are silent, and then catastrophic. Paralysis follows about one in 200 infections, 5 to 10 per cent of the paralysed die when breathing muscles go, and mortality runs 2 to 5 per cent in children and 15 to 30 per cent in adolescents and adults during outbreaks (WHO and ECDC, search summaries). Syria eliminated polio in 1995 and saw wild type 1 return in October 2013 after two years of war, 38 cases in Syria and Iraq, contained in six months by campaigns reaching over 27 million children (CDC MMWR 2017, search summary). A second danger belongs to the vaccine: oral polio strains circulating in under-immunised populations become vaccine-derived poliovirus and paralyse at the same rate as wild virus, causing 212 of 223 paralysis cases worldwide in 2022.

Tuberculosis is already present almost everywhere, and BCG's loss costs mainly infant meningitis and miliary disease. **Rabies** is unchanged in its natural history and worsened by the loss of dog vaccination. **Chickenpox, mumps and rubella** return and are mostly survivable, except rubella in pregnancy and varicella in adults and the immunosuppressed. Pre-vaccine United States varicella caused about 4 million cases and 100 to 150 deaths a year, roughly one death per 27,000 to 40,000 cases by my arithmetic [VERIFY] (CDC, search summary).

11. Is any improvised immunisation defensible? The short answer is no

Variolation against smallpox is moot, because smallpox was eradicated. The last naturally acquired case was Ali Maow Maalin, a hospital cook in Merca district, Somalia, diagnosed 26 October 1977 with variola minor, whose 211 contacts were traced and watched. Eradication was certified on 9 December 1979 and endorsed on 8 May 1980. The last variola major case was Rahima Banu in Bangladesh in 1975 and the last death was Janet Parker in a laboratory-acquired outbreak in Birmingham in 1978. There is no wild virus to variolate with. If smallpox ever reappeared the

argument reopens from the beginning.

Arm-to-arm vaccinia has no source outside a stockpile either, and Rivalta settles the method. Cowpox does persist in European rodents and occasionally infects cats and people, so a village could in theory find it, and would have no way to know what else travelled in the lymph it then passed arm to arm, to protect against a disease that no longer exists. This is a dead end.

Making a killed or attenuated vaccine is settled by section 7. The missing capabilities are not exotic: a separate room for virulent organisms, an animal potency test and an animal safety test for every batch, a sterility test and a preservative. A district with a microbiologist and a decade might rebuild some of it, and its first batches would kill people. WO-14 reaches the same judgement about antitoxin and toxoid.

Nerve-tissue rabies vaccine is the one simple enough that someone might try, and the one with a documented risk of causing rabies and paralysing as many as one in 120. Write it as forbidden, not as a last resort.

The pox party. CDC reports deaths of previously healthy unvaccinated adolescents from varicella and states that there is no way to tell in advance how severe a child's case will be. For measles the case against is overwhelming, because it kills at 1.5 to 11.8 per cent in the conditions this book describes and causes two to three years of immune amnesia (IN-12). Grade **X** for measles, **D** and discouraged for varicella.

Deliberate rubella exposure of girls before puberty. IN-12 raises this and leaves it to MA-07. Rubella in childhood is trivial and in the first trimester catastrophic, so the logic is real, but a deliberately infected child infects the household, and some household holds a woman in early pregnancy who does not yet know it. I do not think it can be made safe without knowing who is pregnant and separating them for three weeks, and this is inference, not evidence [VERIFY].

What is defensible is using salvaged vaccine well, in the right order, reading the VVM, running the shake test, keeping a register, washing bite wounds, keeping cords clean and isolating cases. That is the whole of post-Fall immunisation, and it is not nothing.

12. Rabies: the one place where a drill beats a factory

The most effective intervention needs no vaccine. WHO advises washing the wound immediately and thoroughly with soap and water for at least 15 minutes, with plain water if there is no soap, adding 70 per cent alcohol or povidone-iodine if available (WHO rabies fact sheet. The older WHO FAQ gives 10 to 15 minutes). A household can do this in the first minute, at the lowest rung of the ledger.

If any cell-culture vaccine survives, the 2018 WHO position paper allows an intradermal schedule that stretches it enormously. The one-week two-site regimen, 2-2-2-0-0, gives two intradermal doses of 0.1 mL on days 0, 3 and 7. Total use is about 0.6 mL, roughly one vial, against 1.5 to 5 mL intramuscular, a saving of 60 to 80 per cent, and WHO's systematic review found intradermal administration equivalent to or better than intramuscular (2018 position paper summary, search summary. I did not read the full paper). The 2018 revision also changed immunoglobulin practice: infiltrate the maximum anatomically feasible amount in and around the wound rather than calculating by body weight. Intradermal injection is a skill and a dose placed too deep is wasted, so a village dispensary could learn it and a household could not. Once hydrophobia begins nothing here helps.

Evidence grades

Practice	Tradition says	Record shows	Grade
Variolation against smallpox	mild disease instead of severe	2 to 2.5% mortality Boston 1721 against about 14% natural, under 0.2% by the Suttonian method	B
Variolation as a public measure	protects the town	variolated people are infectious and seeded outbreaks	X
Jenner's own 1798 evidence	cowpox protects	23 case reports, 3 challenges	D
Vaccinia vaccination on later evidence	as above	smallpox eradicated, certified 1980	A
Arm-to-arm chains as transport	keeps vaccine alive	about 100,000 vaccinated in New Spain	B
Arm-to-arm chains revived today	safe, said Balmis in 1807	44 to 46 of 63 children syphilitic at Rivalta 1861, plus erysipelas and hepatitis	X
Pasteur's 1885 rabies treatment	prevents a fatal disease	about 1.34% mortality in 2,682 treated in 1886, against roughly 16 to 40% untreated	B
Semple and Fermi nerve-tissue vaccine	cheap and effective	0.1 to 7 neurological cases per 1,000, fatality to 10%, rabies from incomplete inactivation	X
BCG against infant tuberculous meningitis	protects infants	64 to 86% protection (Colditz 1994, Rodrigues 1993)	A
Locally made BCG, no animal testing	protects infants	67 of 251 infants dead at Lübeck 1930	X
Tetanus toxoid before injury	prevents tetanus	12 US Army cases in the whole Second World War, 94% fall in neonatal deaths	A
Toxoid kept at 2 to 8°C for years	shelf life 3 years	no significant change for 3 to 7 years	B
Toxoid known to have frozen	useless	85% potency after one cycle, 39 to 40% after three, yet every frozen-toxoid recruit reached protection	B, WHO advises against use
Shake test for freeze damage	detects frozen vaccine	predictive in Serum Institute data, missed loss in Connaught data	B
Vaccine vial monitor	shows cumulative heat	good correlation with OPV potency	B
Hepatitis B out of the cold chain to 3 months	still works	81.6% seroconversion against 81.9% refrigerated	B

Practice	Tradition says	Record shows	Grade
Reconstituted vaccine kept past 6 hours	saves doses	12 dead at Bundaberg, 6 in Himachal Pradesh, 4 in Tamil Nadu, all *Staphylococcus aureus*	X
Measles vaccine within 72 hours of exposure	prevents or softens measles	consistent guidance	B
Immune globulin within 6 days	prevents measles	consistent guidance, 0.5 mL/kg IM	B
Washing a bite 15 minutes with soap	prevents rabies	WHO's first and universal recommendation	B
Intradermal dose-sparing rabies schedule	stretches scarce vaccine	WHO 2018, equivalent or better, 60 to 80% saved	A
Pox party, measles	gets it over with	1.5 to 11.8% case fatality plus immune amnesia	X
Pox party, varicella	gets it over with	about 1 death per 27,000 to 40,000 cases, severity unpredictable	D, discouraged
Village manufacture of any vaccine	self-reliance	Mulkowal 19 dead, St Louis 13, Bundaberg 12, Lübeck 67, Cutter 11 dead and over 160 paralysed	X

Means ledger

Rung	What it can do	What it changes
Hands and knowledge alone	Know who is susceptible and keep a register. Isolate cases. Wash a bite 15 minutes. Keep a birth cord clean and dry and put nothing on it. Never close a dirty wound	Prevents some rabies and some neonatal tetanus outright. Lowers measles deaths by lowering infecting dose. Changes nothing about the arrival of epidemics
At the hearth	Soap and water wound washing, boiled blade and cord tie, an isolation room, nursing through measles and whooping cough, a written register of who had what and when	Survival of cases that would otherwise die of dehydration and secondary infection. Still no immunisation
Garden and still	70 per cent alcohol or iodine on a washed bite. Boiled instruments. A cellar at 8 to 13°C. Possibly an ice store	Extends a salvaged stockpile from months to years for toxoids and hepatitis B. Creates not one dose of anything

Rung	What it can do	What it changes
Village dispensary of 300	Hold and ration the stockpile. Read the VVM, run the shake test, keep a temperature log. Give intramuscular and intradermal doses. Reconstitute with the matched diluent and discard at six hours. Measles vaccine within 72 hours of exposure. The intradermal rabies schedule. Maternal tetanus toxoid. A dose register that outlives the healer	The rung where a stockpile becomes protection rather than a cupboard. Doubles or triples the people a given stock covers, through dose-sparing and correct handling
District infirmary of 3,000	All the above plus a central cold store or ice store, allocation across villages, outbreak investigation, the decision on expired or frozen stock, training of village healers, one district register	Decides which villages get the last doses. Can ring-vaccinate an outbreak. Could, after many years and with a microbiologist, attempt antitoxin from hyperimmunised horses, with deaths in the first batches [VERIFY]
Hospital before the Fall	Manufacture, lot release, animal potency and safety testing, 2 to 8°C bench to arm, coverage above 95 per cent, immunoglobulins, antitoxin, intensive care	The diseases in section 10 are rare or absent. Every rung below this is damage limitation

Harm test

Vaccine of unknown storage. Harms by false confidence, not directly: a village that believes its children are protected stops isolating. Sign: cases in children recorded as vaccinated. Treat unverified stock as possibly inert, keep those children under the same isolation rules, and record batch and date for every dose so failures trace to a batch.

Reconstituted vials kept too long. *Staphylococcus aureus* grows in a preservative-free vial and the next child gets a dose of toxin. Signs: vomiting, diarrhoea, collapse and shock within one to thirty-six hours in several children from one vial. Cases: Bundaberg 1928, twelve of twenty-one. Himachal Pradesh, six. Tamil Nadu, four. Stop the session, isolate the vial, treat shock with fluids, expect deaths. Prevention is the whole answer, so write the time of reconstitution on the vial.

Frozen adsorbed vaccine. Harms silently by failing, and causes more local reactions. The error is letting toxoid, DTP, hepatitis B or IPV reach minus 5°C, which an ice store or hard frost will do. Sign: faster sedimentation than a deliberately frozen control. Discard, or in a famine of doses give it knowing it is weak and complete the series.

Heat. Harms invisibly by failing. A VVM at its endpoint is the only field warning. Above 55°C toxoids are destroyed, at 60°C within three to five hours, and a vial on a sunlit windowsill can reach this.

Reused needles. Hepatitis B and C, HIV and abscesses, the most likely iatrogenic killer in a post-Fall session. One needle per person, boiled instruments, no exceptions.

Intradermal technique. A dose placed too deep is wasted and the patient is unprotected while believing otherwise. Sign: no raised blanched bleb. Repeat at another site with a fresh 0.1 mL.

Attempting to make vaccine or antitoxin. Incomplete inactivation gives the disease, contamination gives tetanus or staphylococcal shock, an untested live batch gives what it was meant to prevent. The harmful dose can be a single contaminated bottle. Cases: Mulkowal nineteen of nineteen, St Louis thirteen, Bundaberg twelve of twenty-one, Lübeck sixty-seven of 251, Cutter eleven dead and over 160 paralysed. Signs that it is going wrong: there are none until children start dying, which is the point.

Equine antitoxin, if salvaged. Serum sickness in roughly 8 to 31 per cent depending on preparation, about 8.8 per cent in a series of 1,433 patients treated 1940 to 1950, anaphylaxis in 0.6 per cent, febrile reactions in 4 per cent (Drugs.com and LITFL, search summaries), beginning at seven to ten days. Skin test first, watch during infusion, keep adrenaline to hand, never give a second course.

Who must never receive what. Live vaccines, meaning measles, MMR, BCG, oral polio, yellow fever and varicella, must not go to pregnant women, the severely immunosuppressed, or the severely malnourished with active infection. Measles vaccine has no role once the rash is out. BCG must not go to a child known to have tuberculosis or HIV. Nothing goes to a person with a documented severe reaction to a previous dose of it.

Red flags

1. **Hydrophobia, aerophobia, agitation and hypersalivation weeks after an animal bite.** Rabies has begun and survival is effectively zero. Do not attempt vaccine now. Honest comfort: a dark quiet room, someone unafraid to stay, water offered by sponge rather than cup, sedation with whatever the district has. Tell the family early, while he can still speak. Anyone who handled saliva should wash and, if vaccine exists, take it.
2. **A deep or multiple bite to face, hands or genitals from an animal behaving oddly, with no rabies vaccine in the district.** Wash 15 minutes anyway, every time, then record and watch. Most bites from most animals do not transmit. Say that honestly rather than promising.
3. **A diphtheria membrane spreading with a bull neck, and no antitoxin.** Mortality is high and antibiotics do not neutralise circulating toxin. Nurse upright, keep the airway clear, isolate, and accept that a tracheostomy at the district buys time, not a cure (IN-12).
4. **A newborn who stops feeding on the seventh day with trismus and spasms.** Neonatal tetanus, almost always fatal without ventilation. Sedate, keep the room dark and quiet, and give the next mother two doses of toxoid before she gives birth (WO-14).
5. **Ascending flaccid paralysis in a child during an outbreak of fever and sore throat.** Polio. If the breathing muscles go the village cannot save him. Position, nurse, and protect the limbs from contracture in case he recovers partially.
6. **Measles with fast breathing and lower chest indrawing in a malnourished child.** Pneumonia. Without antibiotics and oxygen many die. Vitamin A, feed, hydrate, keep siblings out of the room (IN-12).
7. **A child who develops meningeal signs after a locally produced injection.** The Lübeck signature. Stop the programme at once, quarantine the batch, vaccinate nobody else from it.
8. **Several children shocked and vomiting within hours of injections from one vial.** Stop the session. The vial is contaminated. Fluids, warmth, and expect deaths.

The case against

Against variolation, in its own time. Francisco Gil argued in 1784 that it spread the disease and exposed to blindness, disfigurement and death people who might never have caught smallpox, and Boylston's critics called it murder if an inoculated person died. Both were right. It only made sense where smallpox was certain to come anyway, which is exactly the condition a reader cannot verify for a modern disease.

Against romanticising Balmis. The expedition is told as an epic and the children in it were state property. Four of sixty-two died. Vaccination described as voluntary was forced on soldiers at Veracruz and on twenty Indian women in Mexico City when the chain was about to break, and the Madrid foundling home's Ladies' Board had to stop an

experiment testing goat pox on foundlings. Mark and Rigau-Pérez judge that state officials showed no hesitation in using wards of the state as tools of public health. The twenty per cent coverage achieved is itself an argument against the method, because a chain that must preserve susceptibles cannot reach everybody.

Against trusting stability data. WHO is its own strongest critic. The figures come from accelerated degradation tests extrapolated by the Arrhenius equation, and WHO states that the precision with which this predicts degradation differs considerably. Potency assays for bacterial vaccines and toxoids need large numbers of animals and carry wide biological variation. Every heat exposure is cumulative, so a vial already through cold-chain breaks will not survive what the table promises. And the data cover weeks and months, with a handful of multi-year figures at refrigerator temperature. Nothing in them speaks to year seven of the Fall. A reader who takes Table 9 as a promise will give inert vaccine and believe his village is protected.

Against my own priority list. Protocol 3 is inference, not evidence. A community whose survival depends on defence may reasonably put fighters ahead of pregnant women for toxoid, as WO-14 notes, and one facing an imminent measles import may reasonably burn its last doses on a ring. I weighted by lives saved per dose, which is one defensible rule among several.

Against this report as a whole. It tells readers that the greatest medical intervention there has ever been is unavailable to them, and offers register-keeping and hand-washing instead. Thomas McKeown argued that infectious mortality in Britain fell mainly through better nutrition and Simon Szreter credited public health measures (neither read, noted in IN-12). If either is even partly right, a village that cannot vaccinate can still do a great deal with food, space, water and sewage, and this report belongs beside IN-12, WO-14 and the sanitation reports rather than read as a counsel of despair.

10-line summary

1. Variolation cut smallpox mortality from roughly 14 to 33 per cent to about 2 per cent in Boston in 1721, and to under 0.2 per cent by the Suttonian method, at the price of making every recipient infectious.
2. Jenner's 1798 *Inquiry* rested on twenty-three case reports and three smallpox challenges, and it was right.
3. The Balmis expedition carried live vaccine across the Atlantic in the arms of sixty-two children, four of whom died, reaching about 100,000 people in New Spain, roughly twenty per cent coverage.
4. Arm-to-arm vaccination was abandoned because it transmitted syphilis, erysipelas and hepatitis, documented at Rivalta in 1861 where 44 to 46 of 63 children were infected.
5. Nerve-tissue rabies vaccine caused neurological complications in 0.1 to 7 per 1,000 recipients with up to 10 per cent case fatality, and could transmit rabies through incomplete inactivation.
6. Every documented attempt to make vaccine or antitoxin without full laboratory control killed people: 19 at Mulkowal, 13 in St Louis, 12 at Bundaberg, 67 at Lübeck, 11 at Cutter with over 160 paralysed.
7. Tetanus and diphtheria toxoids are stable three to seven years at 2 to 8°C, 1.5 years at 18°C and two to six months at 37°C, and are destroyed by freezing, which the shake test detects.
8. Dried measles vaccine keeps two years at 2 to 8°C, a month at room temperature and a week at 37°C, and once reconstituted must be discarded within six hours.
9. A cellar at 8 to 13°C is not a refrigerator but holds toxoids a year or more, and hepatitis B kept out of the cold chain three months gave 81.6 per cent seroconversion against 81.9 per cent refrigerated.
10. Tetanus returns at once, measles within two years, whooping cough within a few, diphtheria within five to twenty-five, polio silently, so the last doses go to tetanus toxoid for pregnant women first.

Open questions

- How much potency does toxoid retain five or ten years past expiry at cellar temperature? No study exists, and this is the most valuable missing number for a post-Fall stockpile.

- Does a vaccine vial monitor keep reading true years after the vial expires? The chemistry should continue, but I found no study.
- What is the real effective R0 of measles in a dispersed rural district with no schools and no markets? IN-12 raises it and it governs epidemic timing.
- Can a district with a microbiologist, horses and a decade produce usable antitoxin, and at what cost in early deaths? WO-14 leaves this open and so do I.
- Is deliberate rubella exposure of pre-pubertal girls ever defensible where no vaccine exists? Belongs with MA-07.
- Does the intradermal rabies schedule survive translation to an untrained hand? No field data found for lay providers.
- How long does a salvaged passive cold storage device keep working, and can its insulation be repaired at a forge? Not addressed anywhere I could find.
- What is the right ethical rule for allocating the last doses, and who decides? I offer one rule and do not claim it is the right one.

Sources to read in full

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2. Mark C and Rigau-Pérez JG, "The World's First Immunization Campaign", *Bulletin of the History of Medicine* 83(1), 2009. The honest account of Balmis, coercion and children's deaths included.
3. Donald PR and colleagues, "Pathogenesis of tuberculosis: the 1930 Lübeck disaster revisited", *European Respiratory Review* 31(164), 2022. For the trial findings and the laboratory failures.
4. WHO Global Vaccine Safety information sheet on rabies vaccine, 2012. Four pages that settle whether nerve-tissue vaccine should ever be attempted.
5. WHO, *Rabies vaccines: WHO position paper*, April 2018. For the intradermal dose-sparing schedule in full.
6. WHO, *Policy on the use of opened multi-dose vaccine vials*, WHO/IVB/14.07, 2014. The six-hour and 28-day rules with their exact conditions.
7. Fenner F and colleagues, *Smallpox and its Eradication*, WHO 1988, chapters 6 and 11. I could not read it and the book should.
8. Razzell P, *The Conquest of Smallpox*, 1977 and 2003. For the variolation mortality tables I had to take second-hand.
9. Offit PA, *The Cutter Incident*, Yale University Press 2005. The best account of what inactivation failure costs.
10. THRIVING library IN-12 and WO-14. This report assumes both and does not duplicate them.

At the bedside after the Fall

For a household. You cannot vaccinate. You can know. Keep one page in the family book listing every person, year of birth, every vaccination anyone remembers with its date, and every infectious disease each has had with its year. That page is the only immunity record that will exist in twenty years, and it decides who must stay out of a measles house and who may nurse there. Wash every animal bite with soap under running water for a full fifteen minutes, counted, before anything else. Keep every birth cord clean, dry and tied with boiled thread, and put nothing on it. Never close a dirty wound. Needs to start: a page, a pencil, soap and a way to count minutes. First failure to expect: the page is not updated in the year somebody dies, and three children's histories are lost.

For a village of 300. The healer holds the stockpile and the register. The stockpile lives in the coolest, darkest, driest place available, above freezing, with a thermometer and a written log. She knows the four VVM types on sight and runs the shake test on any adsorbed vaccine of unclear history. She never reconstitutes more than one session's worth and writes the time on the vial. She gives maternal tetanus toxoid first, two doses four weeks apart with the second at least two weeks before the birth, and measles vaccine within 72 hours of a known exposure if any survives. She

records name, date, vaccine, batch and site for every dose, because a batch that fails must be traceable. Needs to start: a trained lay healer, a cool store with a thermometer, a boiling pot, one needle per person, a bound register, and a written rule about the last doses agreed before they arrive. First failure to expect: the stock is quietly ruined by one hot week or one hard frost, and nobody knows until an epidemic takes children recorded as vaccinated.

For a district of 3,000. The infirmary holds the central store, ideally with ice or a salvaged passive device, and decides allocation across villages. It keeps the master register, trains village healers in injection technique, the shake test, VVM reading and the six-hour rule, and investigates every failure, tracing it to a batch and quarantining that batch district-wide. It makes the hard calls: frozen toxoid or not, expired stock or not, a ring around an outbreak or infants first. It teaches the intradermal rabies schedule and treats rabies vaccine as the highest-value single item. Every year it writes down what remains, so the decision to stop counting on vaccine is made deliberately rather than discovered. Needs to start: a nurse or doctor, a cold store, the master register, a written allocation policy, and someone whose job is the cold chain and nothing else. First failure to expect: the policy is abandoned the first time the decision-maker's own family is in the queue.

Protocols

Protocol 1. Receiving and storing a salvaged stockpile

1. Write down what you have: vaccine, manufacturer, batch, expiry, number of doses, where it was found.
2. Sort into three groups. Freeze-sensitive: tetanus and diphtheria toxoids, DT, Td, DTP, hepatitis B, IPV, any aluminium-adsorbed product. Freeze-tolerant dried: measles, MMR, BCG, yellow fever, OPV. Diluents: keep each with its own vaccine and never mix brands.
3. Store dark, dry, above 0°C and below 20°C, target 2 to 8°C. A cellar at 8 to 13°C is acceptable for toxoids and hepatitis B and a compromise for the dried live vaccines.
4. Put a thermometer in the store and read it twice daily, morning and the hottest hour, writing both in a log. Tolerances: never above 25°C for more than a few days, never above 40°C at all, never below 0°C for the freeze-sensitive group.
5. Check the VVM on every vial on arrival and again before use. Lighter than the ring, usable. Same or darker, discard.
6. Run the shake test on any adsorbed vaccine of unclear history before first use of that batch.
7. Review the store every three months, record losses, and use the oldest usable stock first.

Protocol 2. The shake test

1. Take one vial of the same vaccine, manufacturer and lot, freeze it solid overnight at the coldest temperature you have, and thaw it. This is the control. Label it and never inject it.
2. Shake control and suspect vigorously together for ten to fifteen seconds.
3. Stand both upright side by side in good light against a white background and do not move them.
4. Watch fifteen to thirty minutes. A good vial stays smooth and cloudy. A frozen one shows flakes or granules with a clear layer above sediment.
5. If the suspect sediments as fast as or faster than the control, discard it.
6. If you know the vial froze, discard it even if it passes, because visible change is not reliable in every product.
7. In a famine of doses an unprimed person may be given frozen toxoid rather than nothing, with the full series completed. Record that the dose was known-frozen.

Protocol 3. Allocating the last doses

Work down the list and stop when the stock runs out.

1. **Tetanus toxoid to pregnant women.** Two doses 0.5 mL intramuscular four weeks apart, the second at least two weeks before the birth. The highest return of any dose in the store.
2. **Tetanus toxoid to those doing the dirtiest work or going to fight.** Three doses at least four weeks apart, better with a two-month gap. Toxoid at the moment of wounding does not protect an unprimed person in time.
3. **Rabies vaccine held in reserve for bites, not given preventively**, unless there is far more than the district will need. One vial run as 2-2-2-0-0 treats one patient. Five vials is five lives.
4. **Measles vaccine to children aged 9 to 12 months**, and to any child from 6 months within 72 hours of known exposure. Not in pregnancy.
5. **Measles vaccine as a ring** around a confirmed outbreak if the stock is too small for routine use.
6. **BCG to newborns** if any remains, for meningitis and miliary disease.
7. **Hepatitis B birth dose**, which tolerates the cellar better than anything else.
8. **Polio, pertussis-containing and the rest** in whatever order the district judges, knowing the stock will not reach coverage.

Record every dose: name, date, vaccine, batch, site, who gave it. Review the policy once a year in public, before anyone needs it.

Protocol 4. Giving a dose safely

1. One sterile needle and syringe per person. Boil instruments at least twenty minutes if reusing, and never reuse a needle between people.
2. Wash hands. Clean the skin and let it dry.
3. Check the VVM, the expiry, and that the vial is the vaccine you intend.
4. For a dried vaccine use only the diluent supplied with it, cooled to the same temperature as the vaccine. Never a warm diluent: at 41°C it halves measles potency in thirty minutes.
5. Write the time of reconstitution on the vial in ink.
6. Intramuscular dose 0.5 mL, outer thigh in infants, deltoid in older children and adults. Toxoid and antitoxin always in separate syringes at separate sites.
7. Intradermal dose 0.1 mL, raising a visible blanched bleb. No bleb means it went too deep, so repeat at a fresh site.
8. Keep the open vial on ice or in the coolest place to hand throughout the session.
9. Discard every reconstituted vial at the end of the session or six hours after mixing, whichever comes first, even with doses left. This rule has twelve dead children behind it.
10. For liquid multi-dose vials of toxoid, DTP, hepatitis B or IPV containing a preservative, an opened vial may be kept up to 28 days if it was prequalified for that, is in date, the VVM has not reached its endpoint and it has stayed cold throughout. If you cannot be sure of all four, discard at six hours.
11. Watch every recipient fifteen minutes, with adrenaline in the room if any exists.

Protocol 5. After an animal bite

1. Immediately wash the wound with soap and running water for a full fifteen minutes by the clock, flushing deep punctures. Water alone if there is no soap.
2. Then apply 70 per cent alcohol or povidone-iodine if either exists.
3. Do not close the wound. Leave it open.
4. Give tetanus toxoid 0.5 mL intramuscular, and tetanus immunoglobulin at a separate site in a separate syringe if the person is unprimed and any exists (WO-14, Protocol 1).
5. If rabies vaccine exists and the animal was a dog, bat, fox or any mammal behaving oddly or unknown, begin the intradermal schedule: two sites of 0.1 mL on day 0, two on day 3, two on day 7, nothing on days 14 and 28.

6. If rabies immunoglobulin exists, infiltrate as much as will anatomically fit in and around the wound. Do not calculate by weight.
7. If the animal is a household dog that can be confined, watch it ten days. Alive and well on day ten means it was not shedding virus when it bit.
8. Record the bite, the animal, the date, the washing time and every dose given.

Protocol 6. Measles exposure in a household

1. Confirm the index case clinically: fever, cough, coryza, conjunctivitis, then rash from the hairline down.
2. List every susceptible person in the house and the neighbouring houses from the register.
3. Within 72 hours of first exposure give measles vaccine to any susceptible person aged six months or over who is not pregnant and not severely immunosuppressed, if any survives.
4. From day 4 to day 6 vaccine is too late. Immune globulin 0.5 mL/kg intramuscular within six days if any exists, prioritised for infants under six months, pregnant women and the immunosuppressed.
5. Never give vaccine and immune globulin together. After immune globulin, wait six months to vaccinate.
6. Isolate the case from four days before the rash to four days after. Keep infants and the malnourished out of the room entirely, because crowding and infecting dose decide who dies.
7. Give vitamin A to every case per IN-12.
8. Expect the next exposure wave at 10 to 14 days. Mark the date in the register.

Protocol 7. The quarterly stockpile review

1. Count everything and compare with last quarter.
2. Read every VVM, moving any vial near its endpoint to the front for immediate use.
3. Read the quarter's temperature log, noting the highest reading and the days above 25°C.
4. Discard anything past its endpoint, anything known to have frozen in the freeze-sensitive group, and anything whose label is unreadable.
5. Write the projected exhaustion date for each vaccine at the current rate of use.
6. Say the projected date for tetanus toxoid out loud to the village once a year. People choose differently when they know the year the protection runs out.

Numbers to carry

1. **Variolation killed about 2 in 100. Natural smallpox killed about 14 to 30 in 100.** That ratio is why people accepted a dangerous procedure.
2. **Six hours.** Discard any reconstituted vial six hours after mixing or at the end of the session, whichever comes first.
3. **Fifteen minutes.** Wash every animal bite with soap and running water for a full fifteen minutes.
4. **Three to seven years at 2 to 8°C, 1.5 years at 18°C, two to six months at 37°C.** Tetanus and diphtheria toxoid, the most durable thing in the store.
5. **Two years, one month, one week.** Dried measles vaccine at 2 to 8°C, at room temperature, and at 37°C.
6. **Two days.** Oral polio vaccine at 37°C, the most fragile vaccine there is.
7. **85, 39, 40.** Percentage of tetanus toxoid potency left after one, two and three freeze-thaw cycles.
8. **VVM 30, 14, 7, 2.** Days to endpoint at 37°C for hepatitis B and toxoids, measles, DTP and OPV.
9. **72 hours for vaccine, 6 days for immune globulin.** The two windows after measles exposure.
10. **0.1 mL, two sites, days 0, 3 and 7.** The intradermal rabies schedule that turns one vial into one treated patient.
11. **About 100 new susceptible children a year in a district of 3,000.** Measles becomes possible in about two years without vaccine (IN-12).

12. **Nineteen, thirteen, twelve, sixty-seven.** Mulkowal, St Louis, Bundaberg, Lübeck. Say these numbers to anyone who proposes making vaccine in the village.

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