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Key Note Lecture

Science and society: vaccines and public health☆

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ABSTRACT

Most public health research is devoted to the measurement of disease burdens and of the costs and effectiveness of control measures. The history of immunization provides many colourful examples of various ways in which such measurements are made, of how they have influenced policies, and of the importance of public perception of the magnitudes of the various burdens, benefits and risks. Improving the public's ability to evaluate evidence is itself an important aspect of public health.

One might liken public health to a set of scales, weighing the magnitudes and costs of various ‘problems’ on one side, and balancing these against the effectiveness and costs of various ‘control interventions’ on the other. Everyone in public health is involved somewhere in this spectrum of relating problems to solutions, and insofar as we are doing it scientifically, this means quantifying them in various ways. It may be appropriate to actually go out and measure them, and a lot of the public health workforce does that. But sometimes you cannot measure – it is just too expensive, or it would take too long, or it is not known how. So sometimes estimation is used, and this often means modelling; it often means assumptions have to be made.

It is also important to consider the importance of public perceptions of the magnitude or cost of a problem, and of the intervention being developed, implemented or evaluated. This review looks at measuring, estimating and perceiving the magnitude of burdens and costs with reference to immunization, as illustrative of many of the issues which confront public health.

Smallpox

It all started with smallpox. In terms of burden, before the nineteenth century it was the number one cause of mortality. It is said that a third of the population of Iceland died from smallpox, that there were 40,000 smallpox deaths in Paris in 1723, and that 90% of the Aztec population died from smallpox. The numbers are staggering, as we know from the Bills of Mortality, which collected parish records, starting during the plague period of the seventeenth century. Over 150 years, between 7% and 10% of all deaths in these bills were attributed to smallpox. That is a measurement, the best they could do at that time.

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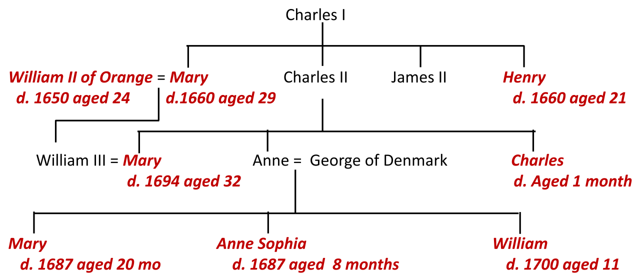

Fig. 1 – Family Tree showing smallpox deaths in the Stuart family. Smallpox deaths in red italics. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Family records are available of various royal families from ages past, including causes of death, as exemplified in the fragment of the Stuart Royal family tree shown in Fig. 1. These families knew their pedigrees, and they knew who died of smallpox. They feared it, and this had implications.

Variolation

So what was done about it? It had been recognized for centuries, by many people around the world, that you got this disease only once. If you survived it, you never got it again and need not fear it – in effect it was recognized to be both a contagious and an immunizing disease. There must have been a variety of folk practices to combat this disease, and one turns out to have been particularly important, a technique later known as variolation – variola being the medical term for smallpox. It is thought this originated in East Asia, perhaps 2000 years ago, when someone developed a technique of taking material from lesions of mild cases – vesicular fluid, or scab, or pus – and inoculating it in a variety of ways – into the nose, or scratching it into the skin. The intention was to induce a mild case, which would immunize. This was variolation.

Mary Montagu

How did variolation get here?[1] A key figure was Lady Mary Wortley Montagu, a colourful lady, who did not like her family's intentions for her life, and so she ran away when she was a teenager, with the ambassador to the Sultan of Turkey. She contracted smallpox herself, but noticed that there was a community in Turkey that escaped the disease. She made enquiries and found out that they were practising variolation. Being concerned about her own children, she had one of them variolated in Turkey. This was done by a Turkish woman, and it was witnessed by the physician of the embassy, Charles Maitland. She came back to this country in about 1720 and had her second child variolated here by Maitland. That procedure was witnessed by an interesting man: Hans Sloane, one of the towering figures of the enlightenment – the man whose collections are the foundation of the British Museum.

Sloane had close connections with the royal court, and knew Carolyn, the Princess of Wales. Carolyn and one of her children had had smallpox, and she heard through Hans Sloane about the procedure that Mary Montagu had brought back from Turkey. She wanted to know if it would work on her children – so let us read what Sloane wrote: 'To secure her other children, and for the common good, she begged the lives of six condemned criminals who had not had the smallpox in order to try the experiment of inoculation upon them'. Maybe this was one of the first experiments, the first formal evaluation of a vaccine. At least one of those condemned criminals was then made to sleep in the same bed as an active smallpox case, to expose him. It was not the last time that convicts were used for evaluating things in public health, but that is another story. That is the way variolation made it into the Palace of Westminster and this country.

Use of variolation

There are very few data available about the practice, but variolation was very widely used – hundreds of thousands of people throughout Europe, let alone large numbers of people in Asia, over hundreds of years. In the West, some variolators set themselves up in business, and some of them became very well-known, such as Thomas Sutton who had a variolation franchise in 40 cities of Europe. Such a practice was not without risk: scraping pus, vesicular fluid, and scabs from one individual and inoculating them into another is not a procedure one would encourage today. Data are not available, but a good many other things must have been transmitted as well. Some of the variolators advertised that only 1% of their subjects died!

Despite such problems the practice spread rapidly in Europe. A particularly interesting example relates to Catherine the Great of Russia, who paid for an English physician, Dr Thomas Dimsdale, to variolate her family. When news of this arrived in France, it prompted none other than François-Marie Arouet de Voltaire to write to Catherine: 'Oh Madam-what a lesson your majesty is giving to our ridiculous Sorbonne and to the argumentative charlatans in our medical schools. You have been inoculated with less fuss than a nun taking an enema. We French can hardly be inoculated at all, except by decree of parliament'.

Daniel Bernoulli

Voltaire was referring in this letter to debates in France over variolation, which ultimately led the French Royal Academy to address the issue. To do this, they turned to one of great intellects of the eighteenth century: Daniel Bernoulli, famed in particular for his work in mathematics and physics. He was invited to examine the smallpox vs variolation problem, and produced a remarkable report: 'an Attempted and New Analysis of the Mortality Caused by Smallpox, and the Advantages of Inoculation to Prevent It'.[2]

In doing this, Bernoulli made another of his many contributions, this time to demography: he developed what is known as the double decrement life table, which is a method for tracing mortality from two different causes. The first life table had been developed by Edmund Halley – the astronomer – in the seventeenth century, on the basis of parish records from Breslau in Germany, as a way of presenting age-specific rates of all-cause mortality. Bernoulli enhanced Halley's table in order to show deaths from smallpox separately from those from all other causes.

Bernoulli did this with differential calculus, developing techniques that demographers still use today. It was ‘double decrement’ because he was able to divide up the deaths according to those that occurred from smallpox, assuming 12.5% incidence per annum, and a 12.5% case fatality rate, vs deaths from all other causes. His table also had columns for those who contracted smallpox each year, those who died, and then the sum of those who had died through cumulative ages.

It is interesting to note that Bernoulli's table started with 1300 births. Halley's life table started with 1000 people – a nice round number – but at one year of age. He knew that the infant mortality was 25%–40% throughout Europe but he did not want to deal with that; so he started with 1000 one-year-olds. However, Bernoulli wished to start at birth, so he started with 1300 births, to make it comparable to Halley's table. According to Bernoulli's calculations, 572 of these individuals – that is about 44% – would survive to 24 years of age, in this population, of whom 94% would have had smallpox, and 8% of them would have died of smallpox. It all makes sense; those are reasonable sorts of numbers, and he did his maths correctly.

Bernoulli did not draw pictures, but his estimates are presented in Fig. 2, showing the numbers surviving by age, up to age 24 out of 1300 births. This illustrates the circumstances in Europe at the time, including the enormous infant and child mortality. It is worth recalling that here in the UK, in 1850, mortality up to age five was still around 30%.

Because of his approach, Bernoulli was also able to illustrate what would be the expected cross-section by age if there were no smallpox (the red line in Fig. 2). He was then able to explore the implications of variolation (he called it ‘inoculation’).

In doing so, he took a very bold step, stating: ‘I am going further. I do not fear to say that even if we were to suppose that the risk from inoculation were as great as to carry off 100 out of 943’ – that is 11% – ‘it would still be a benefit to society’.

His logic is presented in Fig. 3, where the green line shows the expected cross-section age distribution if all babies were

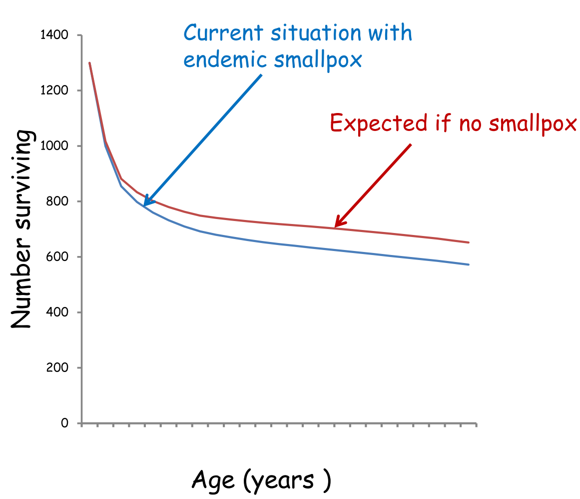

Fig. 2 – Bernoulli's estimates.

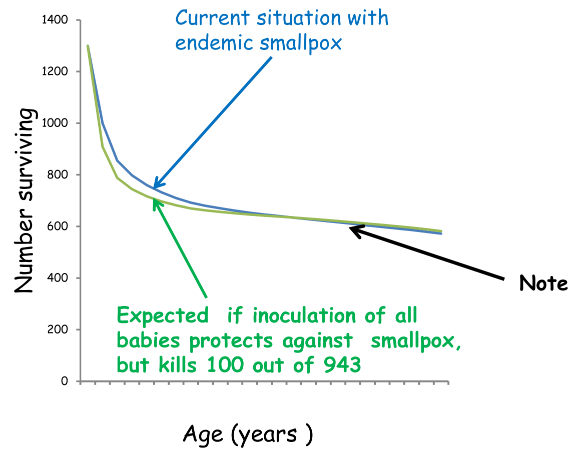

Fig. 3 – Bernoulli's estimates.

inoculated, assuming that 11% died from the procedure, but once inoculated, those who survived did not contract smallpox for the rest of their lives. We see from Fig. 3 that, for children, it is worse with inoculation, in terms of numbers surviving. But Bernoulli noticed that the lines crossed, and that at ages older than 15 there were more survivors if all children were inoculated than if they were not, even if inoculation carried an 11% mortality risk.

‘Useful life’

Bernoulli saw the broad implications of this, and described it thus: ‘We see that the loss would fall solely on children useless to the state and that all the gain would come to the age that is most precious’. In other words, the detriment from adverse effects of variolation in infancy would fall on the young children, whereas the gain in lives and person years is after age 15, among adults. In Bernoulli's words, ‘So it will always be geometrically true that the interest of princes is to favour inoculation, likewise the father of a family with regard to his children’ (if he is interested in long-term survival).

That sort of logic may make us uncomfortable. Bernouilli actually used the term ‘civic life’ for adult life. Some people have talked about ‘useful life’ – useful to the state – recognizing that at age 15 or 18, the economic value of a life changes by some considerations. At that age, the state, the parents, the family, everybody, has invested in the training and nurturing of that individual and he or she is then able to go out and work and contribute to the economy. Bernoulli noted that if the preference should be to maximize the civic person years of life, or person years of useful life, then inoculation should be practiced, despite its acute adverse effects.

DALYs

We may note that this sort of logic is still with us, and is in fact implicit in many calculations of Disability-Adjusted Life Years or DALYs – which have been so important in public health cost-benefit effectiveness analysis for the last 20-odd years. The DALY measure as first described in the World

Development Report 'Investing in Health' includes a weighting of the value of a year of life – peaking at about age 25.[3] This weighting of the value of a year of life is buried in many statistics, for example in many of the global burden statistics. Few people realize that Daniel Bernoulli did it in 1760, and that he brought out the logic in the starkest imaginable example, relating to smallpox and variolation.

There has been a move away from age-weighting in this country, and QALYs (Quality Adjusted Life Years) generally are not age-weighted. This is not an occasion to explore this complex subject, except to say that it is a very important issue and it is not going to go away. Given current and expected demographic trends, shortage of resources, and the increased costs of the technology towards the end of life, practitioners of public health will have to keep facing the issue in years to come.

Edward Jenner

After Bernouilli's contribution, the history of vaccination enters more familiar territory, with the work of Edward Jenner, who is generally credited with the development of the smallpox vaccination – originally by transferring cowpox lesion material from the dairy maid Sarah Nelmes to James Phipps. That was in the year 1796.

Something that is not often discussed is that Jenner did this after almost 100 years of widespread variolation experience in this country. Thus the transfer of lesion material from one person to another had been widely practised long before Jenner. And as the deeper literature informs us, a farmer by the name of Benjamin Jesty, in Dorset, had done it with cowpox material 20 years prior to Jenner. But Jenner was well-connected, even a Fellow of the Royal Society (awarded for his recognition that cuckoos lay their eggs in other birds' nests). Jenner thus knew the scientific establishment, and he could promote his technique. Indeed, he did promote it, and it spread very, very widely – thank goodness for all of us. Smallpox vaccination thus provides a nice example of issues related to attribution and promotion in science.

Variolation ban

By 1807 a National Vaccine Establishment was set up in this country – government funded the production of vaccines with an annual grant from the House of Commons. Then in 1840, 33 years later, one of the first public health acts made variolation illegal. I am not aware of any formal evaluation comparing the effectiveness and risks associated with variolation compared with smallpox/cowpox vaccination, but sufficient influential people must have been convinced that vaccination based on cowpox was preferable, so the previous technique was banned, and vaccination was recommended for all – free of charge – arguably the first free medical service provided in this country.

Death registration by cause

It is interesting to consider why this policy shift took place in 1840. Perhaps the evidence had accrued over 40 years that vaccination really was better than variolation. But something else also happened. Death registration by cause started in this country in 1837, and a very clever man was appointed to look at those data: William Farr, one of the most revered names in the history of epidemiology.

Indirect protection

The country had just gone through one of its periodic smallpox epidemics in 1840, and William Farr was in a position to analyse the data coming to him in the form of death certificates. Clever man that he was, he noticed, when he broke the data down by areas within the country, that smallpox had been disturbed and, in his words, 'sometimes arrested, by vaccination which protected part of the population'.[4] He thus recognized that you did not have to vaccinate everybody in order to stop an epidemic – he recognized indirect protection. Nowadays we talk about 'herd immunity': each time you immunize one child, you reduce by one the sources of infection in the community, and reduce the sources of risk to others in community. Therefore you protect others indirectly. It is a classic example of an externality in public health.

Since this is PHE's inaugural occasion, it is worth pointing out that this organization can take a certain pride in this concept. It was none other than Graham Wilson, the first Director of the Public Health Laboratory Service (PHLS), the grandfather of this organization, who coined the term 'herd immunity' in a classic paper in 1923: 'The question of immunity as an attribute of the herd should be studied as a separate problem, closely related but in many ways distinct from the problem of immunity in individual – an obvious problem to be solved. In what way should resistance be distributed among individuals at risk so as best to ensure against the spread of disease?'[5] That sentence set out one of the major themes in epidemiology and public health of the subsequent century.

Anti-vaccination movements

Following the 1840 legislation, there were further vaccination acts in 1853, 1867, and 1873. A key issue which they addressed was whether it should be compulsory. Vaccinators were paid, avoiders were fined or thrown in jail, and the recommendations became increasingly stringent over those years. This led to resistance and to demonstrations, and triggered the start of anti-vaccination leagues in this country – a movement and point of view which has had long-term effects, and continues still in today's tabloid press.

The UK is well known for the extent of anti-vaccination sentiment and the tabloid headline space that is devoted to it. This goes back, to some extent, to the hard-nosed way that the subject was handled in the mid-nineteenth century.

Anti-vaccination sentiment increased, and ultimately led to a Royal Commission, which met for eight years, from 1889 to 1896. Their report, 493 pages – is a superb document.[6] It is a lengthy argument about effectiveness and risks, and it is convincing. It does not calculate vaccine efficacy as we know it now, but it laid out argument after argument using both cohort type studies, and case–control type logic, showing that the vaccination really did reduce the risk of smallpox.

The Commission also recognized that there were some risks. The way they phrased this is interesting: 'The admission therefore that some risk attaches to the operation, an admission which must without hesitation be made, does not necessarily afford an argument of any cogency against the practice. If its consequences be on the whole beneficial and important, the risk may be so small that it is reasonable to disregard it'. You can imagine them worrying over those words. The appropriate description of risks is always challenging.

To understand the nature of the risks, consider what was actually done in the nineteenth century. The vaccine, supposedly derived from cowpox virus (though apparently it did not come only from the cow in Jenner's barn, and the geneticists now say it even included horsepox genes), was grown in calves. For primary production vaccine material was scratched into the skin of shaved calves, producing massive lesions, the material of which was then scraped off, and called calf lymph vaccine. This was inoculated into individuals, the 'primary' human recipients. As there was often not enough calf lymph to go around, there was also the practice of collecting lesion material (lymph) from primary human vaccinees in order to vaccinate secondary recipients.

All of us can imagine various risks associated with such procedures. The Royal Commission report discusses them, stressing syphilis in particular. Given the scale of vaccination practice, it is credible that syphilitic lesion material might have been transmitted in some rare circumstances, and there were a few case reports of this. Though the Commission did not accept all of the reports, they did accept that a few cases of syphilis had been caused as a by-product of vaccination as it was then practised. Needless to say, the possibility of syphilis as a side effect carried a special concern for the public, given its moral overtones.

The syphilis risk related to the step from primary to secondary human recipients. Though the report did not devote much space to the risks associated with the calf lymph itself, you do not have to be a veterinary surgeon to know that there is a lot of faecal contamination around cattle and calves, and that this opens the likelihood of contamination with tetanus spores. In several countries tetanus was recognized as a major problem associated with primary smallpox vaccination, though it was not mentioned in the Royal Commission report.

Institutional consequences

Recognition of the dangers of contamination of smallpox vaccines led to the first institutions for control of biologicals, with long term institutional implications in several countries. As an example, a particularly important outbreak of tetanus occurred in 1900 among smallpox vaccine recipients in New Jersey, USA, associated with vaccine from a particular vaccine 'farm'. It happens that these vaccines were examined by a Dr Milton Rosenau (who wrote one of the first textbooks of public health) who was working in the Marine Hospital Service Hygiene Lab outside Washington. Rosenau's report describing considerable bacterial contamination in these vaccines is credited as a major influence behind the 1902 Biologics Control Act in the United States – and the hospital service for which he worked became in time the US Public Health Service. The anchor that is on the United States Public Health Service logo has its origin in that evolution, from the Marine Hospital Service lab. And that laboratory itself became National Institutes of Health (NIH). All from the evaluation of smallpox vaccines.

There are similar stories in this country, in that the UK Government Lymph Establishment was established in 1907 in Colindale – which explains the location of the Central Laboratory of the PHLS and today's Colindale site. I understand from Gwyn Morris (General Operations Manager of PHE) that some ex-Central PHL colleagues still remember working in labs with brass rings in the walls, to which the vaccine-producing calves had been tied.

Conscientious objectors

The Commission's acknowledgement of vaccine-associated risks in their main report led to another vaccination act in 1898, which recommended conditional exemption of 'conscientious objectors'. That may have been the first use of the term 'conscientious objector'. It may be that this important concept, with applications in a variety of circumstances today, owes its origins to smallpox vaccines.

George Bernard Shaw

There is a nice twist in the story of smallpox vaccine safety in the late 19th century, in that the guidelines for practice were set out in a handbook: Shaw's *Manual of Vaccination Law*.[7] The irony arises in that the best known Shaw– George Bernard – was a committed opponent of vaccination, throughout his life. Among many Shavian quotations was his quip that: 'As well consult a butcher on the value of vegetarianism as a doctor on the worth of vaccination'.

Another quote from Shaw hits at a particularly difficult point: 'At present intelligent people do not have their children vaccinated, nor does the law compel them to. The result is not, as the Jennnerians prophesied, the extermination of the human race by smallpox; on the contrary, more people are now killed by vaccination than by smallpox'. Hyperbole aside, the difficulty in the remark arises in that Shaw made this particular comment in 1944. The fact that endemic smallpox had stopped in this country in 1934 means that, in a superficial and short-sighted sense, what he said may have been true. The issue of keeping up vaccine coverage in populations where target diseases have reached very low levels or even disappeared is a major challenge for vaccination programmes today. Most young physicians, let alone parents, in this country have never seen a case of measles, or of polio. Convincing the public to accept continued vaccination requires constant reminding that declines in vaccination coverage will bring the return of these infections, as has happened recently with measles. There was still smallpox in most of the world in 1944, though none in England. So Shaw, in that quote, touched upon a difficult point for people who deal with vaccines today and are concerned with keeping up vaccination coverage.

Typhoid

After smallpox, typhoid was the next vaccine widely used in this country. It too has a colourful history involving prominent people: Almroth Wright, the most prominent bacteriologist pathologist in the early twentieth century, George Bernard Shaw, again, David Bruce (the namesake of *Trypanosoma bruceii*, and of *Brucella* – who was the Chief Medical Officer of the British Army), and Karl Pearson, the statistician to whom we owe the chi square and correlation coefficient. These were towering intellects and not one of them was shy about an argument.

A brief version of the story is as follows: killed typhoid vaccine was invented and developed by Almroth Wright, who was working in what is now St. Mary's. It was offered to volunteers – and this is very important – in the army in South Africa and in India. Follow-up data were collected on several of these populations, and they showed lower typhoid incidence and mortality among the recipients than among those who refused or did not take up the vaccination.

There was a contentious debate over these results, and whether to introduce the vaccine as a routine in the army, and Bruce – who did not get along at all with Almroth Wright – said no. The data were given to Karl Pearson, who was not convinced that the differences were real. He was in particular concerned that the vaccine had been given to volunteers, as volunteers are likely to be the sorts of people to take greater care about their health in general, and so the data were not comparing apples with apples. In effect, he argued in favour of a proper controlled trial.

That led to a nasty public argument between Wright and Pearson – in eight successive issues of the *British Medical Journal*. A quote from Pearson: 'I have absolutely no a priori opinions as to the value of Wright's vaccine; I would however be inclined to distrust his science if his letter of last week is a specimen of his logic'.[8]

Despite the controversy, typhoid vaccine was introduced as routine into the British Army by the time of the First World War, and probably correctly so. There was relatively little typhoid morbidity and mortality in World War One, despite the horrendous conditions that so many soldiers had to endure.

Shaw observed the controversy, which no doubt fed his antagonistic views about vaccines, and led to his unflattering portrayal of Almroth Wright as Sir Colenso Ridgeon, in *The Doctor's Dilemma*.

From a broader perspective, the argument between Wright and Pearson in the pages of the British Medical journal, over typhoid vaccines, exemplified, and perhaps fed, tensions between disciplines which affected many institutions over many years during the last century.

Swine flu

Vaccine-related issues continue to provide examples of major themes of science and public health. Despite all the attention paid to swine flu in the last few years, many people do not know that this was swine flu number two. Swine flu number one was itself an amazing story which deserves to be remembered. This takes us back to 1976, an interesting year for infectious diseases – there was Ebola, there was legionnaire's disease and there was swine flu number one.

It has long been known that pandemic influenza comes periodically, and there have been fears that something on the scale of the great Spanish influenza of 1917 might again occur. After the Asian influenza of 1957 and the Hong Kong influenza of 1968, a theory that pandemics might come at 10 year intervals received wide attention in the medical research community. Then, in January 1976, there was an epidemic of respiratory illness among recruits at army training in New Jersey. On 4th February a soldier died, and a 'swine-type' – H1N1 – influenza virus was isolated. There was some evidence that this virus resembled the virus associated with the great pandemic. Subsequent events were dramatic.[9]

Within a month, the US Advisory Committee on Immunization Practices (ACIP) – like the Joint Committee on Vaccination and Immunisation (JCVI) in this country – expressed concern that this might be the precursor of a major pandemic in the next influenza season, and encouraged accelerated production of an appropriate vaccine. It was an election year in the US, and this may have influenced President Gerald Ford to announce that 134 million dollars were set aside for emergency mass vaccination. On 8th April, Merck, which was to be a main producer of the vaccine, got the government to accept all the liability associated with it (a decision which still affects vaccine policies in the USA). On 7th May the ACIP advocated mass vaccination of everyone – the total population of the United States. On 1st October vaccination began. On 2nd November Jimmy Carter was elected president. On 12th November, 10 days after the election, postvaccination Guillain-Barré disease was recognized. The CDC launched various studies. By 16th December, there had been 30 postvaccination Guillain-Barré disease episodes attributed to or strongly associated with the vaccine, and they suspended the entire programme. Ultimately 400 cases of Guillain-Barré were identified out of 45 million who were vaccinated....

Two months later, Joseph Califano, who was Carter's new Secretary for Health, fired David Sencer, the Director of the US Centers for Disease Control, because of what had happened. There had to be a scapegoat. That is another thing that can make one a bit uncomfortable. But that is another important chapter of vaccine history.

Things were done differently in this country. As reported in *Lancet*, on 3 July 1976: 'The newly-isolated human influenza strain containing swine antigens isolated in New Jersey was inoculated in six volunteers. Clinical reactions were mild, although all volunteers were infected'.[10] This was done at the Common Cold Research Centre – a famous, wonderful institution in this country, run by the Medical Research Council (MRC). Because of this result the UK did not take so aggressive an approach, and so escaped the traumatic consequences experienced in the USA.

It is appropriate to reflect on this story in the context of what we have just been through with swine flu number two, on the issue of estimates of severity, and on what the predictions led to around the world, compared to what actually happened. Any such reflections are now *post hoc*, after the fact. But the history is not irrelevant.

Media and public opinion

The tensions between public perceptions and scientific evidence relating to vaccines, which began during the nineteenth-century arguments over smallpox vaccination, remain with us today. Public perceptions are influenced greatly by the media. Some will recall a television programme which was shown in this country in 1974 – a consultant at the Great Ormond Street Hospital showed a child with severe brain damage and attributed it to the child's recent pertussis vaccination. As a consequence of this programme, the coverage of pertussis vaccine fell rapidly from close to 90% down to 35%, with the inevitable result that pertussis case numbers increased immensely. It took 20 years for the coverage to return to the previous level before. That television programme killed a lot of children. And everybody in public health knows about the Andrew Wakefield paper in the *Lancet*, 1998, and consequent tabloid coverage which led to declines in the uptake of MMR vaccine.[11] The extent to which the sensitivity of the media in this country to stories of possible vaccine-associated risks may be attributable to the way in which smallpox vaccination was promoted in the nineteenth century is an interesting question. But inappropriate and negative media coverage is not restricted to vaccines, and includes many aspects of health. It is an important and constant aspect of all aspects of public health.

Misinformation itself is a major public health problem. Among the issues that come up, in this context, are the several motives behind bad tabloid science. For some examples it may be scientists themselves, and their institutions, that are responsible for the misinformation – observations can be exaggerated and hyped simply to attract attention. Some of the guilt is due to ignorance on the part of the media, as reporters may have difficulty interpreting the science – and many of us are involved in various ways in trying to educate science correspondents. And then there is the cynical perspective – the editor who may say 'Truth be damned, I just want to sell copy'. Unfortunately, a six-inch headline about a possible vaccine adverse effect sells newspapers in this country, and newspapers are a business.

Beyond the headlines – what is the ability of the public to understand and interpret the data and arguments and news reports, which have so great an effect on public health. And what does one do about this ? The most obvious solution is surely education – teaching people how to evaluate things critically, how to evaluate evidence. A headline from just a few weeks ago mentions the shortage of science and maths teachers: and this too is a public health problem, in at least two ways. A shortage of science teachers means fewer students being well trained in maths and the sciences subjects required for them to become our successors. We need there to be a lot of good teachers and students for our subject to prosper in the future. And a shortage of teachers will have broad implications on the ability of the public to evaluate scientific data. If we do not train the population in these critical capacities, we cannot expect them to do it better.

The history of vaccines and vaccination is rich with examples of major issues confronting many aspects of public health. Remembering them may help to explain the present and to guide the future experiences of Public Health England.

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Competing interests

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