

John Haygarth's 18th-century 'rules of prevention' for eradicating smallpox

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Introduction

The eradication of smallpox stands as one of the greatest achievements of medical science. When it was finally achieved in 1977, it was based on three principles: find every case; isolate the infected individual; immunise all their contacts. These proved to be sufficient to eliminate the disease because the incubation period of 10–14 days after exposure gave time to mount a defence, and because smallpox only spread by very close contact between infectious individuals, or contaminated materials, and susceptible individuals. However, the crucial features of smallpox, and the possibility of eradicating the disease, were not 20th-century innovations; they can be traced directly to John Haygarth, an English physician, who made his observations in the last 20 years of the 18th century.

Part of the debate over the dangers of partial inoculations revolved around whether smallpox was spread by contagion alone or whether there was some 'epidemic' or 'variola' property of the atmosphere that was required before the disease could spread. Although most people recognised that contact with someone infected with smallpox was dangerous, many doctors argued that something else was required to spread the infection. The answer to this question had an important bearing on strategies to prevent smallpox. If only contagion was important then strict isolation of the patient was required, but if the character of the atmosphere also played a role, then steps to improve the environment, such as removing rotting rubbish, or simply moving to somewhere with better 'air', was equally beneficial. Watkinson¹ and Lettsom² had argued that one of the reasons that inoculation did not spread smallpox was because most of the time the air was not 'variola' so the infection could not spread. Their opponents replied that no one could tell when the air was 'variola' and therefore there was always a risk of inoculation starting an epidemic.

The invention of contact tracing

John Haygarth, a physician in the northern British city of Chester,³ set out to determine exactly how individuals caught and transmitted smallpox. To do this, he carefully traced and followed every single case of smallpox in Chester, in effect inventing what we now know as contact tracing, a very powerful tool for mapping epidemics and finding individuals who require treatment. It is still the basis for studying the spread of HIV/AIDS and for controlling outbreaks of sexually transmitted diseases as well as many infectious diseases. When a new disease, such as SARS or Legionnaire's disease, appears, contact tracing can help to identify the source and the routes by which it spreads. By finding and following every contact of a smallpox patient, Haygarth hoped to discover how smallpox spread.

When he began his investigation he was surprised to find that many experienced and distinguished physicians believed that smallpox could spread through the air over long distances. One friend stated that he knew of cases where the disease had spread over 30 miles. If this were possible, then strategies such as isolating infected individuals to prevent smallpox spreading could not possibly work.

Haygarth confirmed the well-established observation that the fever following inoculation appeared about eight or nine days after the operation and that in natural cases it appeared after about 11 days. Within families, where he could be sure who had been the first child infected, he showed that secondary cases involving other children in the family usually appeared between 11 and 18 days, but a few did not show up for more than three weeks. Using these findings he could analyse everything and everyone with whom a patient had come into contact at the likely time that they had been infected. In the process, he also discovered that smallpox was responsible for about one-third of all childhood deaths in Chester.⁴

He also discovered smallpox was only transmitted from an infected individual to a susceptible individual by close personal contact or by contact with the clothes, scabs or 'serum' (by which he meant the invisible droplets coughed up during active disease). In every case, he could identify the individual who was the source of the infection and the route through which the next case had become infected. He advised doctors not to sit down when they attended a smallpox case to minimise the chance that their clothes would become contaminated. Whatever the 'variolaous poison' was, he showed that it was spread through inhalation since he had uncovered examples of individuals who had caught smallpox after standing very close to someone with the disease, but who had not actually touched them. Only close contact was able to spread the disease. While investigating families where he could be sure of the exact dates when the disease began in each child, he discovered that there was a period of about six days after a child became infected before it became infectious to others. Thus he could conclude that close contact with an individual with smallpox pustules was necessary to contract the disease. He knew of one family in which four children happened to pass by a baby which was covered in recent smallpox pustules. The eldest girl, who was clearly very bright, was able to report that they had all passed within about 18 inches of the child in a narrow passage beside the town walls. She and two of her brothers walked on, but one brother turned back to get a closer look at the sick baby. She was sure that he had not touched the child, but had got much closer than she and her other brothers. Ten days later he came down with smallpox, and then infected his siblings about two weeks later showing that they had all been susceptible to the infection. From this and similar examples, Haygarth concluded that the 'variolaous poison' was quickly diluted in air and that contact closer than about 18 inches was necessary to pass on the infection. The only exceptions were where there had been contact with clothes, household goods, or possibly, food which had been contaminated by a patient with the pustules or scabs still on them. Material collected for inoculation was a special case because it was kept in tightly stoppered vials and retained the capacity to infect for about a year.

Haygarth's theories about how smallpox spread were supported by the observations of physicians in nearby villages during a recent smallpox epidemic. They noticed that the disease spread very rapidly though poor families who were in and out of each other's houses and whose children played together with friends or siblings who had smallpox. But

better off families, who remained within their own homes, often escaped the disease even when they were near neighbours of infected families. No one caught the disease from just walking past an infected house.

Haygarth's rules of prevention

Haygarth distilled his findings as follows (Haygarth, 1793, pp. 57–67)⁵:

Mankind are not necessarily subject to the small-pox, it is always caught by infection from a patient in the distemper, or poisonous matter, or scabs, that come from a patient, and may be avoided by observing these

RULES OF PREVENTION.

I. Suffer no person, who has not had the small-pox to come into the infectious house. No visitor, who has any communication with persons liable to the distemper, should touch or sit down on anything infectious.

II. No patient, after the pocks have appeared, must be suffered to go into the street, or other frequented place.

III. The utmost attention to cleanliness in absolutely necessary:

during and after the distemper, no person, clothes, food, furniture, cat, dog, money, medicines or any other thing that is known or suspected to be bedaubed with matter, spittle, or other infectious discharges of the patient should go out of the house until they have been washed... When a patient dies of smallpox, particular care should be taken that nothing infectious be taken out of the house so as to do mischief.

IV. The patient must not be allowed to approach a person liable to the distemper, till every scab is dropped off, till all the clothes, furniture, food, and all other things touched by the patient during the distemper, till the floor of the sick chamber, and till his face and hands, have been carefully washed...

If the patient was kept away from anyone who might catch the disease, if all those things that he came into contact with were washed and if he and his room were carefully cleaned, then Haygarth believed that smallpox would not spread. Only then was there no risk to others.

Finding that there were no cases that could be traced to susceptible individuals, merely passing by the home of a patient eliminated the idea that a 'variolaous atmosphere' determined when the disease would be contagious. And no cases could be traced to a physician spreading the disease from house to

house on his rounds to visit the sick. Haygarth identified individuals who had been infected in the street by close exposure to someone with pustules, or to infected clothes sent out for washing, but only direct exposure to an active case or the patient's body fluids spread the infection. He wrote: 'The small-pox continues spreading as long as persons liable to the infection approach patients in the dis-temper or infectious matter, either in the same chamber or very nearly in the open air, and then ceases'.

Haygarth strengthened his argument by showing that when two or more individuals together, as would happen in a household, did not develop smallpox, it was highly likely that they had never been exposed to the disease. He calculated that if one in 20 people were naturally resistant to smallpox, the chances that two were resistant were 1 in 400 (the two probabilities multiplied), and that if three were uninfected the probability that all three were naturally resistant was 1 in 8000, making it very unlikely that they had actually been exposed to the disease.⁴ Haygarth asked mathematician friends to confirm his calculations, which they did with slight modifications. Thus, if someone was exposed to smallpox they were likely to develop the disease, and if someone did not catch smallpox it was highly likely that they had not been exposed to it. So if someone in an infected household observed his rules of prevention and did not develop smallpox it was likely that his rules had kept them from being exposed to the disease.

Testing the rules of prevention

In 1778, Haygarth put his rules to the test during an epidemic of smallpox. Twenty families agreed to comply with his protocol, and a charitable society, which he and several friends had founded, offered a reward of 10 shillings if all the rules were observed. An inducement was necessary as parents would have to remain at home to nurse their children and would lose their livelihood until the disease was gone. Without the 10 shillings, the physicians could not expect poor families to follow the rules when they faced starvation as a consequence. The society even had a written contract and appointed an inspector whose role was to visit each infected house every day to determine whether the rules were being followed. Only when the disease had been extinguished and the inspector signed the necessary certificate was the reward paid.

Fourteen families complied in full; six transgressed for a variety of reasons. One family did not realise that one of their children had smallpox until the pocks were fully developed before sending for the

inspector; by then the child had exposed his playmates. In another family, an infected child saw one of his friends playing in the street outside his window and passed him the candy he was sucking. In one case, the inspector turned up too late to verify that the conditions had been observed. What delighted Haygarth was his finding that there were no examples of infection spreading from one family to another from any of the households who stuck to his rules. In several cases, he could show that a secondary infection had occurred when there had been a lapse. Twelve families received the reward, and two, who were too well off to need compensating, were thanked for their care.

Extending the rules of prevention

Haygarth began to wonder whether his 'rules' could be used to prevent smallpox becoming an epidemic by choking off the source of the infection. He was encouraged to develop and extend his 'rules of prevention' by Benjamin Waterhouse, a young American physician, who visited him in 1778. Waterhouse had experience of the successful practice in Rhode Island where epidemics had been absent for many years. Inoculation was still illegal in most of New England but had become acceptable in New York and Pennsylvania. Many New Englanders passed through Rhode Island to reach Long Island, New York, where they were inoculated. Patients were kept in strict isolation while the disease was active and were required to leave behind any clothes that they had used during their stay. If a case of smallpox did appear in Rhode Island the patient was removed to a special 'pest island' until they had recovered. Originally, the patient was transported in a large box which would accommodate a bed and had a lid with several holes to admit air. However 'this formidable apparatus did more mischief, especially to timorous minds, than the disease itself' (p. 143),⁴ so it was dropped in favour of an enclosed sedan chair. If the patient could not or would not be moved, the authorities boarded up the entire street and blocked all traffic until the disease had run its course. Although draconian, these measures had successfully prevented epidemics from developing in Rhode Island.

While Haygarth admired the results of the Rhode Island regimen, he felt that the procedures were unacceptably harsh for England. He demonstrated that his own rules were just as effective by calculating death rates when his rules were in place, and when they were suspended. Mortality was reduced by about 75% when his system was followed, and he showed

that if it was fully observed at all times, the death rate would fall by 97%.

The only problem arose when there were so many cases in town that there was too much work for the inspector, and the regulations had to be suspended. The arrival of a new regiment in Chester without officers started one such epidemic. A passing physician noticed a young soldier covered in pocks and admonished him to take care not to spread the disease, to which the soldier replied 'nobody takes care of me, and I will take care of nobody' and continued on his way. Without officers, there was no one to discipline the men to remain in camp. The resulting epidemic swamped the system.

Poor children in Chester, like poor children in London, bore the main burden of smallpox. To try to save their lives Haygarth established a charitable foundation called *A Society for Promoting General Inoculation at Stated Periods and Preventing Natural Smallpox in Chester*. This attempted to persuade those too poor to participate in a general inoculation by paying a reward. After some debate, the Society's donors agreed that the inducement should be five shillings for the first child, three shillings for the second and one shilling for each succeeding child, to compensate the parents for the time and trouble involved in looking after their inoculated children. An additional five shillings would be paid to the inoculator for his services, but the doctors of Chester united in refusing this fee and agreed to provide the operation for no charge. Haygarth pointed out that the reward for observing the 'rules of prevention' could be omitted during a true general inoculation because when everyone was inoculated at the same time there was no risk of spreading the infection. Although Chester had an inoculation house, it was useless for most cases because endemic disease usually affected children under seven, the age at which they could be admitted to the hospital. If partial inoculation of the poor was attempted, it would be impossible to isolate cases because mothers would insist on accompanying their children to the pest house; and if the mother went, then the rest of the children would have to go with her. There would not be enough room or food to accommodate everyone. It was only practical to inoculate the poor at home and enforce strict quarantine.

Although Haygarth advocated a general inoculation every two years and wanted to encourage the well off to postpone their own treatment until then, the poor would not co-operate. 'In Cross-gun entry in Forrest Street the inhabitants deliberately spread the disease' by exposing their children to an infected

child. Families did not take up the reward for following the rules for prevention for several reasons. Despite the good intentions of the Society, many remained ignorant of the existence of a financial benefit, or were put off by the fact that it was only paid after the disease had completely cleared, and it often took several weeks before the virus had run through a whole family. Also, the inspector was not particularly welcome or efficient. Often he turned up several days after the pocks appeared and by then it was too late for the family to observe the rules even if they had wanted to. The only real success for Haygarth's inoculation scheme was to prevent smallpox spreading through the workhouse.

Ironically, although the 'Rules of Prevention' were not entirely successful in Chester, they were adopted in other northern cities such as Leeds, Newcastle and Carlisle, where, carefully observed, they reduced the death rate from smallpox by about 50%.

The challenge of achieving population level immunity

General inoculation never proved popular in Chester. Groups of children were brought forward when an epidemic threatened, but it proved impossible to persuade all the poor families to accept the operation at the same time. By 1785, the Society found that it had paid out so many rewards for agreeing to isolate cases under the rules of prevention that it was in danger of going bust. The members voted to end the reward for inoculation on the grounds that it was unacceptable to bribe a family to accept a practice if they felt that it was wrong. Of course, when the payment disappeared, the incentive for treatment went with it. Haygarth began to view inoculation as a double-edged sword. Whereas in the past wealthy benefactors and country squires accepted that it was their duty to inoculate those in their immediate community at the same time as they inoculated their own families, once they were fully protected they no longer had a motive to extend the practice to those who could not afford it. Financial support for general inoculation began to melt away, leaving the poor more vulnerable than before. By selfishly inoculating themselves without providing for others, the well-off had made the practice dangerous. Haygarth intimated that it would be a good thing if inoculation were banned unless it was part of a general scheme covering the entire population. Wealthy patrons would then force the poor to accept inoculation as it was the only way they could obtain the benefits for themselves.

Haygarth's careful investigation of smallpox in Chester plus his extended correspondence with physicians in other large northern cities paints a striking picture of smallpox in the last quarter of the 18th century. It was largely a children's disease. Over half the children who died between the ages of two and 10 were killed by it. Even about one in four of the children who died under the age of one had died of smallpox, making all previous estimates of smallpox mortality invalid because they had excluded deaths under the age of two. When Haygarth compared the number of deaths from smallpox to the number of christenings in several places, he came to the conclusion that about one in six of all children died of the disease. He also concluded that almost all the poor had had the disease before the age of seven and that most teenagers were therefore immune. In the Chester militia, less than 10% of new recruits were still susceptible to smallpox and most of those who were immune had suffered from the natural form of the disease. These recruits were then in their late teens so they showed that inoculation was scarcely practised in northern towns in the 1760s when they were infants. While Haygarth's insights into smallpox were all gathered from northern towns such as Chester, Manchester and Leeds, there is no reason to believe that similar conditions did not prevail among the poor of London.

Extensive experience in Chester and Leeds showed that if a family followed the rules of prevention exactly, then there was no spread beyond the initial case. In Lyon, France, a Dr O'Ryan had performed a series of experiments that reflected Haygarth's theory that smallpox did not spread far through the atmosphere. He took groups of children who had not had smallpox and had them sit around a table on which there was placed a cotton ball soaked in smallpox pus. They sat about 18 inches from the infected cotton for an hour and then they were allowed to leave and carefully followed for several weeks. None of them ever came down with smallpox. O'Ryan appears to have come up with these experiments before he knew of Haygarth's suppositions and Haygarth found them welcome proof for his own ideas.

Haygarth's grand unworkable plan for the eradication of smallpox

Encouraged by the success of his rules and by further evidence that smallpox did not spread through the air Haygarth came up with a grand plan. Almost 200 years before the virus was finally extinguished by immunisation, he had done enough to realise that it should be possible 'to establish regulations which would

exterminate the Small Pox from Great Britain'.⁵ He also recognised that eradication would require a firm and efficient system to halt the spread of the infection. He proposed a fully developed network of public health inspectors who, like his agents in Chester, would be responsible for inspecting a community for smallpox and for ensuring that his rules of prevention – effectively, tight quarantine – were observed by any affected family. His inspectors would be entitled to receive information when the code was breached, and they could impose a fine of between £10 and £50 on the transgressors, half to go to the informant and half to the costs of running the scheme. There were to be 500 health districts, each with its own inspector, one physician supervisor for every 10 districts, with the whole network being controlled by five commissioners appointed by the King and based in London. In outline, it was a general method for identifying and controlling any infectious disease. Eventually something like his scheme would become the basis for the Public Health Acts in the 20th century.

Haygarth could not calculate the exact cost of his scheme, but he believed that it would be substantially less than the cost of smallpox. According to his reckoning, there were 38,000 smallpox deaths each year and 190,000 cases, which cost the public £394,500 for charitable care in the pest house, as well as the costs of maintaining the widows and dependent children of the deceased in the workhouse. This huge sum did not reflect the loss of 'innocence, reputation, and that sense of independence which is the surest principle of industry', which resulted when children were raised in the care of the parish (Haygarth, 1793: 148–154).⁵ Even generous payments to the inspectors and overseers would not cost as much.

Only two things stood in the way of Haygarth's grand plan. Despite his argument that the inspector should be seen as a tutor whose function was to educate the poor so that they did not poison their neighbours, the public felt that the system infringed their liberties and it amounted to being spied upon by the government. Also, the plan could not be introduced without legislation and government finance, and neither was forthcoming. Haygarth's visionary plan to eradicate smallpox, which presaged the development of public health laws, was a non-starter.

Author's note

This article is based on Chapter 22 (A Grand Unworkable Plan) in Boylston AW (2012). *Defying Providence: Smallpox and the Forgotten 18th Century Medical Revolution*. ISBN 978-1478232452.

Declarations

Competing interests: None declared

Funding: None declared

Ethical approval: Not applicable

Guarantor: AB

Contributorship: Sole author

Acknowledgements: None

Provenance: Not commissioned; invited contribution from the James Lind Library

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