The Price of POLIOMYELITIS

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Office of Health Economics

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Cover: A photograph of an ancient Egyptian Stele, dating from the 13th century B.C. and considered the earliest known recording of the effects of poliomyelitis. The Stele, depicting an offering to the goddess Astarte is in the collection of the Ny Carlsberg Glyptotek, Copenhagen, and is reproduced with their permission.

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The Price of POLIOMYELITIS

THE risk of permanent paralysis is the predominant feature of poliomyelitis, and the dread of disability has profoundly affected society's attitude to the disease. In the broad medical context of disease in society, acute poliomyelitis is comparatively uncommon. Pneumonia causes over twenty times the number of premature deaths, even though premature deaths from pneumonia are less than a fifth the number twenty-five years ago. The risk of a young adult contracting respiratory tuberculosis was more than ten times greater than his risk of contracting acute poliomyelitis even during the years when the incidence of poliomyelitis was at its height.

The magnitude of the impact of paralytic poliomyelitis on an individual over-shadows all other aspects of the illness. Unlike other dangerous illnesses, the victims of poliomyelitis live on, many of them permanently damaged. The number of disabled grows larger year by year. The disease becomes a social rather than a medical problem, one which is far greater than its annual incidence indicates.

There is a popular impression that poliomyelitis is a disease of modern civilisation, but there is evidence to suggest that it existed as long ago as the time of the Pharoahs. The first clinical description was published in 1789 by the London physician Michael Underwood. He observed that "it is not a common disorder, and seems to occur seldomer in London than in other parts. It seems to arise from debility, and usually attacks children previously reduced by fever; seldom those under one, or more than four or five years old". A fuller and better known description of the late effects of poliomyelitis was published in 1840 by the German bonesetter, Dr. Jacob Heine.[1]

The hygiene and sanitation of modern society indirectly inhibited the growth and development of immunity in communities, leading to a change in the epidemic character of poliomyelitis, deepening its impact. In 1881, a sudden outbreak occurred in the small town of Umea, in the far north of Sweden. Six years later a larger outbreak occurred in Stockholm; during the first half of the century large epidemics occurred in most advanced communities of the world—particularly in the United States.

Poliomyelitis was made notifiable in England and Wales in 1912. At this time, because of the problems of recognising and diagnosing the disease it is very doubtful whether the number of cases reported represented the true incidence of the disease. There is evidence which suggests that an epidemic occurred during the years immediately before the first world war.* For the next 35 years notification of cases tended slowly to rise, but rarely exceeded 1,000 in any one year (*Fig.* 1).

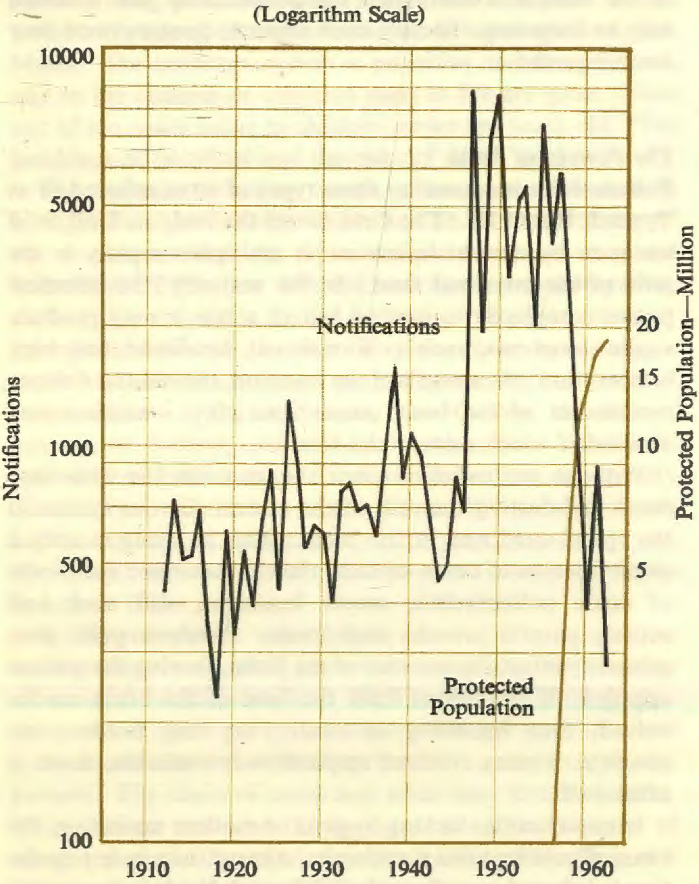
In 1947 the pattern changed dramatically. In that year almost 8,000 cases were notified, a number nearly five times greater than any previously recorded. The next ten years saw repeated recurrence of similar outbreaks. Between 1947 and 1958 over 50,000 persons contracted the disease, of whom probably 32,000 showed some degree of paralysis. Deaths averaged 330 a year; the majority of the victims were young adults.[2]

Vaccination started on a very small scale in 1956. An intensive campaign was launched in 1958. From then on notifications of the disease declined rapidly and in 1962

* A high proportion of the members of the British Polio Fellowship contracted the illness during the years 1907 to 1913. In some cases the illness was diagnosed as pneumonia, and probably fatalities were often attributed to this cause.

Fig. 1. Poliomyelitis. Annual number of Cases Notified. England and Wales. 1912–1962, and Total Protected Population (Initial Course Two Doses) 1957–1962.

Source: Registrar General. Statistical Reviews (Various Years). Ministry of Health Reports (Various Years).



numbered less than one tenth the number in the epidemic years. The polio vaccination campaign makes it possible that by the end of the 1960's poliomyelitis will become even more rare than diphtheria.

The immediate medical problem of preventing poliomyelitis is nearly solved. But even so, there will remain the legacy of the epidemic years, the residual social problem of the large number of victims permanently disabled by the disease. There is a danger that when the risk of the disease is eliminated the problems of the disabled may be forgotten. Society soon neglects diseases once they are conquered.

The Pattern of Polio

Poliomyelitis is caused by three types of virus referred to as Types I, II and III. The virus enters the body in food or in water or by droplet infection. It multiplies rapidly in the cells of the intestinal tract. In the majority, the infection passes completely unnoticed but in a few it may produce vague symptoms, such as sore throat, headache, and high temperature. As a result of the invasion, the natural defence mechanism of the body comes into play, manufacturing antibodies which destroy the virus.

Without antibodies to check the invasion, the virus may reach and destroy the cells of the central nervous system in the spinal cord and in the brain. This happens in only a small fraction of cases, causing the characteristic symptoms of acute poliomyelitis, severe headache, stiff neck and acutely painful muscles and joints. Paralytic polio may primarily affect the muscles of the limbs, leaving the patient crippled. If the nerves from the base of the brain are involved, then breathing or swallowing may become impossible. Unless artificial respiration is available, death is often swift.

In communities lacking hygiene or modern sanitation, the virus of poliomyelitis is endemic. Almost the whole population is infected, usually early in life, and develops immunity. Even though immune, such people can pass the virus in their motions, which may then be carried by flies which feed on the sewage. The infection reaches its height during the summer when flies abound and intestinal disease is most common. In these communities acute poliomyelitis is rare.

The risk of paralysis appears to be lowest early in childhood, and infants and young children may obtain immunity lasting throughout life from an infection which probably passed unnoticed.

This situation existed in Britain, Europe and the United States during past centuries. It still exists in parts of the world with a long history of crowded living conditions, like Malta. The sewerage system is primitive and flies abound, and so the chances of infection early in life are great. Nine out of ten cases occur in children under ten years old. The incidence of paralysis and the risks of death are low.[3]

The opposite situation occurs when a new infection is brought to a community which has no past experience of the disease so that the older people have not acquired immunity. If they are infected and develop poliomyelitis, the risk of paralysis or death are much greater than amongst young children. In the past 20 years there have been a series of epidemics amongst people in remote and isolated communities—in Guam, Samoa, New Guinea, the Gilbert Islands, St Helena, and in Arctic settlements. The Arctic epidemic of 1949 is typical. A small Eskimo community was infected. The brunt of the disease fell on adolescents and young adults; 14 per cent. of the population died, and 40 per cent. were paralysed. There were no cases of paralysis in infants under 3 years.[3]

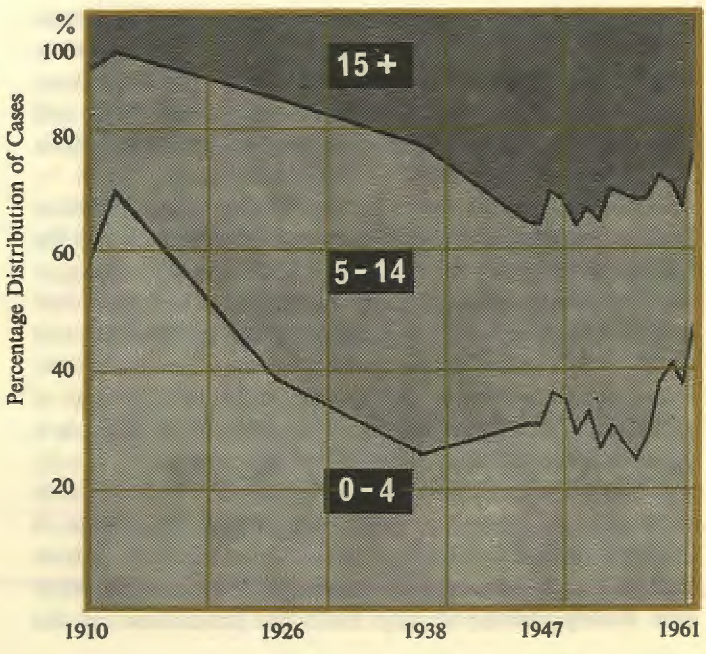
In Britain and in other highly developed communities modern standards of hygiene have gradually reduced the chances of infection early in life. Improved sewerage systems, the eradication of unsanitary living conditions and greater care over infant feeding have all contributed to this process. The chain of cause and effect may stretch further. When the car replaced the horse as the normal means of urban travel, the fly population diminished. The virus, in a sense, may have lost part of its transport system.

Under these circumstances the vulnerability already seen in wholly non-immune communities began to emerge in Britain. Instead of being endemic poliomyelitis became epidemic, and infected those adults who had escaped infection during childhood. By 1947 the proportion of the population lacking immunity apparently exceeded the levels of tolerance; the epidemic between 1947 and 1958 fell heavily on ages up to 30 years—on those whose childhood years were spent in the period after the First World War. Since the decline of the epidemic the proportion of cases in infants under five years, those born since 1958, has risen until it now accounts for half the cases notified (*Fig.* 2).

The factors which changed the pattern of poliomyelitis in recent decades have directly aggravated the social impact of the disease. The risk of paralysis increases with age and the disability of an adult results in immediate hardship.

Fig. 2. Poliomyelitis. Percentage Age Distribution of Notifications for Various Years. England and Wales.

Source: Ministry of Health Annual Reports (Various Years).



Artificial Immunity

IN both the prevention and the treatment of disease, it is a good general principle to induce artificially a natural response. If a disease is capable of producing natural immunity, the same results can be obtained by artificial means. Pasteur showed that bacteria could be killed and injected into animals or man to produce artificial immunity without the animal or the man becoming ill. He thus introduced the use of dead vaccines. But he also showed a more remarkable thing; he showed that, if bacteria were grown under circumstances unfavourable to them, they lost their power to produce disease, yet still retained their power to induce immunity. This decline in virulence is known as "attenuation". In general, live vaccines are more effective than dead vaccines. Since most permanent natural immunity to paralytic poliomyelitis is acquired by mild infection with relatively harmless strains, it was probable on theoretical grounds alone that a similar condition could be induced with a harmless strain propagated in the laboratory. Although this possibility had been appreciated for many years, the technical problems of cultivating and testing the vaccine were very great.

Enders' made the eventual development of vaccines against poliomyelitis possible.[4] He showed that poliomyelitis could be grown in a culture of tissue cells (1949). The virus could infect other cells so that it could be produced in quantity and harvested in bulk. In addition, the virus produced discernible changes in the cells which made it easily detectable. This made possible the full study of the virus in the laboratory and the identification of the type and pattern of infections during an epidemic.

Salk Vaccine (Dead Vaccine)

Salk used Enders' methods to grow poliomyelitis virus in cell cultures (1954). The virus was then killed with formalin. The dead vaccine provided the first acceptable answer to an urgent problem. It proved to be safe and 60–70 per cent. effective in preventing paralytic poliomyelitis.[5] A mass vaccination campaign was started in the United States, 1955. Almost immediately it received a major set-back due to contamination of the vaccine with live virulent virus—the Cutter incident. The mass production of the vaccine had revealed that the question of inactivation of the vaccine was more complex than had been predicted in the laboratory. This led to more elaborate controls and stricter tests for safety by the manufacturers. Since the mid-fifties millions have been vaccinated with Salk vaccine and the vaccine has been proved to be safe, free from local reactions, and up to 90 per cent. effective after three or more properly spaced injections.

Shortly after the first production of Salk vaccine, a British pharmaceutical company announced supplies would be available in 1956.* The Medical Research Council and the manufacturer collaborated in stringent tests for safety and for potency. In the spring of 1956 a relatively small number of primary school age children were given an initial course of two injections. Distribution by the Ministry of Health was stopped during the summer.

In 1957 the campaign was broadened to include infants and all school-age children, expectant mothers and others exposed to special risk. The age range was further extended in 1958 to include adolescents; also in that year third injections were started, to raise the level of immunity.

Up to the end of 1958, the response by the public to the campaign was poor, particularly amongst adolescents and young people (*Tables* 1 and 2). In the spring of 1959 how-

* The major part of research into polio vaccine is usually attributed to the United States. Research expenditure on polio vaccine development by the industry in this country amounted to almost £1½m. In co-operation with the Medical Research Council this work resulted in the production of a vaccine which has seldom been equalled for potency and uniformity.

Table 1 Poliomyelitis Vaccination. Number of persons Protected and Notifications as a percentage annual average 1947–1958. England and Wales 1956–1962.

Source: Ministry of Health Annual Reports (Various Years).

Persons Protected (Millions)

—	Two Doses	Third Dose	Fourth Dose	Notifications per cent. Epidemic Years 1947–1958
1956	0·1	—	—	73
1957	1·4	—	—	111
1958	6·4	0·7	—	46
1959	11·3	6·5	—	23
1960	13·6	10·6	—	8
1961	16·7	12·7	2·4	20
1962	18·0	15·1	3·2	6

ever, the death of a famous and popular footballer focused attention upon the campaign. During 1959 more people received a primary course of two doses of vaccine than in any one year before or since.

In 1960, vaccine was made available through local authorities to all up to the age of 40, and through general practitioners for those over 40 years. Fourth doses for school children were started in the following year.[8] By the end of 1962, about two-thirds of the population under 40 years had received a primary course of two injections (*Table* 2).

Table 2 Poliomyelitis Vaccination. Estimated percentage of population at risk Protected (initial course of two doses) by Ages. England and Wales 1958–1962.

Source: **Ministry of Health Annual Reports (Various Years).**

	0–19 years	20–29 years	30–39 years
	per cent.	per cent.	per cent.
1958	60	5	3
1959	75	47	10
1960	77	54	31
1961	82	63	53
1962	83	65	56

Dead vaccine protects a person from paralytic poliomyelitis, but it cannot replace the natural method of inducing immunity in a population. Nor can it prevent the spread of infection or control an outbreak, it can do one thing, produce immunity in the blood of an individual and so prevent poliomyelitis virus from reaching the nervous system and causing paralysis. It would not protect the individual from becoming infected with a virus or from excreting virus in his motions and thus infecting others. It is not yet certain for how long the protection afforded by dead vaccine will last.

Sabin Vaccine (*Live Vaccine*)
Live oral vaccine imitates the way immunity develops naturally more closely than killed vaccine. Instead of being injected, it is taken by mouth and through a mild infection induces prolonged protection against the disease. The

relative merits of dead and live vaccine are listed in the Appendix on pages 32 and 33.

The development of a live vaccine required the solution of two difficult problems. The first was that the virus must be attenuated, that is to say made mild and incapable of producing paralytic disease in man—even in the most highly susceptible persons or communities. The second problem was that of making the virus harmless not only to the host but also to anyone else to whom it might be transmitted. There is a risk that it might be transferred from patient to patient and in the process become more virulent and thus dangerous to man. This *virulence en passage*, as it is called, is a well known phenomenon. It needs to be guarded against, and checked and counter-checked in laboratories before live vaccines can be used in man. Koprowski, Cox and Sabin (c. 1950) selected strains of poliomyelitis virus and set about the complicated and slow task of producing live vaccine.

The strain eventually developed by Sabin in the United States proved on monkey testing to be the most suitable. The monkey is very susceptible to poliomyelitis virus, and was used by Sabin to show that his vaccine was safe for human use.

Live polio virus vaccine was first used on a large scale in the Congo during 1957. The live oral vaccine was given to all of the few thousand inhabitants of four villages in the Congo where four cases of poliomyelitis had developed. No new cases were observed after the vaccine had been administered. In 1958, a sharp outbreak of poliomyelitis occurred in Singapore. Administration of Sabin vaccine was begun on a large scale. Almost half the child population under the age of ten was vaccinated. It was found that the vaccine conferred a substantial degree of protection after eight or nine days.

In July 1959 there occurred a large outbreak of poliomyelitis in Tashkent in the U.S.S.R. Within four weeks almost 90 per cent. of the child population received a single dose of live oral vaccine. The number of cases of poliomyelitis declined sharply during the following four weeks.

Although a number of cases occurred in those vaccinated, the rate of attack was substantially lower than in unvaccinated children.[6] From 1959, Sabin oral vaccine has been used on a massive scale for routine protection in the U.S.S.R. and in East European nations. In 1960, oral vaccine was used following an outbreak of the disease in Berlin, and was introduced for routine mass vaccination in several cities in the United States, as an alternative to Salk vaccine.

Oral vaccine was first used in this country to control an outbreak in Hull during the autumn of 1961. So great was the desire for protection, that the campaign attracted people from outside the borough area, and so great was the influx that within a few days the number protected exceeded the total population at risk in Hull. The outbreak declined rapidly from the start of the campaign. Because of the very high response to the campaign from the population of Hull, it was impossible to measure the effectiveness of the vaccine by comparing the experience of protected against unprotected groups.[7] From February 1962, live oral vaccine was made available in this country for routine vaccination.

The Impact of Vaccination—England and Wales

The experience in Hull illustrated some of the difficulty in measuring exactly the effects of the campaign on the course of the poliomyelitis epidemic. An epidemic will, like a forest fire, inevitably burn itself out. During the epidemic the numbers infected who consequently develop natural immunity grow rapidly. After a number of years, the supply of vulnerable people becomes exhausted, and the epidemic dies away.

In England and Wales notifications rose to epidemic proportions in 1947 and remained at high level until the late 1950's (*Fig.* 2). The benefits of the vaccination campaign were expected to be seen in 1959 and in fact for that year notifications were at their lowest levels since the epidemic started. It was, however, also an expected low point in the normal cycle of the disease. By 1960, notifications had fallen to less than one-tenth the level of the epidemic years. The cyclical increase in notifications returned in 1961; but a feature of this outbreak was that cases were concentrated in a few areas. The number of notifications in 1962 was 271, the second lowest figure ever recorded in this country since notification started in 1912. Figures for the first half of 1963 are less than one-fifth of the record low figure for the same period of 1962.

Many international studies of the effects of polio vaccine suggest that the decline can be directly attributed to the vaccination campaign.

Economics of Polio Vaccination

THE costs of either preventing or treating poliomyelitis falls upon the National Health Service. The possibility of eliminating the disease provides an example of the classical health economic questions—Is prevention cheaper than cure? Will preventive medicine bring long term reductions in expenditure on health? The balance of costs in poliomyelitis does not present a clear-cut answer. The cost to the National Health Service of preventing rather than treating poliomyelitis works out to be cheaper only if it is assumed that the epidemic would continue at high levels.

The cost of preventing poliomyelitis becomes fully justified when account is taken of the economic and social losses falling upon patients or their kin through incapacity, or premature death. This loss does not fall upon the health service; it is borne partly by the community through social insurance and private aid, but the bulk of it falls upon the patient or his kin. If the elimination of poliomyelitis in fact raises the cost of the health service, it illustrates a further theme of health economics; higher health levels mean greater rather than a lesser expenditure on the National Health Service but this can pay high dividends in preventing social and economic losses falling upon individuals.

Prevention or Cure?

Whether the health service enjoys a net gain from preventing poliomyelitis depends upon a basic principle in the economics of preventive medicine. This principle may be simply stated. The health services will obtain a net gain if the average cost of treating an individual multiplied by the number of cases of the disease is greater than the cost of protection per head multiplied by the total population at risk.

The brunt of treating poliomyelitis falls upon the hospital service. General practitioners are less involved although clearly in a severe local outbreak the demands upon a few doctors may be very great. The work load obviously varies with the epidemic cycles, but even at their height the total burden on the general medical services is slight (*Table* 3).

The difficulties of diagnosis and the importance of early medical care results in far more cases being referred to hospitals than the number eventually diagnosed as having poliomyelitis. The mere existence of an epidemic leads to precautionary provision of medical facilities. Both these factors inflate the total cost of treatment. If all cases of poliomyelitis were eliminated by prophylactic control, the need for precautions would end. A similar situation existed when diphtheria was a common disease; a doctor had to swab the throat of many children in order to exclude diphtheria. With poliomyelitis, essential precautions involve far heavier costs.

Since the vaccination campaign started, there has been a rapid decline in the number of cases of poliomyelitis treated in hospitals (*Fig.* 3). The hospital service is thus already reaping the rewards of the protection campaign. If the disease is virtually eliminated, saving in cost of treatment at epidemic levels would amount to £1½m. a year (*Table* 3).

Clearly, however, it would not be correct to assume that if there had been no vaccination campaign, the incidence of poliomyelitis would have remained at the high epidemic levels of the 1950's. The disease declines naturally, flaring up again perhaps every 10 or 20 years. If the epidemic had returned to, and remained at, the levels experienced before the upsurge in 1947, the costs of treatment would be far lower, about £½m., and so the annual saving would be less (*Table* 3).

Table 3 Poliomyelitis. Annual Treatment and Prevention Costs. Epidemic levels 1947–1958 and 1937–1946 at 1961 levels of prices. England and Wales.

Sources: See Notes below.

	Epidemic Levels 1947–1958	1937–1946
	£m	£m
Treatment Costs		
General Medical Services	0·01	0·00
Hospital Service	1·69	0·33
Total Treatment Costs	1·69	0·33
Prevention Costs		
Existing Population		
(i) Programme to end of 1961 £14·2m		
(ii) Completion £3·7m		
£17·9m	0·89	0·89
Future Generations	0·29	0·29
Total Prevention Costs	1·09	1·09

Notes and Sources

The cost of poliomyelitis to the general medical services is estimated by allocating total general medical services costs proportionately to the number of consultations concerning poliomyelitis. (*Source:* Logan, W. P. D., *et al. Morbidity Statistics from General Practice, Vol.* 1. H.M.S.O. 1958.)

The cost to the hospital services is derived from average duration of stay by poliomyelitis patients in isolation and orthopædic hospitals, the estimated total number of poliomyelitis in-patients and the average cost per in-patient week for isolation and orthopædic types of hospital in 1961. (*Sources:* Registrar General: *Hospital In-Patient Enquiries* 1956–1957 annually to 1959. Ministry of Health: *Hospital Costing Returns* 1960–61. H.M.S.O.)

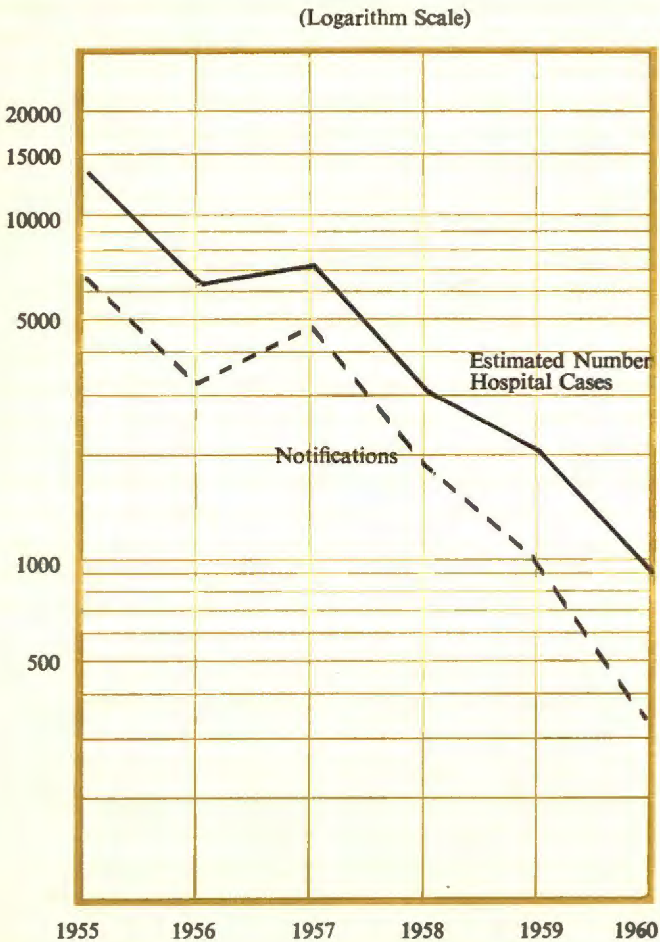
The total cost of the protection campaign to end of 1961 is calculated from the polio vaccine purchases by the Ministry of Health. The cost falling on local authorities has been represented by the increase over the long term trend of expenditure on immunisation and vaccination for the years 1957–1961 (see footnote on page 20). The cost for completing the campaign is calculated from dosage requirements for 80 per cent. coverage of the under 40 years population. The capital cost has been amortised at 5 per cent. to obtain its equivalent annual value.

The cost of protecting future generations is based on the Registrar General future population estimates and allows for 80 per cent. coverage. It is assumed that costs of protection will continue to fall at their present rate for ten years and then level out. The use of oral vaccine should lead to economies in administration while the development of triple or quadruple antigen vaccinations can produce the same result with inactivated vaccine. Costs will also generally fall as the polio vaccine becomes a routine part of infant and child protection.

(*Sources:* Civil Estimates Class V.5—D.9. Supplementary Estimates Class V.5—D.9. Appropriation Accounts Class V.5—D.9. Annually 1955–56 to 1960–61. *Ibid*—D.8 1961–62. Ministry of Health Annual Report, Part I, 1958, p.200; 1959, p.150; 1960, p.251; 1961, p.240.)

Fig. 3. Poliomyelitis. Estimated Number of Hospital Cases and Number of Notifications. England and Wales. 1955–1960.

Source: **Registrar General. Statistical Review (Various Years). Report on Hospital In-Patient Enquiry 1960.**



Prevention Costs

There are two parts to the vaccination campaign; firstly there is the task of protecting the existing population, and secondly there is the long term commitment to protect each new generation as it is born. In economic terms, the first is in the nature of a capital expenditure while the second is equivalent to the annual running or maintenance costs on this outlay.

Up to the end of 1961, the polio vaccination campaign had cost at least £14¼m. Completion of the campaign, at present levels of cost, would involve a further expenditure of nearly £4m. If this capital amount is considered as an annual cost, it is equivalent to more than £¾m. a year (*Table* 3).*

The gradual rise in the age incidence of poliomyelitis is largely responsible for the size of the initial capital outlay. If the disease had remained an illness of children, the health services would have been faced with a population of 10m. rather than 25m. persons to be protected. As it is, in terms of the number of persons needing protection the poliomyelitis campaign is the largest ever undertaken in this country. Compared with diphtheria, poliomyelitis has a relatively low incidence spread over a large number of persons; diphtheria at epidemic levels, showed a higher incidence confined to a smaller section of the community. In

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* The estimated cost of the polio vaccination campaign up to the end of 1961 is £14·2m. It comprises £9·4m. spent on the purchase of polio vaccine and £4·8m. as the minimum amount spent by local authorities on carrying out the programme.

When polio vaccine was first introduced in 1956–7, the average cost per dose worked out at 7*s.* 9*d.* By 1961, this had fallen to 2*s.* 0*d.* Annual purchase of polio vaccine by the National Health Service amounted to 1956, £0·2m.; 1957, £1·2m.; 1958, £2·3m.; 1959, £3·1m.; 1960, £1·4m.; 1961, £1·2m. (*Source:* Civil Estimates Class V.5—D.9. Supplementary Estimates Class V.5—D.9. Appropriation Accounts, Class V.5—D.9. Annually 1955/56 to 1960/61. Ibid.—D.8. 1961/62.)

The costs falling on the local authorities is an estimate based on the pattern of expenditure under "vaccination and immunisation" during the period 1956 to 1961. The cost attributed to the polio vaccination campaign is the amount expended over and above the long-term trend of rising expenditure. The amounts allowed for each year are 1957, £0·4m.; 1958, £1·0m.; 1959, £1·3m.; 1960, £0·9m.; 1961, £1·2m. (*Source:* Ministry of Health Annual Report, Part I, 1958, p.200; 1959, p.150; 1960, p.251; 1961, p.240.)

The estimate for local authority expenditure on the polio vaccination campaign is probably low. Some local authorities included costs of vaccination under other heads such as Maternity and Child Welfare or Prevention and After-Care of Illness. Costs of these items however, have not varied sympathetically with the progress of the campaign. At most, probably an extra £1m. could be allowed to obtain a higher estimate.

consequence poliomyelitis needed a much greater initial outlay for a smaller saving in treatment costs.

The cost of protecting each new generation depends upon the birth-rate. The latest estimate of population predicts a rise in the annual number of births from the present 850,000 a year to 1,130,000 by the end of the century.[10] On this basis and allowing for further falls in the cost of protection as the poliomyelitis campaign is assimilated into local authorities' normal health services, the annual commitment averages about £¼m. a year (*Table* 3).

The total cost of the protection campaign is thus equivalent to an annual expenditure of slightly more than £1m. a year. The saving in treatment costs at high epidemic level exceeds this but at low epidemic levels the saving in treatment costs is substantially less than the annual cost of protection. Given the most likely pattern of the disease uninterrupted by the vaccination campaign, of alternating periods of high and low epidemic periods, savings in treatment costs would, on average, just fail to cancel out the cost of protection. The economic benefits of the campaign are not to be found in savings to the Health Service but in avoiding the losses falling on individuals.

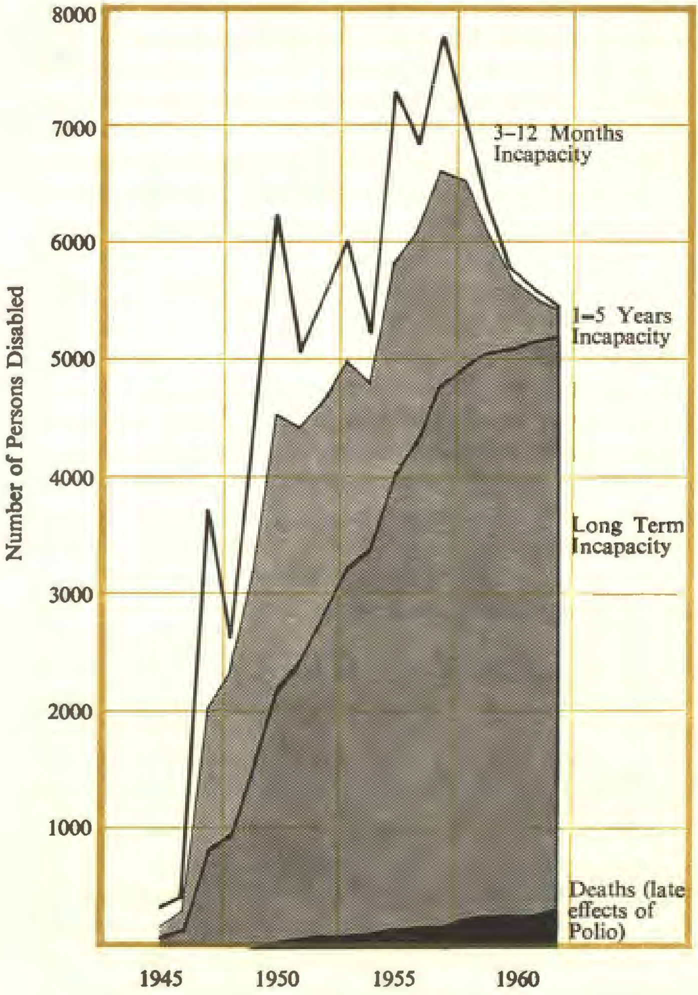
The Impact of Poliomyelitis

The simplest measure of incapacity is an inability to work. The pattern of return to work after poliomyelitis[11] can be used to assess the outcome of the disease. Over half of those who survive the acute stage return to work in less than three months; three-quarters are back within a year. One-tenth, however, remain disabled five years or longer after first contracting the disease.

There are many ways of measuring incapacity and different opportunities for return to work for different skills, ages and sexes. There is also a wide range of personal reaction to incapacity. Because of this, the pattern of recovery can give no more than a general impression of the effect of this disease. It provides merely an indication of the order and not a precise estimate of the numbers disabled by polio.

Fig. 4. Estimated Number of Persons Disabled by Poliomyelitis, by Duration of Incapacity. Constructed Analysis –Cumulative Numbers. England and Wales. 1945–1962.

Source: Fig. 2.



This population fluctuates, increasing with each year's notifications and decreasing when those incapacitated for a short time regain the use of their limbs. The numbers permanently disabled, however, steadily accumulate (*Fig.* 4). The total number incapacitated reached its peak in about 1957, with approximately 7,700 persons suffering from short or long term disability as a result of the 1947–1958 epidemic. From 1957 the number steadily declined with the return to work of those incapacitated for a short period, and with the decline in new cases following the vaccination campaign.

The risk of long term or permanent disability is the predominant feature of this disease. An estimated number of 5,000 persons suffered long term or permanent disability as a consequence of the poliomyelitis epidemic (1947–1958); to this number must be added those disabled in earlier years, bringing the total to between 7,500 and 10,000.

Poliomyelitis is not one of the leading causes of death. During the whole of the epidemic period, no more than 4,000 persons died from acute poliomyelitis, under one death for every ten cases. The important feature of poliomyelitis mortality however, is that the risk of death increases rapidly with age. Half the fatalities were in their twenties. Thus poliomyelitis mortality is greatest in the stage in life where family responsibilities are probably at their highest.

Loss of Earnings

Inability to earn a living is the most obvious economic loss resulting from incapacity, and an estimate of this is sufficient to indicate the order of financial losses individuals suffer. There are many other costs both to individuals and to society, through the losses of skill and training, costs of welfare services and work and so forth. The amounts involved can be great. Only about one-third of those affected by poliomyelitis are of working age; about half of these return to work within a few weeks and the loss of earnings is not substantial. Substantial losses come with permanent disability, as it involves not only the current and potential

Table 4 Poliomyelitis. Loss of Earnings, Current and Potential of Patients together with Social Security Payments Received. Constructed Analysis on epidemic levels 1947–1958. England and Wales. 1961 price and earning levels.

Sources: See *Table* 3.

	Loss of Earnings Present and Potential	Social Security Benefits	Proportion of loss covered
	£m	£m	per cent.
Short-term incapacity	0·03	0·01	35
3–12 month incapacity	0·10	0·03	35
1–5 years incapacity	0·17	0·05	29
Long-term incapacity	2·02	0·31	15
Death Loss	2·02	0·30	15
Total	4·34	0·70	16

Notes

The analysis is constructed on the assumption that poliomyelitis victims formerly enjoyed the same earning and employment experience as an identical age and sex group in the whole population.

Loss of earnings or social security payments for periods of incapacity over one year include not only current amounts but also the present value of future sums discounted at 5 per cent.

Social security benefits are calculated from the scales ruling during April 1961.

The death loss represents the present value of future earnings involved in fatalities. It is the gross amount, i.e. the estimated present value of consumption of those dying prematurely has not been deducted. The social security benefits set against the death loss are for widows' benefits appropriate to a constructed analysis of the marital condition of deaths among male adults.

earnings of those already in employment, but also the loss of potential capacity of those below working age. To the loss of earnings from incapacity, can be added the loss of potential earnings which is involved in death.

The total loss of earnings both current and potential involved each year in the poliomyelitis epidemic amounts to

£4·30m. and all but a minor part of this arises from long-term incapacity or from death (*Table* 4).

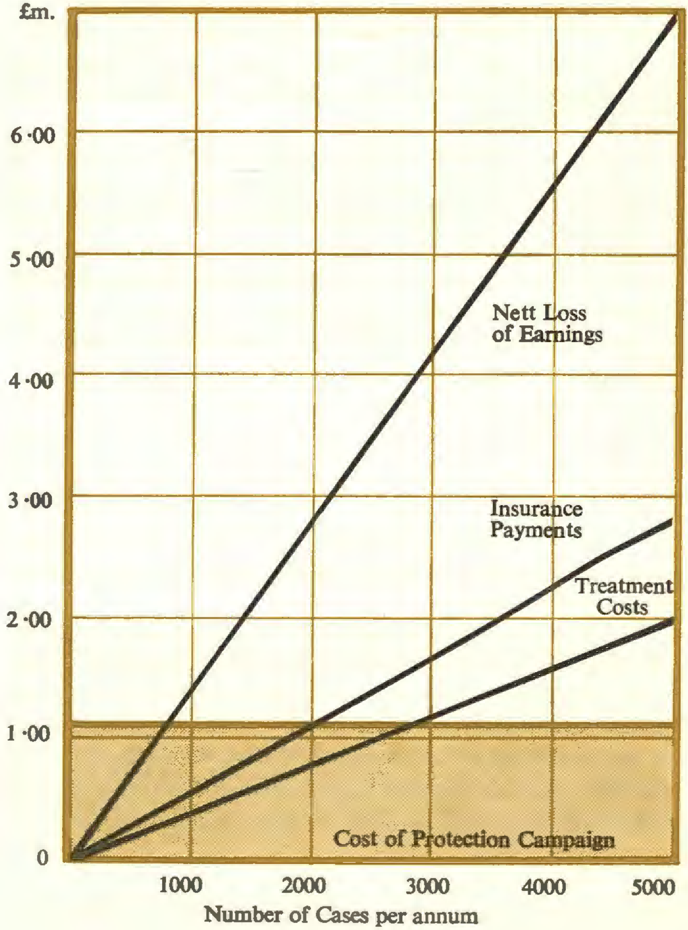
Not all of this loss falls upon the patient. Part of it is shared through sickness and other social security benefits. Permanent incapacity or the death of a husband from poliomyelitis places a long-term commitment on insurance funds. Each year claims arising from the poliomyelitis epidemic were equivalent to a burden on public funds of £0·71m. (*Table* 4).

For persons suffering short-term disability, insurance benefits cover just over one-third of the total loss of earnings (*Table* 4). The coverage is high since annual earning capacity for young adults tends to be low and a high proportion of those of earning age tend to be in employment and thus entitled to benefits. The proportion of lost earnings covered by social security payments for those suffering long-term incapacity is substantially lower. A large number of those suffering permanent disability are below working age and thus have not yet established any claim to sickness insurance benefits. As these persons, disabled in their childhood or in their youth, will probably be unable at any time to join the working population, they will have no claims on the sickness funds. Their loss must be borne privately or through national assistance.

When all the costs and direct savings are brought together, the poliomyelitis vaccination campaign produces an economic gain only if without the campaign the number of cases in any year would have exceeded 800. The bulk of the saving is the avoidance of lost earnings. Public funds show a gain for any year if cases exceed 1,950, while the National Health Service show a net gain only if cases exceed 2,800 (*Fig*. 5).

Fig. 5. Poliomyelitis. Protection Costs and Benefits for Different Levels of Epidemic. Annual Amounts—£million.

Source: Tables 3 and 4.



Social Effects of Poliomyelitis

THE decline of the disease has brought a change in emphasis on the problem of poliomyelitis disability. In the early 1950's approximately half those disabled were probably affected only for a short time. The rehabilitation and welfare programme was directed at enabling these people to return to work. Now, with the steady accumulation of the totally disabled and the decline in short-term incapacity, the main problem of poliomyelitis disability is caring for the welfare and social needs of those permanently handicapped.

The extent to which the paralytic type of poliomyelitis disrupts the life of an individual depends primarily on individual and personal reaction which in turn can be conditioned by the age at which the illness was contracted, on the severity and site of the paralysis, and upon family background and income. Adjustment to any disability is often determined by age. The older the victim, the more difficult is the psychological adjustment. Paralysis in any form increases the dependency of the patient upon others; the psychological problems become greater the more independent and mature the individuals. The younger the victim, the greater in contrast become the questions of personal and physical maturation.

The restriction of the physical movement of a handicapped child may have serious repercussions on his development, as this would limit his contact with people outside his own family especially with children of the same age. Before the passing of the 1944 Education Act, the isolation of the handicapped child was very real. Most of them were housebound. Few, even of those with comparatively slight disability, received a normal education, and in consequence many are now barely literate. The 1944 Education Act made provision for every child to continue his education until at least the minimum school leaving age, whether in hospital, under home tuition, at a special school for the physically handicapped, or wherever possible in a normal school.

The major difficulty today is the employment of those able to work. Those with middling capability present the greatest difficulty. Those capable only of repetitive manual work or those of high intellectual ability are not too difficult to employ.

When an adult becomes paralysed a wider circle of people become affected, especially if the victim is the breadwinner or the mother of a family. Normal family life is disrupted; the financial strain can be severe. Over a short period a family may be able to meet day-to-day expenditure with the help of national insurance or national assistance payments; but the accumulation of financial commitments will mean that another member of the family must assume the responsibility of breadwinner. If it is to be the wife, many wider repercussions may follow. The nature of the problem, however, varies according to the previous occupation of the patient; the more he depended on physical ability, the more severe will be the effect of paralysis. The chairbound solicitor can continue with his work, whereas a similarly disabled window cleaner cannot. He must find some alternative occupation.

The loss of the use of his legs is generally not as serious a handicap as the loss of the use of the arms. A housewife in an electrically-powered wheelchair can lead almost a normal life in an adapted house, whereas a mother with useless arms is not only unable to help with household tasks herself but adds to them. In some cases the household collapses, and the patient must be re-admitted into a hospital or a hostel.

The ability of a patient to cope can be greatly improved by special apparatus. This may include electric spoons, mouth-operated typewriters, micro-film projectors, pulleys and hoists in the bathrooms and bedrooms, and specially equipped kitchens. Structural alterations to the house, sliding doors, adapted staircases, mechanised transport can all help maintain the independence of the disabled. Welfare officers are empowered to make special grants for the provision of equipment. However, much of the equipment is expensive as it has to be modified for specific needs. Therefore, frequently the individual or his family must bear part of the costs. When this extra burden is calculated on top of loss of earnings, the financial burden can be impossible.

Further difficulties in obtaining help through the welfare services can arise through the problems of defining what is essential. For example, a request for an electrically-powered chair may be turned down in favour of an ordinary wheelchair. The statutory power of local authorities in this field is permissive, so that practice varies considerably from area to area.

Voluntary organisations may bridge the gaps left by the welfare state. There are many such organisations, but the largest concerning itself directly with polio victims is the British Polio Fellowship.

The British Polio Fellowship has a total membership of just over 10,000 of whom two-thirds are disabled. The Association is predominantly concerned with their welfare; they have a hostel in Surrey housing up to 18 patients and two specially adapted hotels for members' holidays. The Fellowship is organised into 90 branches throughout the British Isles—the local organisations arrange social activities and assist with members' transport problems. The Fellowship Welfare Committee considers applications for assistance, such as providing special equipment, structural alterations to the house and finding employment and accommodation. In 1962 400 cases were considered, approximately half of these were referred by the local branches and the rest came from hospitals, local authorities, private organisations and from individuals.

The Conquest of Poliomyelitis

The several thousands of persons permanently disabled by poliomyelitis are a legacy of the epidemic years of this disease. It is one of the great triumphs of modern research that this number is not being added to year by year. Notifications in 1962 were only 6 per cent. of the levels ruling just five years earlier. Already if the number of permanently disabled had increased as rapidly as in the epidemic years a further 1,600 persons would have suffered paralysis.

Poliomyelitis, perhaps more than any other disease, has a social rather than a medical significance. The growth of modern metropolitan society has brought a fundamental change in its epidemic pattern. The disease is not an outstandingly large element in general morbidity and the burden of the illness becomes heaviest after the acute stage has passed. The care of the victim is essentially a social problem.

Because of the shock and tragedy of paralysis, poliomyelitis has received perhaps more attention than its comparative rarity might have justified; its social impact demanded its prevention. The elimination of other more common diseases brings immediate economic benefit to the Health Service; but the cost to the National Health Service of the virtual elimination of poliomyelitis has probably exceeded the previous cost of treating its victims. It is important to recognise that the eradication of disease may be a very costly process. It is amply repaid by indirect economic savings and social benefits to the community.

The virtual elimination of poliomyelitis from this country and from other parts of the world is now a practical possibility. Whether the population is non-immune in remote islands or in small communities isolated by ice or deserts, or whether the teeming, unhygienic over-populated areas of the world are maintaining an immune population at the appalling cost of paralysis, there is little doubt that vaccination can effectively and safely eliminate the disease or control an epidemic.

The principles for the elimination of poliomyelitis are straightforward. In every country a mass vaccination campaign is needed to immunise not less than 80 per cent. of the population. Following this campaign, the new-born should be routinely immunised by feeding the vaccine before they have reached the age of one year.

There has been much controversy about the safety of different drugs and vaccines and their cost to the National Health Service. It is easy to overlook the risks of not using them, and the economic impact of the diseases they seek to prevent. The final assessment of any drug or vaccine must be made by comparing the risks and costs of using it against the risks and costs of not using it.

APPENDIX

Live Poliomyelitis Vaccine (Sabin)

ADMINISTRATION

(a) Easy and acceptable to patient.
(b) No injections.
(c) Rapid.
(d) A single feed will suffice in an emergency. Two or three feeds are advised for routine use.
(e) Relatively unskilled attendants required. No apparatus.

Conclusion
(a) Suitable for sophisticated or unsophisticated community.
(b) Cheap to administer.

PRODUCTION

(a) Standardisation and production of potent vaccine relatively straightforward.
(b) Dose—wide margin.

Conclusion
Vaccine has been consistently potent.

PROTECTION

(a) Rapid (days)
(i) The presence of the attenuated virus prevents virulent virus becoming established, so-called "interference protection".
(ii) Antibody begins to appear in about one week giving specific protection (immunity proper).
(b) Relatively enduring (many years).
(c) Produces antibodies in blood and immunity of gastro-intestinal tract and so prevents spread of disease to others.
(d) There is a danger of inefficiency through interference by other (E.C.H.O.) viruses in the community.

Conclusion
(a) Can eradicate virulent poliomyelitis virus from community.
(b) Can control epidemics.

COST

(a) Expensive to produce, inexpensive to administer.
(b) Cost falls rapidly as numbers increase.

Inactivated Poliomyelitis Vaccine (Salk)

(a) Difficult and unacceptable to patient.
(b) Repeated (three or four) injections.
(c) Time consuming and restricted by supply of sterile syringes, etc.
(d) Three or four visits.
(e) Skilled medical attendants and apparatus.

Conclusion
(*a*) *Unsuitable for unsophisticated community.*
(*b*) *Expensive to administer.*

(a) Standardisation and production of potent vaccine difficult.
(b) Dose critical.

Conclusion
Vaccine has failed in some areas through lack of potency and might fail again in countries where biological control is poor.

(a) Slow to develop (several months).
(b) Relatively transient (few years).
(c) Produces antibodies in blood which protect individual against paralysis but do not prevent gastro-intestinal infection and spread to others.
(d) Other (E.C.H.O.) viruses do not interfere with the action of the vaccine.

Conclusion
(*a*) *Cannot eradicate virulent poliomyelitis virus from community.*
(*b*) *Cannot be used to control epidemics.*

(a) Expensive to produce and to administer (see above).
(b) Cost relatively little influenced by numbers.

References

1. Fishbein, M. (Ed.) 1951. *A Biography of Infantile Paralysis*, Philadelphia.

2. Registrar General (Various Years). *Statistical Review of England and Wales. Part I, Medical.*

3. Siddon, M. J., *et al.* (1945). *Quant. J. Med.*, 14, 1.

4. Wilson, J. R. *Margin of Safety*. Collins, London, 1963.

5. Francis, T. *et al.* (1955). *Evaluation of* 1954 *Field Trial of Poliomyelitis Vaccine, Anne Arbor, Michigan.* Michigan University, Poliomyelitis Evaluation Centre.

6. W.H.O. Fifth International Poliomyelitis Congress (July 1960).

7. Ministry of Health (1963) *Report on the Outbreak of Poliomyelitis during 1961 in Kingston-upon-Hull. Public Health and Medical Subjects No.* 107. H.M.S.O.

8. Ministry of Health (Various Years). *Annual Reports, Parts I and II.* H.M.S.O.

9. Registrar General (1961). *Report on Hospital In-Patient Enquiry*, 1956, 1957. H.M.S.O.

10. Registrar General (1963). *Quarterly Return No.* 456. H.M.S.O.

11. Ministry of Pensions and National Insurance. *Digest of Statistics Analysing Certificates of Incapacity*, 1953–54 and 1955–56. M.P.N.I.