**Cleanliness Costs:**

**the evolving relationship between infection and length of stay in antibiotic-era hospitals**

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Hospital acquired infection [HAI] - referred to as ‘nosocomial’ infection in US terminology - emerged as a specific policy concern in the mid-twentieth century, although it has a much longer recognition.[[1]](#endnote-1) This chapter repositions the debate on the history of HAIs, which has to date been focused on scientific understanding of infection through the use of evolutionary paradigms, the development of new approaches such as clinical epidemiology and the enduring fascination with the discovery, use and abuse of antibiotics and associated rise of antimicrobial resistance (AMR).[[2]](#endnote-2) Some of this historical research has marginalised or ignored (by choice or ignorance) the key issue that health care is a *commercial*, as well as a scientific-clinical activity. These lacunae are particularly evident when historians discuss how responses to HAIs resulted in the formation of protocols and teams, which they invariably articulate as comprised of clinical/technical staff (surgeons, physicians, nurses, microbiologists and epidemiologists). There has been minimal recognition that hospital administrators and managers could (and did) play key roles in these developments because of the significant and increasing impact of HAIs on hospital costs, or of the role of economists at national policymaking levels.[[3]](#endnote-3)

To present the history of hospital infection control, or wider AMR, as the result of scientific discovery, or episodic crisis, is naïve, but understandable, if one draws primarily on medical and/or scientific primary literature.[[4]](#endnote-4) This is a literature often produced or co-produced by those whose reputations were built upon it – especially the microbiologists, clinicians and epidemiologists. It is found in elite medical journals such as the *British Medical Journal*, *Lancet*, *Journal of the American Medical Association* and the *New England Journal of Medicine*, and in landmark monographs, such as Macfarlane Burnet’s *Natural History of Infectious Diseases* and Wesley Spink’s *Infectious Diseases: Prevention and Treatment in the Nineteenth and Twentieth Centuries*.[[5]](#endnote-5) As hospital infection control emerged as a distinct discipline it established its own culture and hierarchies – through new societies (national and international) and linked publications including the *Journal of Hospital Infection* and *Clinical Microbiology and Infection.* The emergence of managerial and economic literature on HAIs appears to have lagged behind its scientific and clinical counterparts. This was partly related to the relative priority of the issue for these disciplines, and also their publishing culture (less tied to producing peer-reviewed papers for an academic audience). I suggest that the history of this literature is critical. Publications (journal articles, textbooks, practical manuals) are integral to the explanation for the emergence and prioritisation of economic components in HAI policies – they exemplify the problem of knowledge transfer between disciplines – in this case between non-clinical and clinical hospital employees. It also demonstrates that historians of science, medicine and health would benefit from actively seeking, and exploiting, a wider range of primary sources for their research on infections and infection control. It provokes a reconsideration of our own (historian/social science) publication choices (type of journal, monograph, policy briefing paper) to ensure efficient and effective knowledge transfer and mobilisation, both within academia and, more importantly, into policymaking environments.

This chapter demonstrates that increasing interest in the wider (and often hidden) costs of hospital care, beyond the immediate cost of treating the infected patient (usually the cost of the antibiotics), played a key role in the introduction of hospital infection control policies. It shows that health care financing choices (fee-per-item; prospective vs retrospective payments) were critical in driving the shift in both state-funded and mixed-economy health care systems from traditional ‘blanket’ infection surveillance and hygiene regimes to targeted interventions and management practices (individual and institutional) that drew on economic as well as clinical ‘effectiveness’ data. It establishes the parallel trajectories of intentional shortening of lengths of stay in hospitals (traditionally called convalescence) and the unintentional lengthening of stay due to HAIs. This was observed in all western ‘modern’ hospitals, and the chapter uses examples from the UK and the US to demonstrate the critical role of health care systems – their *modus operandi* and their governance culture – in determining the direction and pace of change in hospital infection control.

**Hospital management for efficiency and effectiveness**

Hospitals consolidated their dominance in the health care systems of high-income economies (and in public expectations) in the second half of the twentieth century. It was careful planning and media savviness that had the Minister of Health Aneurin Bevan photographed alongside a bed-bound hospital patient on the first day of the British National Health Service on 5 July 1948, rather than in a general practitioner’s surgery. During the 1950s and 1960s, increasing numbers of patients were admitted to hospitals for tests, a greater proportion of births took place in hospital, and there were more ambitious treatments, including renal dialysis and chemotherapy that initially could only be delivered in a hospital environment. Yet, as the number of episodes of hospital care increased, the average length of hospital stay followed a different trajectory. After the basic science of physiological and psychological recovery had been established, patient management, especially for surgery, was increasingly viewed from an economic perspective. Medical, managerial and cultural expectations aligned so that recovery came to be seen as something to be achieved as fast and efficiently as possible.

The history of hospital length of stay illuminates the fractured process of knowledge transfer both within and between national clinical cultures.[[6]](#endnote-6) As early as 1886 the French surgeon Just Lucas-Champonniere had expressed the belief that repair was more rapid and more complete when some early patient movement was permitted after surgery and that this also reduced the level of pain experienced.[[7]](#endnote-7) By the end of the nineteenth century early post-operative walking – early ambulation as it came to be known - was a common practice in European hospitals, with an extensive related scientific literature. However a survey conducted in the 1920s suggested that most British, European and American doctors shared a ‘traditional attitude of passive care’ towards post-operative patients.[[8]](#endnote-8)

In the inter-war period two main foci of research interest around convalescence/length of stay emerged: the role of nutrition and return to ambulation after surgery. This was reinforced by the quantity and severity of injuries sustained by troops during the Second World War, which triggered fresh investigations in how to repair human bodies as quickly and fully as possible. Hospitals were forced to critically examine their post-surgical regimes due to reduced bed capacity and staffing levels. British doctors and scientists were also beginning to challenge conventional post-surgical theory, but within a relatively conservative medical culture. In an editorial in 1945 entitled ‘Keep Moving Please’ the *Lancet* had urged a more permanent adoption of early movement, even if this was initially through exercises within bed.[[9]](#endnote-9) A *British Medical Journal* editorial in 1948 generally supported early ambulation, but not early discharge: ‘A surgeon would be in a difficult position if he allowed a patient to be discharged on the fourth day after appendectomy or the seventh day after cholecystectomy (as reported in some American Journals) and that patient subsequently developed a fatal embolism in the second week.’[[10]](#endnote-10)

It is clear from the above discussion that clinicians had been aware of length of stay as a management issue for some time, but almost invariably for the impact that it had on the patient, not the hospital. Robert Pinker used data collected by Henry Burdett for the British Hospitals Yearbooks to demonstrate that average lengths of stay shortened in both voluntary and public hospitals over the period 1921-38, and speculates that for patients with infectious diseases this could have been due to the use of sulphonamides as well as improvements in clinical knowledge and practice.[[11]](#endnote-11) The Creation of the NHS in 1948, with its centrally funded system and hierarchical administration, facilitated the production of information to measure hospital activities. The initial massive over-spend (£305 million) relative to Beveridge’s estimate (£170 million), triggered a sustained interest in understanding how costs were apportioned, and could possibly be controlled.[[12]](#endnote-12) The Hospital In-Patient Enquiry collected a sample of data which could now be used to investigate the efficiency and effectiveness of the service. But there was amazingly little information on what individual hospital procedures actually cost until a basic costing scheme was introduced in 1950. Even then the data was not easy to interpret, and few analyses were returned from the Ministry of Health to the regional boards and their hospitals.

The 1956 Guillebaud enquiry into the cost of the NHS used a novel social accounting methodology, pioneered by the economist Brian Abel-Smith, working with the social administration guru Richard Titmuss. It opened up broader discussions on what constituted acceptable variability around NHS norms.[[13]](#endnote-13) Yet even before the first significant economic analyses of the NHS, especially Martin Feldstein’s 1963 study ‘Economic Analysis - Operational Research and the National Health Service’, the NHS at the regional level was responding to pressures on the service, through innovative schemes that brought together clinicians and administrators.[[14]](#endnote-14) Controlled trials were being conducted in hospitals, with mixed motivations: to identify the most effective recovery process for the patient, but also the most efficient use of healthcare resources.

Parallel to concerns about variations in lengths of stay for specific procedures, such as hernia repair, appendectomy, hysterectomy, were also concerns about variability between clinicians and across NHS regions. Some of this was linked to factors such as bed supply, as the US economist Milton Roemer notably demonstrated with his theory that ‘a built bed is a filled bed’ (i.e. the more beds, the more use of them in insurance-funded healthcare systems).[[15]](#endnote-15) There was also recognition that convalescence in hospital might reflect the relative availability of domestic care and patients’ socio-economic status. Yet there was an absurdly late recognition in the medical literature that reducing length of patient stays will actually increase the hospital’s costs: as the patient through-put rate rises there will be more investigative procedures, meals, linen changes, etc. A study directed in Manchester in 1962 by the hospital administration expert Teddy Chester, and published by his researcher Beatrice Hunter, attempted to calculate the cost of each patient treated in a hospital (medical, nursing costs, food, laundry, share of the overheads, etc).[[16]](#endnote-16) Similar studies were being conducted in the US by Anne Scitovsky at the Stanford Research Center in California. Specific studies on the inpatient costs of heart disease were undertaken by the University of Louvain Medical School in France, Yale University and the World Health Organisation. The common aim of these projects was to determine whether optimal use was being made of hospital resources. Efficiency was becoming quantifiable and separated from effectiveness.

As the NHS experienced significant financial crises and budget cuts in the 1970s, economists became more influential within its parent government organisation - the Department of Health and Social Security (DHSS) - especially those working from the newly established Economic Advisors Office.[[17]](#endnote-17) In 1977 analysis of data from the Hospital In-Patient Enquiry (HIPE) calculated the average hospital stay at between seven and thirteen days. The average length of stay for general surgery in Britain was already on a downwards trajectory. It fell from 8.9 days in 1974 to 7.1 days in 1984; for appendectomies it fell from 14.9 to 11.9 days, and for inguinal hernias from 7.3 to 4.9 days.[[18]](#endnote-18) The impact of new surgical techniques such as keyhole surgery in the 1980s facilitated shorter lengths of stay and more day surgery. Its widespread adoption also forced changes in hospital practices: patients now required tuition in changing dressings and domestic wound care.

In the US, where a significant percentage of the population have traditionally relied on private health insurance, there was an earlier and more proactive engagement with health economics. This reflected the marketised nature of the healthcare business, in which pricing mechanisms could be used overtly to control demand and supply. The creation of Medicare in 1966 introduced a limited public provision, but always within the broader philosophy of a mixed economy of healthcare. Even non-profit hospitals had to respond to wider fluctuations in demand.[[19]](#endnote-19) Length of US hospital stays appear to have fallen faster than in the UK for most specialities. For example, the average hospital stay for hernias in 1985 was 3.0 days. [[20]](#endnote-20)

**Hospital acquired infection and delayed recovery**

The knowledge that hospital acquired infections [HAIs] delay patient recovery and have a cost is longstanding. Even Florence Nightingale recognised the causative relationship between HAIs and length of hospitalisation in the mid-nineteenth century.[[21]](#endnote-21) Yet, this relationship, and more importantly, the potential to use it to improve hospital efficiency, emerged surprisingly late as a topic of interest and research in twentieth century clinical literature.

HAIs in the mid-twentieth century were partly a reflection of the success of medicine. More patients were being processed through an often static number of hospital beds; subjected to more intrusive diagnostic and surgical interventions which increased the risk of infections – from staff (hidden carriers of staph organisms); from equipment (especially urinary and cardiac catheters); from other patients (interactions in wards and use of shared facilities).[[22]](#endnote-22) From the mid-1940s antibiotics offered another way to treat infections (original and HAI), alongside sulphonamides and isolation practices. Hospitals adopted protocols in which patients were routinely given pre-operative antibiotics as deliberate efficiency strategies that reduced the need for some laboratory screening tests and helped to minimise length of stay post-operatively.[[23]](#endnote-23) Rising levels of HAIs were also integral to the emergence of antimicrobial resistance [AMR], which Alexander Fleming and colleagues had predicted at the dawn of the antibiotic era in 1939.[[24]](#endnote-24) In the 1950s hospital clinicians and scientists such as Mary Barber and her team at the Hammersmith Hospital in London pioneered antibiotic combinations to halt the spread of multiple resistant staphylococcal infections on their surgical wards.[[25]](#endnote-25)

British acute hospitals responded to rising rates of HAIs with a variety of initiatives, including new surveillance regimes that moved beyond the traditional records of wound infections maintained by ward staff and surgeons.[[26]](#endnote-26) The staphylococcal outbreaks of the 1940s and the 1950s stimulated routine recording of infections to detect outbreaks. In 1959 the Torbay Hospital and the Royal Devon and Exeter hospital introduced proactive surveillance by creating a new role of infection control sister [ICS or infection control nurse: ICN], who visited wards to detect infections and worked with laboratory staff to use phage-typing of samples from wounds and noses to identify carriers.[[27]](#endnote-27)

In 1957 Suzanne Clarke at the Virus Research Laboratory at Lodge Moor Hospital in Sheffield, UK, published a paper on sepsis in wounds, with particular reference to *Staphylococcus aureus,* which explicitly analysed the relationship between infection and length of stay. She noted: ‘The average length of stay in hospital of patients whose wounds were infected with Staph. Aureus was found to be five days longer …however, many patients stayed in hospital for more than the usual length of time for reasons not connected with staphylococcal infection. These patients then, owing to their long stay in hospital, acquired *Staph. aureus* in their wounds.’[[28]](#endnote-28) Clarke calculated that each patient with a staphylococcal wound sepsis ‘wasted’ an average 8.1 bed-days.

An indication of the increasing concern about hospital infection control was the publication of the first British textbook in 1960, by Robert Williams, (Arthur) Robert Blowers, Lawrence Garrod and Reginald Shooter: *Hospital Infection: Causes and Prevention*.[[29]](#endnote-29) A scrutiny of the index shows no interest in the costs of HAIs. The preface to the second edition published in 1966 noted the identification of new penicillinase-resistant penicillins, and increases in non-staphylococcal infections. It contained a new chapter on hospital architecture and design that recognised that trying to exclude infections from the operating room would ‘probably be more costly that can be justified by any possible effect in preventing wound sepsis.’[[30]](#endnote-30)

On the other side of the Atlantic in the US, there was a parallel emerging awareness of the wider ramifications of uncontrolled hospital infection. Although in 1965 only sixteen per cent of hospitals had some kind of surveillance programme for nosocomial (the preferred US term) infections, there was increasing interest, including the relationship between infection and length of stay.[[31]](#endnote-31) Larger acute hospitals began to employ infection control staff, and some undertook long-term epidemiological studies, such as those by Maxwell Finland at the Boston City Hospital in the 1950s.[[32]](#endnote-32) The Communicable Disease Center (later the Centers for Disease Control: CDC) established infection prevalence pilot studies in the 1950s in six community hospitals. The Foothills Hospital Wound Study was initiated in 1967 - an ambitious ten year prospective study that analysed 62,939 surgical wounds. It found that infection extended a patient’s hospital stay by an average of 10.1 days. This was later costed at $4,000 per patient for hospitalisation, not including loss of earnings, etc.[[33]](#endnote-33)

In 1968 the American Hospital Association (AHA) published the first edition of its handbook *Infection Control in the Hospital*. Costs barely featured – just one brief mention in the introduction: ‘The financial cost to the patient and to the hospital as a result of nosocomial infection is considerable. If a conservative 2 per cent of 30 million persons admitted to American hospitals each year develop nosocomial infections, which extend their average stay by one day, at a per diem rate of $50, this represents an annual cost of £30 million.’[[34]](#endnote-34) The US CDC, based in Atlanta, Georgia, had already published a first set of nosocomial definitions, which was used in the Comprehensive Hospital Infections Project (CHIP) from 1969 to 1972 and in the National Nosocomial Infections Study (NNIS) from 1970 to 1974. The first international conference on nosocomial infections was held at the CDC in 1970, with around 200 delegates. The proceedings were published as a monograph which was distributed widely to US and Canadian medical schools and other healthcare organisations.[[35]](#endnote-35) Two years later, the Association for Practitioners in Infection Control (APIC) was founded in 1972, with a linked journal.[[36]](#endnote-36) From the early 1970s more US hospitals started to introduce infection control programs, but with little apparent concern for their costs, as most charges were passed on to patients or their insurers.

In 1975, reacting to increasing pressure from the AHA and the Joint Commission on Accreditation of Hospitals, the CDC began the Study of the Efficacy of Nosocomial Infection Control (SENIC), with Robert Haley of its Bacterial Diseases Division in the Bureau of Epidemiology, as the project director. It studied 338 US hospitals selected at random. Cost-benefit analysis was built into the SENIC study from the planning phase onwards. Haley and his team assumed an average nosocomial infection rate of five per cent in the annual 37 million patient admissions to all US hospitals (acute, long-stay, community), which would result in around two million infections annually. Working on an average 1975 cost per infection of $600, this equated to $1 billion p.a.[[37]](#endnote-37) Haley found that nosocomial infections increased the average length of stay, and that the employment of an infection control nurse/physician could achieve an average 32 per cent reduction in infection rates.[[38]](#endnote-38) The SENIC project’s cost-benefit analysis calculated the costs for those hospitals that had an organised hospital-wide infection control programme: an Infection Control Nurse cost $12,000 p.a.; with other costs for infection control physician cover, clerical assistance, etc, the total costs for intensive surveillance of 250 beds would be approximately $20,000 p.a. If this was scaled up to cover all 898,000 US hospital beds in 1975, the cost would be around $72 million. Thus, only six per cent of infections would have to be prevented to offset the costs of having a hospital infection control programme. Haley and his team published the SENIC results widely, but it had little immediate impact on hospital practices.[[39]](#endnote-39) Alongside the SENIC study, other studies were conducted on the relationship between specific nosocomial infections and length of stay. For example, Givens and Ward found that urinary tract infections (many linked to use of catheters post-surgery) extended stays by an average 2.4 days, which in 1980 cost $558 per patient.[[40]](#endnote-40) Epidemiologists not only had to battle with getting accurate costings; developing appropriate methodologies to handle multiple linked risk factors was a huge challenge. Working in Boston in the 1970s, Jonathan Freeman and John McGowan showed that surgical patients experienced the highest risk of acquiring HAIs, and proposed for ‘cost-effectiveness’ that infection control activities should be matched to surgical risk and predicted length of stay. However, one of their biggest challenges was in getting clinicians to routinely and accurately record HAIs in the first place. They suspected that reluctance to do this was linked to fear of ‘legal consequences’.[[41]](#endnote-41)

The US publication of two key hospital infection handbooks marked a sea change in interest. John Bennett and Philip Brachman edited *Hospital Infections*, the first edition of which appeared in 1979.[[42]](#endnote-42) Mary Castle and Elizabeth Ajemian published the first edition of their *Hospital Infection Control: Principles and Practice* in 1980.[[43]](#endnote-43) Bennett and Brachman noted the relationship between nosocomial infections and increased length of stay, and how the increased charges were usually redistributed among different cost centres rather than fully charged direct to the patient or their insurance company.[[44]](#endnote-44)

The second international conference on nosocomial infections was held at the CDC in Atlanta, Georgia in 1980, this time with around 1,400 delegates. The emerging professional support infrastructure of the APIC coincided with the expansion of the scientific data base on infection control that the second international conference had initiated and was facilitated by the increasing use of computers. A slew of publications followed, exploiting the ability to analyse specific types of infections. A study by Haley (with Pinner and Blumenstein) published in 1980 showed that nosocomial urinary tract infections occurred most frequently but incurred only fifteen per cent of the overall costs of the nosocomial infections. However, surgical patients who developed a post-operative wound infection accounted for 48 per cent of the overall costs for nosocomial infections but accounted for only one third of the total infections. The most expensive site per infection was the lower respiratory tract, with thirteen per cent of the total infections accounting for 29 per cent of the total costs.[[45]](#endnote-45) There were wide variations: combined data from the SENIC and NNIS studies purported to show 19,000 deaths annually in the US directly attributable to nosocomial infections, and as a contributing factor in a further 58,000 deaths.[[46]](#endnote-46) But a study by Platt et al., published in the *New England Journal of Medicine* in 1982, estimated 300,000 deaths in the US per annum from nosocomial urinary tract infections alone.[[47]](#endnote-47)

Other studies, such as that by Craven et al. in 1982, demonstrated that it was a good investment to fund educational conferences and journal publications to inform ICPs (infection control practitioners) of new research on cost-effective changes in infection control practices. Their research showed that there was no increased incidence of infection if respiratory or intravenous therapy tubing was changed either at 24 or 40 hour intervals.[[48]](#endnote-48) But sometimes the most basic hygiene policies remained the most effective. Isolation was confirmed as an appropriate strategy in intensive care environments.[[49]](#endnote-49) Studies by Steer and Mallison, and by Condie demonstrated that proper handwashing was the single most important infection control practice and could reduce nosocomial infections by 50 per cent.[[50]](#endnote-50) The rising concerns about indiscriminate use of antibiotics was also finding its way into HAI cost benefit studies, with increasing transatlantic recognition of related literature. Katherine Chavigny and Janet Fischer’s 1984 paper in the Journal of Hospital Infection on HAI risk factors highlighted Price and Sleigh’s study in Glasgow in 1970 in which the elimination of all antibiotics from a neuro-surgical ward almost halved the rate of HAIs.[[51]](#endnote-51)

**The impact of healthcare financing policies on HAIs**

A key driver in changing US policy on treatment and prevention of nosocomial infections came in October 1983, when patients covered by Medicare had their costs reimbursed to hospitals under a new prospective payment system. This used 383 diagnosis-related groups [DRGs] to calculate a fixed reimbursement rate for each hospital-based procedure or ‘product’, for example, appendectomy or hysterectomy.[[52]](#endnote-52) Any additional hospital stay because of nosocomial infection was no longer automatically reimbursed. A study in Massachusetts found that the introduction of DRGs reduced hospital stays by an average twenty per cent.[[53]](#endnote-53) Patients in adjacent beds in an American hospital having the same surgical procedure could find that they had different lengths of stay purely because they had different health [insurance] plans, with those covered by Medicare being discharged earlier than those with private or employer-paid health insurance.[[54]](#endnote-54)

The impact of this change was clear when the second edition of Castle and Ajemian’s *Hospital Infection Control: Principles and Practice* was published in 1987.[[55]](#endnote-55) They noted that the pressure of the DRG (diagnostic-related groups) system had initially led to fears that hospital administrators might perversely scale back infection control work to reduce overheads. In response, some infection control groups seized the initiative and conducted their own cost-benefit analyses to justify their work. One group noted that they ‘calculated that 26 nosocomial infections cost their institution more than $43,000, of which only $1,696 was reimbursable under the DRG system of payment. This was so effective in this institution the [infection control] program was expanded rather than reduced. The hospital expects to more than recover the cost of the expanded program.’[[56]](#endnote-56) Costs of nosocomial infections were increasingly difficult to ‘hide’ in hospital budgets. However, Castle and Ajemian also noted in their textbook that handwashing, long established as the most effective infection control measure, remained ‘the least practiced infection control measure in most hospitals’.[[57]](#endnote-57)

Five years earlier in 1975, the first edition of a British hospital infection handbook had also placed a new emphasis on costs as a reason to improve infection control. Graham

Ayliffe, Edward Lowbury, Alasdair Geddes and J. D. Williams’ *Control of Hospital Infection* included information on prices and suppliers for infection control products.[[58]](#endnote-58) The Preface justified this with a historical quote from Wilson Jameson, Chief Medical Officer for England and Wales between 1940 and 1950, that hospital infection was ‘a steady drain on the hospital purse and efficiency’ and that costs as well as effectiveness needed to be considered.[[59]](#endnote-59)

Increasingly, hospital infection control experts collaborated at the international level in an attempt to influence policy development. In 1977 an international workshop was held at Baiersbronn, Germany, at which Robert Haley presented some early SENIC results.[[60]](#endnote-60) An International Symposium was held at Trinity College Cambridge in 1979, with funding from ICI Pharmaceuticals. It brought together infection control practitioners and surgeons from hospitals in Gothenburg, Oslo, London, alongside staff from the Division of Hospital Infection at the Central Public Health Laboratory at Colindale, London.[[61]](#endnote-61) A key proponent of targeted surveillance was Frans Daschner, an epidemiologist at the University Hospital, Freiburg, who was an active collaborator with US and UK colleagues in testing methods for determining economic costs.[[62]](#endnote-62) He highlighted through a series of publications in the 1980s that German hospitals had no interest in infection control because insurance companies paid the same amount of money for each day spent in hospital irrespective of the patient’s type or severity of illness. In fact, the longer the hospitalisation, the higher the profit for the hospital. German hospitals also spent considerable amounts of money on routine floor and surface disinfection which had no evidence-base. Daschner’s trials, which included reducing the frequency of changing surgical dressings, moving from wet razor-shaving to electrical shavers to prepare surgical sites, and suprapubic bladder drainage instead of traditional urinary catheterisation, had significant impacts on HAI costs. He used his participation at international meetings to urge infection control practitioners in other countries, especially the US, to move from continuous surveillance to surveillance by objectives for economic reasons. He also urged ‘It is of utmost importance to regularly inform doctors about the costs of antibiotics in general, treatment costs for specific infections, and the antibiotic consumption of the department or ward’.[[63]](#endnote-63)

Economics was becoming a more prominent mode of analysis employed at national level in the UK, which facilitated studies that investigated the two-way relationship between HAIs and length of stay.[[64]](#endnote-64) A study undertaken for the Department of Health and Social Security in 1987 calculated that HAIs caused an average additional stay of four days per patient, with a total cost to the NHS (England and Wales) of around £120 million.[[65]](#endnote-65) This was the chronic, ‘hidden’ cost of HAIs: ‘visible’ outbreaks of methicillin-resistant *Staph. aureus* infection (MRSA) could cost around £250,000 per hospital.[[66]](#endnote-66)

By the time Ayliffe et al. wrote the preface to the third edition of their handbook in 1992, economics was a much more prominent theme, with frequent references to costs and benefits. It noted a concern that

high costs of hospital care have had an increasing influence on hospital practices and infection control staff have had to justify their policies and provide evidence of improved quality of care by audit of infection control practices. The increasing involvement of hospital managers and outside agencies in control of infection has led to a tendency for a return of rituals which previously had been eliminated from most hospitals. These are often associated with increased costs without benefit to patients or staff. Examples are microbiological sampling of the environment, increased use of disinfectants in the environment and of expensive single-use products.[[67]](#endnote-67)

By the early 1990s there was an infection *prevalence* rate of around 10 per cent for British hospital patients, mainly of the urinary tract, surgical wounds, lower respiratory tract and skin. The *incidence* rate for infections presenting after hospital admission was slightly lower – Glenister et al in 1992 calculated it at 7.2 per cent for 3,326 patients admitted for general surgical, medical, gynaecology and orthopaedics specialties in a UK District General Hospital. Ayliffe et al. commented in their 1992 handbook edition that now ‘the importance of hospital infection can be considered both in terms of the patients’ illness, and of the prolonged occupancy of hospital beds….The cost of a prolonged stay is a convenient measure of the cost of infection, although it represents a reduction in the number of beds available from the waiting list rather than an actual increased cost to the hospital.’[[68]](#endnote-68) In a section of the handbook entitled ‘Balances of risks of infection and cost-effectiveness of preventive measures’ they noted:

decisions on measures required in a particular situation must be made in terms of possible benefits to patients, benefits to the hospital community, and the cost of measures. Cost benefit is obviously not a term to be used lightly when considering infection in patients or staff, but it is unfortunately a necessity…. A good selective surveillance system is likely to be more cost-effective than routine environmental monitoring, or routine screening of faeces of catering staff or noses of theatre staff; routine monitoring of air or surfaces in operating theatres or pharmacies is an example of a test method which is not related to the risk of infection.[[69]](#endnote-69)

By scrutinising the multiple editions of these key hospital infection control handbooks, published both in the UK and US, it is possible to track the emergence of cost/economics as a significant policy driver. It was also attracting new interest from academic health economists. In 1989 E. Currie and Alan Maynard at the York Centre for Health Economics published a study ‘Economics of Hospital Acquired Infections.[[70]](#endnote-70) A case control study published by Coello et al. in 1993 estimated that 93 per cent of the total additional cost incurred by surgical patients with an HAI could be attributed to an extended length of stay (the rest of the cost being antibiotics, biology tests and radiological investigations).[[71]](#endnote-71) Many of these costs continued to remain ‘hidden’ in the UK NHS as they were not routinely specifically allocated to individual patients.

Jenny Roberts, a health economist at the London School of Hygiene and Tropical Medicine (LSHTM), had a long-standing interest in the economics of infections. In 1993 she began working with colleagues at LSHTM and from Colindale Public Health Laboratories (CPHL) to set up a collaborative study to assess the socio-economic burden of HAI, with funding from the UK Department of Health. Her colleague Rosalind Plowman was subsequently appointed as Project Co-ordinator/Lead, and the findings were submitted to the Department of Health (DH) in August 1997, followed by an extended period of review and discussion before the report was accepted for publication in September 1999. It estimated there were 5,000 deaths a year due to HAIs in the UK, and attempted to calculate the number of years of life lost by these patients. As an indication of the ‘political urgency’ around HAIs, the Department of Health had issued guidelines in 1995.[[72]](#endnote-72) Plowman had also co-authored *Hospital Acquired Infection*, a publication from the Office of Health Economics in 1997.[[73]](#endnote-73) The DH-funded socio-economic burden of HAI study resulted in spin-off publications, including a 1999 report by Plowman et al. which was published by the Public Health Laboratory Service and sent to all UK hospitals. This contained the most detailed breakdown of HAI costs to date, showing that hospital overheads, capital charges and management costs accounted for 33 per cent of the additional costs; nursing care accounted for 42 per cent and medical care for six per cent; operations and consumables six per cent; paramedics and specialist nurses four per cent; antimicrobials two per cent; other drugs three per cent; microbiology tests one per cent; other tests and investigations three per cent. It highlighted the impact on length of stay: acquiring an infection could mean an extra eleven days in hospital.[[74]](#endnote-74) The British government was also becoming more concerned about the parallel issue of anti-microbial resistance [AMR], and in 2000 it introduced a new UK Antimicrobial Resistance Strategy and Action Plan.

In 2000 Jennifer Roberts established the Collaborative Centre for Economics of Infectious Disease at LSHTM, an ambition she had held for some time, and which facilitated a leading role for the UK in hosting international meetings and leading collaborative research. In 2001 the UK National Audit Office (NAO) commissioned a study: *The Management and Control of Hospital Acquired Infections in Acute NHS Trusts in England* from Roberts and Plowman, who worked with Karen Taylor, an NAO audit manager who had developed ‘value for money’ studies since the mid-1980s.[[75]](#endnote-75) They brought complementary expertise, which was reflected in their linked publication *The Challenge of Hospital Acquired Infection*.[[76]](#endnote-76) The NAO study republished the estimates produced by the earlier DH-funded study of 300,000 HAIs and their cost to the NHS of around £1bn. The NAO report hypothesised that if infections could be reduced by fifteen per cent it would release NHS resources valued at £150 million a year (although this did not take into consideration the costs of achieving the reduction, or variations linked to factors such as sites of infection, specialty, etc). The NAO report generated considerable public attention, and called for more information to be collected and analysed on the extent, costs and impact of HAIs. It found that many NHS hospitals were not adequately prioritising resources to tackle HAIs, and made 29 recommendations. Partly in response, the UK government established the Nosocomial Infection National Surveillance Scheme and linked it to new Clinical Governance and Controls Assurance initiatives that the Department of Health introduced in the early 2000s.

In the US, there was a similar increasing willingness to translate HAIs into economic terms, and to use this to bring pressure to bear at national policy level. From October 2008 the Centers for Medicare and Medicaid Services [CMS] no longer reimbursed hospitals for conditions not present on admission. Infections were now also required to be noted on hospital scorecards alongside financial data.[[77]](#endnote-77) Journals on hospital infection control more frequently published papers that combined clinical, epidemiological and economic methodologies. Patricia Stone and colleagues conducted systematic reviews of the US literature in 2002 (covering the period 1990 to 2000) and in 2005 (covering January 2001 to June 2004). They found 55 eligible articles for the first ten year period, but 70 for the second two and a half year period. They found that publications estimating the cost attributable to an infection were almost seven times more likely to be judged of higher quality than studies of the cost of interventions. They recommended the development of more sophisticated mathematical models, training of infection control professionals in economic methods, and significantly, training for journal editors and reviewers in economic methodologies.[[78]](#endnote-78)

**Finding the right language**

But it was not until 2006 that the first publication entirely devoted to the economics of infection was published. *The Economics of Infectious Disease* was edited by Jennifer Roberts.[[79]](#endnote-79) The book had two linked objectives: to introduce economic analysis and its application to those who were involved in infectious disease and its control, and to introduce economists to infectious disease and the challenges that it raised. Roberts’ book resonated with fears that infectious disease was becoming more difficult and costly to control. There were threats of new and resurgent old pathogens, growing resistance of organisms to prophylactic therapies and antibiotics, and the spectre of bioterrorism. All of these had significant economic impacts, and the relationship was reciprocal: the state of the economy, especially investment (or lack of) in healthcare, water, sanitation, education and transport, could also enable infections to flourish.[[80]](#endnote-80)

Roberts presented infection control activities through the language of economics. She suggested it was helpful to see the practice as having the features of a ‘public good’ - a good that is provided or consumed in common. But, alongside the potential benefits of tools such as Cost Benefit Analysis (CBA), Quality-Adjusted Life Years (QALYs), Willingness to Pay (WTP), and Cost of Illness (COI) measures, Roberts placed a warning: ‘economic evaluations are not sufficient. Economists wanting to contribute to efficient policy formation must contribute to the governance debate and indicate the effects of different forms of governance of infectious disease.’[[81]](#endnote-81)

Rosalind Plowman’s chapter in Roberts’ edited book used a literature review for the period 1975 to 2003 to draw attention to the wide range of estimates of HAI costs that could be generated according to the type of analytical tool employed (e.g. cost of illness; cost effectiveness; cost utility; cost benefit analysis).[[82]](#endnote-82) Other confounding factors included hospital-specific treatment patterns, the changing point at which patients were deemed fit for discharge, and the difficulties of calculating the costs of HAIs when the patients re-entered their communities (social care, informal care, district nursing services, loss of earnings, etc). Plowman highlighted the significant disagreements that existed within the health economics community on the most appropriate methods for calculating HAI costs (concurrent; comparative; comparative with matching cases). Her chapter, and that of Nicholas Graves and Diana Weinhold – ‘Complexity and the Attribution of Cost to Hospital Acquired Infection’ - highlighted and epitomised respectively the opportunities and challenges of developing an accessible language in health economics to convey useful findings to policymakers.[[83]](#endnote-83)

**Conclusion**

This chapter has set out two significant trends in hospital-based health care: (1) progressively shorter lengths of stay, especially for surgical procedures (2) increasing attention to Hospital Acquired Infections (nosocomial infections in US terminology). It has demonstrated that the two issues are more linked than hitherto understood. By constructing an ‘economic’ history of hospital infection control, that is to say, by analysing when infection control practitioners turned their attention to the costs and benefits of practising infection control, we can see that the emerging relationship between HAIs and extended (and therefore more expensive) lengths of stay, was an increasingly important factor in the adoption, albeit slow and uneven, of infection control practices and, vice versa, in fuelling attempts to reduce length of stay.

The early infection control studies in the US in the 1960s pre-date the use of DRGs in Medicare, but appear to have been largely ineffective in achieving policy change, precisely because most hospitals operated as independent commercial enterprises, and there was a wide degree of discretion in how much (and how) they chose to reclaim HA1-associated costs from patients and insurers. Daschner’s studies in the German healthcare system, in which all costs were reimbursed by insurance schemes, found a similar disinterest in reducing HAIs for economic reasons. In the UK, where there has been no ‘market’ to drive healthcare costs since the creation of the NHS in 1948, policymakers appear to have responded relatively late to the emergence of the association between HAIs and length of stay as a route into reducing hospital costs and improving efficiency. Despite increasing numbers of studies, perhaps the language of health economics, and internal debates and doubt about what they were measuring, meant that there was an ambiguity about the evidence base. This did not help the nascent hospital infection control experts demonstrate the authority necessary to convince policymakers, or individual clinicians, to take action.

Literature searches, for example in the journal *Hospital Infection Control and Prevention*, demonstrate that these concerns about the relationship between infection, length of stay and costs have often been cyclical. The creation of national and international organisations, such as academic societies and research centres, appears to be critical in establishing and maintaining an analytical focus. This study has also highlighted the importance of building ongoing relationships between clinicians, experts (usually academics) and policymakers. Roberts and Plowman at LSHTM are a prime example of the benefits of maintaining an ongoing collaboration, and acting as a bridge between different government organisations: in their case the UK Department of Health, its arms-length body the Public Health Laboratory Service, and the National Audit Office. There are also ‘costs’ of a different sort involved in such collaboration: results can be taken by one body and repurposed, sometimes losing in translation the accuracy or intent of the original research.[[84]](#endnote-84) Yet, even in the early 2000s, the narrative of studies were still often focused on the ‘novelty’ of HAI findings.[[85]](#endnote-85) The recent costs of HAIs, in the US alone, are staggering: between $28.4 and $33.8 billion per annum.[[86]](#endnote-86) A single surgical site infection (SSI) was estimated to cost as much as $60,000 per patient.[[87]](#endnote-87) With the relentless rise of antimicrobial resistance (AMR), the need for proactive economic analyses is more pressing than ever, yet economists still appear to be some way off securing a routine place in the average hospital infection control team.[[88]](#endnote-88)

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