Hospital infections in Birmingham, England, in the 19th and 20th centuries

Christina R Bradley¹ and GAJ Ayliffe*

This paper was begun by Professor Ayliffe and the week before he died he asked me if I would help him finish it. I think this is a fitting tribute to him that his last paper has now been published.

The 18th-century Midlands Enlightenment saw the sudden emergence of the English city of Birmingham at the forefront of worldwide developments in science, technology, medicine, philosophy and natural history. This was the beginning of a massive growth in population that continued through to the 20th century. The population of 24,000 in 1750 grew to 73,000 by the end of the 18th century, to 140,000 by 1841 and to over 500,000 by the end of the 19th century (Upton, 1993). This population growth led to overcrowding, poor sanitation and an increased need for hospitals, particularly in the industrial areas. However, hospitals built during this period often proved inadequate for the requirements.

The General Hospital in Birmingham was opened for patients in 1779; by 1790, 700 patients were being admitted with a remarkably low mortality rate of 3%. However, the annual reports in this hospital during the 19th century showed many community-acquired infections were treated, including typhoid, smallpox, dysentery and pulmonary tuberculosis. Overcrowding became an increasing problem and by 1857 it was reported that all wards were overcrowded. In 1860, no less than 10 children with burns were reported in a ward containing only four beds. In 1862–1863, the medical Board called the special attention of the hospital management to the bad sanitary state of the hospital as manifested by the unhealthy appearance of wounds and slow recovery of patients. Infections reported that year included smallpox (six cases), typhoid fever (24 cases), pulmonary tuberculosis (43 cases), phagedaena (hospital gangrene) (20 cases) and erysipelas (21 cases). Already, hospital-acquired infections were becoming important. In 1865–1866, a new hospital wing was built which included a fever ward. Thereafter phagedaena was no longer reported in the hospital, although erysipelas, cellulitis and pyaemia (septicaemia resulting in metastatic abscess formation) (11 cases) were still common. At this time, miasmas (unpleasant or unhealthy smell/vapour) were still considered to be mainly responsible for infection although contagion was being increasingly recognised as possibly more important. Good hygiene and avoidance of overcrowding were still the main preventative measures and were, to some extent, effective but the discovery of bacteria

as a cause of infections was being reported by Pasteur, Koch and others. Lister was already working on his antiseptic methods and surgeons in many hospitals across Europe began to take an interest in the prevention of hospital infection. By now, many new, often specialist, hospitals were being established by medical practitioners in Birmingham and some of these doctors were pioneers in the field of infection prevention and control.

The Queen's Hospital, or Royal School of Medicine and Surgery, whose first president was Prince Albert (the Consort of Queen Victoria), opened in 1841. After opening, the hospital expanded rapidly and by 1845, separate wards were added containing 28 beds for infectious and contagious disease cases. Dr Joseph Sampson Gamgee was appointed to the Queen's Hospital in Birmingham in 1857. He studied wound care and believed that dry absorbent dressings were optimal for wound healing where he introduced the well-known Gamgee dressing. Although he had a great respect for Lister, he did not believe that a germ theory should be used as a foundation for surgical procedures. He opposed the use of strong phenolic solution but did believe in absolute cleanliness and was probably the first surgeon in Birmingham to wash his hands before operating.

In 1871, Lawson Tait, a nationally recognised surgeon who had a special interest in gynaecology, was appointed surgeon to the newly incorporated Birmingham and Midlands Hospital for women. He wrote an essay on mortality in British hospitals (Tait, 1877). Although he identified that large hospitals were more unhealthy than small, he found that accurate statistics were difficult to obtain and that multiple factors influenced differences in mortality, making comparisons between hospitals difficult. A similar problem still exists today with hospital league tables. Although Lawson Tait was a supporter of the germ theory, he also disagreed with Lister and considered soap, water

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¹Hospital Infection Research Lab, Department of Clinical Microbiology, Queen Elizabeth Hospital, Birmingham, UK

*Deceased

Corresponding author:

Christina R Bradley, Hospital Infection Research Lab, Department of Clinical Microbiology, Queen Elizabeth Hospital, Edgbaston, Birmingham, B15 2GW, UK

Email: tina.bradley@uhb.nhs.uk

and general cleanliness (including boiling his instruments) to be as effective as phenolic solutions. In a short study on ovariectomies in 1877, he reported deaths in 3/50 operations. Two of the deaths occurred in the 29 operations that used the antiseptic technique of Lister, while one death occurred in the 21 operations that used no antiseptics. Lawson Tait was a meticulous surgeon and believed his improved results were due to increased skill and experience. However, his operations were mainly clean and quite different from the traumatic surgery carried out by Lister. Lawson Tait was in effect one of the earliest surgeons to use the aseptic, rather than antiseptic, technique.

Research into hospital infection as we know it today really began in Birmingham during World War II. The old Queen's Hospital reopened as the Birmingham Accident Hospital in 1941 with William Gassane as Clinical Director and is generally recognised as the world's first trauma centre. Wound infection was a major problem at the time, both in war wounds and in industrial injuries sustained locally in Birmingham. Gissane persuaded the UK Medical Research Council (MRC) to set up a wound research unit with Professor Ashley Miles, a distinguished bacteriologist, as the Director. He was joined by a young bacteriologist, Robert Williams, who later became a leading national expert in hospital infection. After leaving Birmingham, he became Director of the Public Health Laboratory Service in London and President of the Royal College of Pathologists. The research laboratory was housed in a converted pre-Listerian operating theatre on the top floor of the Accident Hospital. The team found that in open war wounds, staphylococcal and streptococcal cross-infection was common; haemolytic streptococci increased in wounds from about 8% to 30% over 2–4 weeks. The group was also involved in the development of the 'no touch' dressing technique for reducing cross-infection of wounds.

In 1943, an MRC Burns Research Unit was set up in Birmingham by another distinguished bacteriologist, Leonard Colebrook (Hardwicke et al., 2015; Lowbury, 1983). In addition to studies on asepsis and use of topical penicillin, he introduced a ventilated dressing room and demonstrated a considerable reduction in airborne bacteria. He designed the unit with an engineer, Robert Bourdillon, who devised an air sampler, a modification of which is still in use (Bourdillon et al., 1941). Edward Lowbury was appointed bacteriologist to the burns unit on Colebrook's retirement in 1949. He continued with clinical trials and confirmed the effectiveness of the ventilated dressing room in terms of a reduction in clinical infection as well as a reduction in airborne bacteria. He also studied the use of plastic isolators in the prevention of burns infections and collaborated with burns surgeons in a series of controlled trials of topical antimicrobial agents. He was particularly interested in the emergence of antibiotic resistance and its prevention and kept a unique record of resistance changes in the burns unit until his retirement in 1979. The burns

research team, together with the Hospital Infection Research Laboratory (see later), identified a plasmid encoding for resistance to carbenicillin, the first penicillin with activity against *Pseudomonas aeruginosa* (Lowbury et al., 1969). Other important work during Lowbury's tenure included studies on surgical handwashing, wound healing and even a vaccine against *P. aeruginosa* which was successfully tested in India but never developed commercially. Edward Lowbury received many awards and honorary degrees for his work in medicine, and also as a poet, and was appointed to the Order of the British Empire on his retirement (Ayliffe, 2007).

Concern about the general problem of infection in hospitals in the Birmingham Region led to the establishment of the Regional Hospital Infection Research Laboratory (HIRL) at the Dudley Road Hospital (later the City Hospital) in Birmingham in 1964. This laboratory was administered by the MRC Burns Unit and Edward Lowbury became the Honorary Director while retaining his post at the Burns Unit. Graham Ayliffe was first appointed there as an MRC Senior Scientific Officer and became Director of the Laboratory on Lowbury's retirement in 1979 and Professor of Medical Microbiology at the University of Birmingham in 1980 (Bradley, 2017).

The initial functions of the HIRL were to assess the extent of infection in local hospitals and to determine the causes of infection and recommend preventative measures. Later, this evolved into a special interest in disinfection and sterilisation. In the early days, the laboratory investigated outbreaks of infection in the region. These were mainly caused by *Staphylococcus aureus* and *P. aeruginosa*, but other problems encountered included outbreaks arising from operating theatres and *Klebsiella* and *Salmonella* in maternity units.

During the first years of the HIRL, over 38 hospitals in the region were visited or revisited by a bacteriologist or Senior Technical Officer, together with Kathy Brightwell, a research nurse who became a founder member and treasurer of the Infection Control Nurses Association in 1970. The team accumulated data showing that the prevalence of hospital-acquired infection was around 10%, similar to that in a much later national UK prevalence study in 1980, and to prevalence surveys performed in hospitals across the developed world (Ayliffe et al., 1977). Subsequent surveys focused on Dudley Road Hospital in Birmingham showed a reduction in the prevalence of infection to around 5% and proposed the concept of an 'irreducible minimum'. Detailed analysis of the combined prevalence surveys showed that the main factors associated with wound infection and acquisition of resistant strains of *S. aureus* were patient-related, such as age, length of stay, use of antibiotics and type of wound (clean or contaminated). Although overcrowding also appeared to be important, other infrastructural factors such as age of hospital, structure and facilities, and overall cleanliness were surprisingly not clearly related

to the risk of infection. More cross-infection was found in large hospitals, which was considered to be probably due to mainly to the type of patient and complexity of surgery.

A mathematical model of the combined results of the prevalence surveys was developed from existing models in the car industry by Dick Etheridge and Brian Bibby of the Aston University Engineering Department. This was used to predict the likelihood of emergence of surgical wound infection and the probability of a patient being colonised by antibiotic-resistant *S. aureus* (Bibby et al., 1986).

The experience of the HIRL was used to develop regional recommendations for controlling infection. These were later developed into a handbook on Control of Hospital Infection initially edited by EJ Lowbury, G Ayliffe, A Geddes and D Williams (Lowbury et al., 1975). First published in 1975, this handbook has been used widely both nationally and internationally and is now in its fifth edition as *Ayliffe's Control of Healthcare-Associated Infection*, edited by Adam Fraiese and Tina Bradley (Fraiese et al., 2009).

During the 1960s and 1970s, the HIRL made major contributions to our understanding of cross-infection with *S. aureus*. Carriage sites such as the nose and perineum were described and spread on skin scales was observed. A study on normal subjects confirmed that male carriers dispersed more staphylococci than females, but the real hazards to patients were heavy staphylococcal shedders (dispersers) with discharging wounds or disseminated skin lesions. Removing the disperser from the ward to isolation usually ended the outbreak of infection. Contaminated skin scales from the disperser fell slowly to the floor or onto other surfaces or patients, but once on the floor, scales could only be raised with difficulty (Noble et al., 1976). Disinfection of the surface was initially effective, but recontamination occurred rapidly in busy wards reaching equilibrium in 1–2 h. Routine daily disinfection was therefore of limited value. Patients, and not the dry environment, were the important factors in the spread of infection which not necessarily related to physical cleanliness (Ayliffe et al., 1967).

An experimental surgical ward was used to study the effect of different methods of isolation and ventilation systems (Ayliffe et al., 1971). There were 14 beds in an open ward and five single-bedded rooms equipped with different plenum ventilation systems or recirculators. A cubicle with positive pressure ventilation was shown to reduce hospital-acquired staphylococcal colonisation.

In the 1970s, antibiotic-resistant staphylococci, including MRSA, were causing major problems and the experimental surgical ward was converted into single ventilated rooms for both source and protective isolation (Ayliffe et al., 1979a). The purpose was to determine the effectiveness of an isolation ward in reducing cross-infection in a large general hospital. In fact, because a reduction in colonisation and infection with antibiotic-resistant staphylococci was already occurring, both within the hospital and elsewhere across

Europe, it was not possible to demonstrate the impact of an isolation ward. One possible reason for this decline was the almost complete discontinuation of use of tetracycline, to which most epidemic strains had become resistant (Ayliffe et al., 1979b).

HIRL staff were closely involved in the setting up of the Infection Control Nurses Association (ICNA) in 1970 and the Hospital Infection Society (HIS) in 1980, as well as contributing actively to these and other national and international learned societies, including the Central Sterilising Club, the Institute of Decontamination Sciences and the International Federation of Infection Control. Edward Lowbury was the first President of HIS; Graham Ayliffe had the unique privilege of becoming President of ICNA, HIS and the Institute of Decontamination Sciences, as well as Chairman of the Central Sterilising Club and the International Federation of Infection Control.

As noted earlier, the HIRL developed an international reputation for its work on disinfection and decontamination. Alcohol hand rubs for hand disinfection in hospitals were widely used in Europe in the 1960s and 1970s, but not in the UK or the USA. The HIRL led the use of hygienic hand disinfection with alcoholic solution in the UK, first in the Burns Unit. The HIRL undertook a collaborative study with the Committee for Standardisation of Disinfectants in Europe that showed that alcohol was more effective than other existing agents (Ayliffe et al., 1978). Despite this work, alcohol remained unpopular for hand hygiene in the UK until very recently. The HIRL also demonstrated that there were drawbacks to the use of alcohol for hand hygiene. First, using a dye test, Lynda Taylor, the infection control nurse in the laboratory, showed that there was often a failure to cover all of the hands (Taylor, 1978a, 1978b). This led to the development of a new technique for hand disinfection which is now widely used all over the world (Ayliffe et al., 1978). Second, alcohol is not active against all viruses. Work by Ruth Tyler and Tina Bradley from HIRL showed that while the herpes viruses were sensitive to alcohols, some non-enveloped viruses, such as polioviruses, were more resistant and hand washing with soap and water was still required during outbreaks of enterovirus infection (Tyler and Ayliffe, 1987; Tyler et al., 1990).

As flexible endoscopy became more common, outbreaks of infection related to inadequate decontamination of these instruments became more common. The HIRL worked with manufacturers (and continues to do so today) to improve the cleaning and disinfection of these devices (Babb et al., 1981, 1984; Griffiths et al., 1997, 1998).

Over the years, the HIRL has collaborated on many more projects with many more researchers than is possible to describe here. Suffice to say that the HIRL and its collaborators contributed hugely to the knowledge base upon which current infection and control proactive is based, and to the education of healthcare professionals on infection prevention and control.

The MRC was very supportive of clinical research of immediate practical use in the 1960s. However, research priorities of major funding bodies change over time. The MRC began to divert most of its resources into supporting immunology and molecular biology research. The HIRL continues, but mainly supported by industry; as such its capacity for original research has become much reduced. We think that it is unfortunate that an independently funded research unit no longer exists at a time when so many new, expensive and exciting technologies are being developed for infection prevention and control. Without independent clinical- and cost-effectiveness assessment of the use of new technologies in routine practice, it is very difficult to make a convincing case for investment in them in individual hospitals.

Authors' Note

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