Chapter 13
Deep Infection

Deep Infection [1]

We define deep infection as – infection around the implant.

The most likely source of infection that was not under control by standard aseptic precautions appeared to be the air of the operating room. It was therefore decided to build a clean air operating enclosure.

"*The general opinion would seem to be that the air of an average operating theatre is relatively innocuous. In the ward, on the other hand, the aerial route for post-operative cross-infection is regarded as potent…*" "*This was the opinion I myself held until some two years ago when a very high rate of wound infection in a new type of arthroplasty prompted this study*" (1964).

Post-operative sepsis, resulting in the infection around the implant, during the years 1958–1967, was so high (8.9%) that it would have been necessary to abandon this type of surgery had not special precautions in the operating theatre shown a marked improvement.

A prototype filtered air enclosure was constructed to contain the lower half of the patient's body and the three surgeons of the operating team. Filtered air is forced in at the top of the enclosure and the surgeons wear respirators through which their exhaled air is extracted so as not to mix with the filtered air of the enclosure. (1964) (Fig 13.1).

The First Survey

The study related to 2170 consecutive arthroplasties of the hip joint performed between January 1959 and September 1967 (Table 13.1, Fig. 13.2) "… *to permit at least 12 months to elapse between the last operation and completing the report*."

B.M. Wroblewski et al., *Charnley Low-Frictional Torque Arthroplasty of the Hip: Practice and Results*, DOI 10.1007/978-3-319-21320-0_13

Fig. 13.1 The original clean air enclosure "the Greenhouse" at Wrightington Hospital

Table 13.1 Study of infection after low-frictional torque arthoplasties – Jan 1959 to Sept 1967 and subsequently (Fig. 13.2)

Phase	Period	Operating room	Colonies per plate per hour	No. of hip replacements	Infection rate %
1	Jan 1959 to Nov 1961	Primitive	80–90	190	8.9
2	Nov 1961 to June 1962	Prototype filtered air enclosure 10 air changes per hour	2.5	108	3.7
3	June 1962 to March 1966	Clean air enclosure 130 air changes per hour	1.9	1164	2.2
4	June 1966 to Sept. 1967	Clean air enclosure 300 air changes per hour	Air not sterile Lowest that can be recorded	708	1.3
5	1969 -	As above Total body exhaust suits	Lowest recorded	1000	1.0

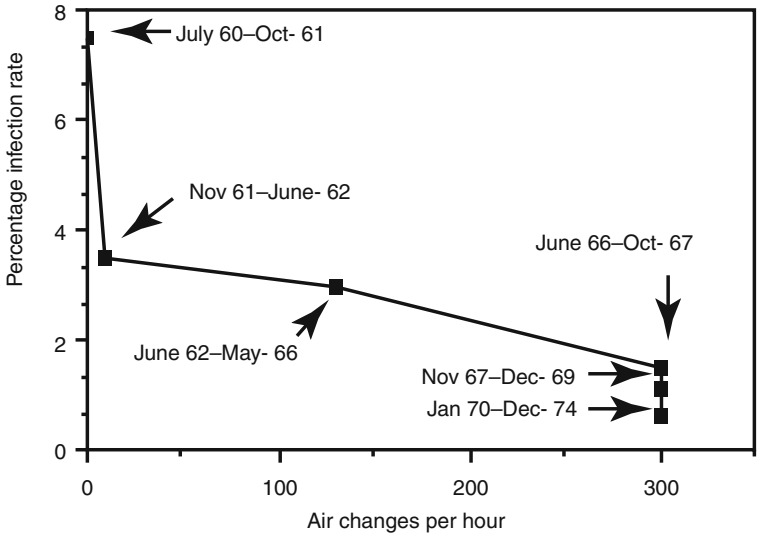

Fig. 13.2 Graph of infection rates. The study related to 2170 consecutive arthroplasties of the hip joint performed between January 1959 and September 1967. Further information was added to 1974 (Reproduced from Wroblewski [10])

> "*It was not possible to exclude a number of additional variables which could contribute to a reduction in wound infection … improved form of wound closure … the bodies of the surgeons or the others in the operating team, through permeability of the textile gowns*." "*Though the filtered air enclosure has improved the air cleanliness 25 times … it is still not completely sterile. It would be unlikely that a total abolition of infection could be expected*." "*Despite extreme precautions our rate is still about 1.8 %*" (1968).

It was in the early stages of the development of the clean air operating enclosure (1964) "… *another line … A form of* '*air curtain*' *in which the enclosure acts as a hood or shield to reduce the tendency of the cold air flow to entrain infected particles*." Charnley was clearly considering the next stage in the development of clean air enclosure – without side panels, pointing out that this "… *will effect an economy in the volume of air required and necessitate in the method of illumination*."

The complexity of the problem becomes obvious when one considers numbers of operations, diagnostic criteria, follow-up, and the time interval from the primary operation to establishing the diagnosis of deep infection.

Establishing the Diagnosis

Clinical experience suggests that establishing the diagnosis of deep infection is easier in cases referred for a second opinion than after our own operations.

Clinical Diagnosis

Pain relief after THA is such a consistent feature that failure to relieve pain must put the surgeon on guard. Barring any problems at surgery there are only three possibilities: inappropriate indication, inappropriate patient selection, infection.

Inappropriate Indication

Clinical assessment fails to identify the source of pain. The radiograph is viewed before, or at the same time, as taking the history and examining the patient. Clinical assessment must come before viewing radiographs; radiographs merely confirm and offer a record of what is usually obvious from the history and examination.

Inappropriate Patient Selection

It must not be assumed that every patient with an arthritic hip would benefit from THA. Rare though it may, beware of a patient with a very high expectation and flattering the surgeon's apparent skill and reputation. Does the surgeon's ability match patient's expectations? It must not be assumed that to do something is to do good, while to advise delaying surgery implies unwillingness to help, or negligence.

Complications

Dislocation is obvious, loosening of components comes later and is largely asymptomatic, fracture of the stem is now a late rarity – that leaves infection.

History of haematoma, delayed wound healing, courses of antibiotics – increase the index of suspicion. Regular follow-up with good quality radiographs and continuity of observer method is essential.

Bacteriology in the study of deep infection after THA is outside the scope of this work. It is best left in the hands of the experts on the subject.

Classification of Deep Infection

The practical usefulness of any classification is inversely proportional to its complexity. Infection will continue to be studied retrospectively if meaningful information is to be gathered.

Early Infection

Signs of inflammation, delayed would healing, infected haematoma, purulent discharge and early sinus formation. Wound dehiscence of deep fascia is extremely rare. Early exploration under conditions as in the primary operation, evacuation, examination of the deep fascia for deep extension, but without probing or opening unless communication is obvious.

Charnley arranged for photographs of the wounds to be taken before discharge from the hospital: 5400 photographs are available for further studies to anyone interested in the subject.

Late diagnosis of early infection is probably the most common scenario. Delays or lack of follow-up, inadequate radiographs, and lack of awareness of the possibility of infection.

Late presentation following early contamination. This is a complex subject that continues to be debated. If this is a true entity in clinical practice then fortunately it has not presented itself, as would have been expected, with increasing follow-up.

Late haematogenous infection – fortunately very rare. The criteria for the diagnosis must be strict: Primary surgery in a patient not at risk, no post-operative complications suggesting a possibility of infection. Clinical success with normal radiographs – well documented over a period of probably not <3 years, a source of possible bacteraemia, for example lower limb skin infection.

Establishing the Incidence

Deep infection after THA is rightly considered a very serious complication. Other than being a disappointment both to the patient and the surgeon, it brings with it the added socio-economic problems. It is, therefore, not surprising that so much effort has been put in by Charnley not only to identify and, if possible, eliminate the sources of infection, but also develop methods to reduce the chances of wound contamination. With deep infection rate reduced to about 1 %, efforts to establish infection rate – in general – has become a complex issue; increasing effort – diminishing return.

The Size of Sample Under Review

It is suggested that the value of any study of deep infection after THA is proportional to the size of the sample and the length of follow-up. This sets the limit on a particular unit to be able to provide “numbers” and suggests multi-centre studies. Multi-centre studies bring with them the problems of variations in patient selection,

theatre environment, surgical technique, prophylactic measures, criteria of establishing the diagnosis, but above all, good quality records – and of course availability of follow-up.

Since no single case is likely to be recorded more than once, conversely loss of one case, where the incidence is very low, will have a significant effect.

The Length of Follow-Up

> *Deep infection after this operation can never be overlooked … if sufficient time is allowed to elapse*. (1969)

Infection with dehiscence of the wound and skin – implant communication is extremely rare. More common, but still rare, is the sequence of: delayed wound healing followed by apparent success – both clinical and radiological – at least for a period of time. Detailed history and good quality radiographs are invaluable.

In case where deep infection is eventually confirmed, they offer very useful material for retrospective reviews and learning material for future interpretations.

As an example, Van Niekerk and Charnley (1979) studied the incidence of infection in a group of 2154 cases operated upon during a 2 year period: Jan 1974–Jan 1976. Deep infection was reported as 0.3 % – a remarkably low incidence. Caution is essential in interpreting the results. Not only was the follow-up relatively short but **infection was confirmed by bacteriology at revision** [2]. The information indicates that any infected arthroplasty that has not been revised, or where cultures failed to produce a growth of an organism, were excluded. This would possibly explain the very low incidence. In a further study the results of 1542 LFAs, carried out over an 8 year period, were reviewed with a minimum follow-up of 2 years. Deep infection was recorded as 1.5 % [3].

Since a number of cases of spontaneous healing of deep infection have not attracted attention it is probably correct to suggest that: given time, infection will declare itself. Although 1 year may be sufficient, with good quality records and frequent follow-up, ideally a 2–4 years period is probably more realistic.

Patients at Risk for Deep Infection [4]

> *The analysis relates to cases which were technically much more difficult as well as more prone to infection*.

Failures of Previous Hip Operations

Between November 1962 and April 1969, 203 patients had undergone 217 LFAs for failures of previous hip operations (Table 13.2). They reflect a spectrum of operative procedures that had been in common use until the advent of the LFA. Plain acrylic cement was used in all cases.

Table 13.2 Previous hip operations in 203 patients, 217 LFAs

Previous operation	Number
Femoral osteotomy	121
Hemiarthroplasty	51
Other: Cup arthroplasty	17
Pseudarthrosis	9
Arthrodesis	9
Total hip replacement (Not LFA)	10
Total	217

A review of the results of 217 LFAs carried out in 1971/1972 emphasised some aspects of the technique, the clinical results as well as infection rate. Eight patients (3.7 %) developed wound infection: four early and four after the first year [4].

Urethral Instrumentation After LFA

One hundred and ninety five males had urinary retention in the immediate post-operative period requiring insertion of urethral catheter and, at times, prostatectomy. Twelve, 6.2 % developed deep infection around the hip implant [5]. "Catheter fever" is a well documented complication of urethral instrumentation.

(It may be of interest to put it on record that when the operation, the LFA, was first introduced as a routine procedure, all patients had catheter insertion pre-operatively. The objective was to avoid possible perforation of the bladder during the preparation of the acetabulum using the perforating, deepening and expanding acetabular reamers).

Diabetic Patient

There was a low representation of diabetic patients because selection was prejudiced against diabetics for this type of surgery.

A retrospective review of 62 LFAs in 44 diabetic patients has shown a superficial wound infection rate of 9.7 %; deep infection rate was 5.6 % – with a follow-up of 1–7.5 years.

The conclusion was: antibiotic prophylaxis should be part of the routine practice [6].

Patients with Psoriasis

Retrospective review of 55 LFAs in 38 patients with established psoriasis has shown a superficial infection rate of 9.1 % and a deep infection rate of 5.5 % with a follow-up of 1–12 years. Antibiotic prophylaxis is indicated in patients with psoriasis undergoing LFA [7].

A summary of patients at risk for deep infection can be seen in Table 13.3.

Table 13.3 Summary of results in patients at risk for deep infection

Patients at risk	Number of LFAs	Follow-up years	% Infection
Previous hip surgery	217	5	7.6
Urethral instrumentation	195	2.1	6.2
Diabetes	62	1–7.5	5.6
Psoriasis	55	1–12	5.5

Table 13.4 Time to revision after primary LFA

Time to revision (years)	Number of LFAs	% of Revisions
1–4	147	59
5–10	71	28.5
10+	31	12.5
Total	249	100 %

Late Haematogenous Infection

Deep infection after this operation can never be overlooked … if sufficient time is allowed to elapse.

Late haematogenous infection is not a topic of frequent reports other than single sporadic cases. The reason for this probably stems from the very definition and the criteria that must be fulfilled to identify such cases. Included must only be the patients undergoing primary operations, not at a risk for infection, having had well documented successful clinical and radiographic evidence of success, and a continuous follow-up for a number of years yet to be specified. Late diagnosis of early infection must be excluded and late clinical presentation of contamination, during the primary operation, must also be considered.

Results

To offer some indication of the complexity of this topic the details are given below:

During the 43 year period 1962–2005, 22,066 Charnley LFAs had been carried out at Wrightington Hospital. During that time 249–1.13 % had been revised for deep infection. The timing of the revisions are shown in Table 13.4.

Of the 31 revisions for deep infection carried out after 10 years or more, 11 are analysed in some detail in Table 13.5. (This is merely an attempt to highlight the complexity of the issue; the availability of good quality records is immediately obvious).

Rare though this may be, late haematogenous infection must always be considered as a possible cause of long-term failure.

With increasing numbers of young patients accepted for this type of surgery, increasing possibility of long-term problems is to be expected. Continuity of well structured follow-up facilities must be part of the original consent for the operation.

Table 13.5 Details of 11 cases revised for late haematogenous infection

Follow-up (years)	Source of infection suspected/ identified	Bacteriology at revision	Comment
31	Infected total knee (ipsilateral)	Staph epidermidis	Antibiotics Before revision
22	Abcess behind knee (ipsilateral)	Staph aureus	Fractured stem
18	Infected bunion (contralateral)	Haemolytic strep Staph aureus	Antibiotic Before revision
15	Bladder surgery for neoplasia	Staph epidermidis	Antibiotic Before revision
11	Dental abcess	Negative	Antibiotic Before revision
10	Bacterial endocarditis	Streptococcus	Antibiotic Before revision
10	Compound fracture dislocation of finger	Staph aureus	Diabetic
18 Bilateral	Bilateral infections Dislocation left Source unknown	Staph aureus	Trochanteric Non-union
12	Source unknown	Coag. neg. staph	
11	Source unknown	Coag. neg. staph Acinetobacter	Heavy fall

Deep Infection: Theatre Gowns

Bacteriological tests show that the fine woven material … used extensively for operating gowns, can be penetrated by the organisms from surgeon's body

Charnley Total Body Exhaust Suits (Fig. 13.3)

Although the introduction of clean air enclosure, total body exhaust suits and the instrument tray system have reduced the infection rate from 8.9 % to about 1 %, infection was not eliminated altogether. It was essential to identify further possible sources of wound contamination which may lead to infection. Charnley and Eftekhar [8] studied permeability of the surgical gowns which were in common use. Their suspicions were confirmed: bacteria did penetrate the surgeon's gowns. One further source of possible wound contamination was established. Attention could now be directed towards alternative, non-permeable materials for the gowns. The findings also "*offered an explanation that operations which were unusually difficult technically and require unusually physical effort, tend more often to be followed by infection than do simple operations*." Physical exertion generating movement and heat, glove-gown-wound contact, plus tissue damage and prolonged exposure of the operation site all contribute to the possibility of infection.

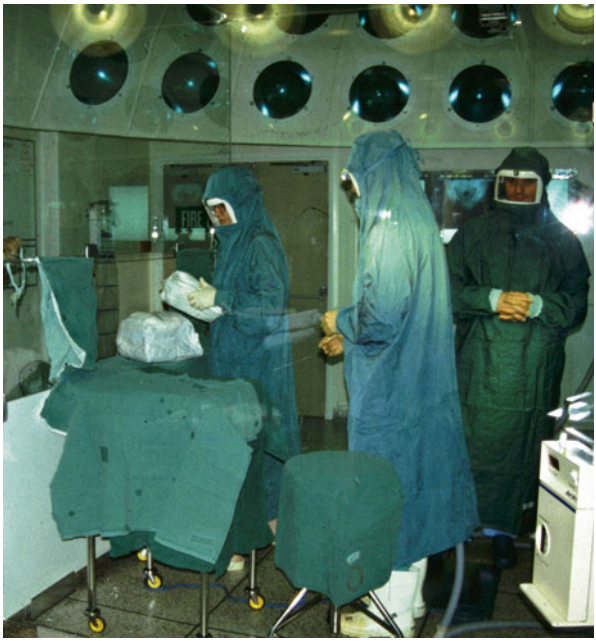

Fig. 13.3 The original Charnley total body exhaust suits

Charnley and Eftekhar also stated: "*The more impermeable the material of the surgeon's gown the more the surgeon needs to have a cooling system to take away the very considerable amount of heat generated in strenuous orthopaedic operations*."

For the detailed description of the design and function of the Body Exhaust System the reader must reference Charnley's book: Low Friction Arthroplasty of the Hip – Theory and Practice [9].

Disposable Gowns and Ventilated Helmets

The recent introduction of disposable gowns and ventilated helmets poses a number of questions:

- Is the independently powered fan which is a part of the helmet, powerful enough to counteract up-currents to expel the air to the ground level; not only at rest but also during the physical exertion at surgery?
- Is the air introduced into the helmet merely mixed with the up-currents and the exhaled air, and forced out through the nearest "escape routes"?
- Is the benefit primarily for the surgeon's comfort than the safety of the patient?

Here we have a very fertile ground for research.

Comment

It is essential to understand the principle underlying the design and function of the total body exhaust suits. The Charnley system is designed to protect the operation site and the clean air enclosure from contamination by the operating team.

The suction system extracts the air from within the gowns and disposes it outside the operating theatre. The air flow follows the pressure gradient: from the clean air, into the exhaust suits and to the outside.

The self-contained pressure suit system takes the clean air from the operating theatre, filters it further by the helmet filter, and delivers it to the inside of the suit.

The airflow will follow the pressure gradient from within the gowns into the clean air enclosure through the nearest available exits. Whether the system is powerful enough to overcome the up-currents generated by the bodies of the operating team and deposit it at the floor level is debatable.

Is the system designed to offer personal protection for the wearer? Any risk to the operating team from the clean air theatre environment is yet to be documented. A higher infection rate should not come as a surprise.

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