# An Overview

# of

# Laminar Flow Ventilation

# for

# Operating Theatres


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## EXECUTIVE SUMMARY

Laminar flow ventilation is used in modern orthopaedic operating theatres to reduce the number of infective organisms present in the air, which may lead to post-operative wound infection. This is of particular significance in joint prosthesis surgery, where delayed and deep-seated post-operative infection may result in poor patient outcomes and substantial costs, both to patients and health care providers. To be most effective, key operating theatre staff should wear body exhaust suits whilst working in the ultraclean environment.

Laminar flow ventilation was first pioneered by Charnley in the 1960s and 1970s and resulted in a marked reduction in post-operative wound infection. As it was introduced in conjunction with other strategies to reduce sepsis, it was not until the results of trials conducted in the 1980s by Lidwell became available, that laminar flow ventilation became widely adopted in orthopaedic operating theatres. Studies were confined to total hip or knee surgery and results demonstrated that the lower the count of airborne bacteria, the lower the sepsis rate.

Much of the more recent literature is predicated on Lidwell's findings, examining the different types of laminar flow ventilation available, the role of prophylactic antibiotics and the effectiveness of body exhaust suits. A relatively small amount of work has been published on the relationship between the number of airborne bacteria and the post-operative wound infection rate. Two recent studies, involving the move from existing older conventional theatres to modern ultraclean facilities have indicated that the role of laminar flow ventilation in the context of the use of modern prophylactic antibiotics may be marginal.

In Australia, no current standards or guidelines indicate that laminar flow ventilation must be adopted in any operating theatres, however in instances where laminar flow ventilation is installed, standards prescribe the operation and testing of such ventilation.

## INTRODUCTION

Laminar flow or ultraclean ventilation is used in modern orthopaedic operating theatres to reduce the number of infective organisms present in the air, which may lead to post-operative wound infection. A continuous flow of highly filtered 'bacteria-free' air is recirculated under positive pressure into the operating field and air contaminants generated during surgery are removed from the site. This is of particular significance in joint prosthesis surgery, where delayed and deep-seated post-operative infection may result in poor patient outcomes and substantial costs, both to patients and health care providers.

While conventional or *plenum* type ventilation in operating theatres maintains approximately 20 air changes per hour, laminar flow operating theatres may operate at upwards of 300 air changes per hour (Humphreys 1993, Hubble 1996). Airborne organisms or colony forming units (cfu) are typically of the order of between 150 - 300 cfu/$m^3$ in conventional operating theatres, while with laminar flow ventilation, the number of cfus should be at 10cfu/$m^3$ or less (Lidwell et al 1982, Whyte et al 1983, Howorth 1985). A number of different types of systems are available, whereby air may be introduced in a horizontal, uni-directional fashion or vertically in an enclosed, semi-enclosed or open manner (Howorth 1985). To be most effective, key operating theatre staff should wear body exhaust suits whilst working in the ultraclean environment (Lidwell et al 1982, 1983, Humphreys 1993, Hubble 1996, Whyte et al 1983).

### Background

Laminar flow ventilation was first introduced by Charnley in the 1970s and resulted in a marked reduction in post-operative wound infection (Babb et al, 1995). As other changes to operative technique were also introduced simultaneously, it was difficult to determine the precise contribution of airborne bacteria to the sepsis rate (Holton and Ridgway 1993). The use of laminar flow ventilation became more widely accepted in the early 1980s, following a large clinical trial conducted between 1974 and 1979.

The trial was established to determine the relationship between air quality and post-operative sepsis, by comparing the post-operative wound infection rate in conventional operating theatres and laminar flow ventilation operating theatres. Studies were confined to total hip or knee surgery and results demonstrated that the lower the count of airborne bacteria, the lower the sepsis rate (Lidwell et al 1982, 1983, 1984, 1988, Whyte et al 1983).

### Objective

The aim of this paper is to review the effectiveness of laminar flow ventilation for orthopaedic surgery in reducing post-operative wound infection. In the context of the redevelopment programme for metropolitan hospitals, information provided may be used to assist in decision-making when planning for operating theatre facilities.

## Scope

A review of current literature has been undertaken related to the use of laminar flow ventilation in operating theatres, however formal discussions with clinicians at various sites have not been undertaken. Informal clinical consultation has taken place through Dr David Robinson, Clinical Advisor to the Policy Co-ordination Unit and Ms Dolly Olesen from the Communicable Diseases Unit has provided valuable input.

Comparative capital and recurrent costs for laminar flow and conventional ventilation are considered to be beyond the terms of reference for this assessment, as they may be more appropriately addressed in the redevelopment project.

## LITERATURE REVIEW

### Lidwell's Trial

A significant body of literature was published in the mid 1980s, much of which was based on the work undertaken by Lidwell and colleagues. He first published in the *British Medical Journal* in 1982 and has published subsequently in several other well-respected journals (Lidwell et al 1982, 1983, 1984, 1988).

The trial was a prospective, randomised-controlled, multi-centre trial, involving sites in both the United Kingdom and Sweden, with a sample number in excess of 8,000 patients undergoing hip or knee replacement surgery. Most patients were followed up for between two to three years for evidence of deep-seated infection. Lidwell showed that the incidence of joint sepsis at re-operation was 50% less in those patients operated on in an ultraclean environment, while, when body exhaust suits were worn, the incidence of re-infection was further reduced to 25%. Overall, the incidence of sepsis in the control group of 1.5% was reduced to 0.6% in the ultraclean air group, but these findings relate only to "deep sepsis after operations for total hip or knee replacement, which expose large areas of tissue for a considerable amount of time to possible contamination by bacteria in the air" (Lidwell 1982, p 14).

Lidwell states that the "design of the study did not include a strictly controlled test of the effect of prophylactic antibiotics" and wide variations in the use of antibiotics in different institutions occurred (Lidwell 1982, p 10). He estimated that patients not receiving prophylactic antibiotics were about four times more likely to acquire a post-operative wound infection (Lidwell 1982, p 14, Lidwell et al, p 117). He further concluded that vertical laminar flow ventilation performed better than horizontal ventilation, those systems with walls were more effective than those without and that wearing of body exhaust suits further enhanced the reduction of airborne bacteria (Lidwell 1982, 1983).

**More recent literature**

Much of the more recent literature is predicated on Lidwell's findings. Several articles address the effectiveness of laminar flow ventilation in reducing the cfu/$m^3$ but do not further associate these findings with improved patient outcomes (Hubble 1996, Humphreys 1993). Holton and Ridgway argue that although there is a relationship between air quality and sepsis, once a moderate level of air quality is achieved, further improvement in sepsis rates will be dependent on better aseptic technique (Holton and Ridgway 1993).

Several authors have addressed the topic of the effectiveness of body exhaust suits in conjunction with laminar flow ventilation (Lidwell et al 1982, 1983, Humphreys 1993, Hubble 1996, Whyte et al 1983, Torbjorn et al 1995, Madeo 1996). A study in Sweden found that body exhaust suits worn in conventional operating theatres reduced the airborne bacteria to less than 10 cfu/$m^3$, although the sample was relatively small (n=90), (Torbjorn et al 1995). Most authors agreed that the wearing of body exhaust suits contributed substantially to the reduction of airborne bacteria and some have also suggested that improper positioning of surgical staff may actually increase infection rates in laminar flow operating theatres, by drawing contaminated air into the field, a view supported by both Torbjorn and Madeo (Madeo 1996, Torbjorn 1995).

Other literature addresses the role of prophylactic antibiotics in the reduction of post-operative wound infection in orthopaedic surgery (Marotte 1987, Mayhall 1996, van Griethuysen et al 1996, Babb et al 1995, Fitzgerald 1992, Hill 1981). Fitzgerald raised doubts concerning the Lidwell trial due to its failure to randomise for the use of prophylactic antibiotics. In 1981, he initiated a prospective, randomised and blinded study comparing the incidence of deep sepsis following hip and knee arthroplasty in both laminar flow and conventional theatres adhering to a standard protocol of prophylactic antibiotics ( Fitzgerald 1992). In this sample of approximately 7,000 patients, Fitzgerald found no statistical difference between the two types of ventilation used. He stated that "the data support the concept that prophylactic antimicrobial agents may be the single most important aspect in the reduction of deep sepsis following total hip or total knee arthroplasty" (Fitzgerald 1992, p 261). A retrospective comparative study undertaken by Marotte also offers compelling argument for the dominant role that prophylactic antibiotics play in the management of post-operative wound infection (Marotte 1987).

Of particular interest are two recent prospective studies undertaken during the process of redevelopment of hospital sites. In the Netherlands study, approximately 3,000 patients undergoing surgery in the old hospital were evaluated for post-operative wound infection against approximately the same number of patients undergoing similar surgery in the new hospital with laminar flow ventilation. The groups were further stratified into those undergoing joint replacement surgery. Stringent criteria were employed to ensure that other confounding factors were controlled for. Results found no decrease in post-operative wound infection, either immediately after surgery or in follow-up of one year (van Griethuysen et al 1996). The other study focussed on early wound infection in similar circumstances of moving from an old site with

conventional ventilation to a new hospital with laminar flow ventilation. Again no difference was demonstrated in post-operative wound infection (Kelly et al 1996).

## DISCUSSION

The Lidwell study demonstrated that laminar flow ventilation reduces the number of airborne bacteria present in operating theatres. Some criticism has been directed towards this study, in that although the trial was randomised, it was not well-controlled, involving a large number of sites, surgeons, treatment regimes and types of ventilation (Marotte 1987, Fitzgerald 1992). Whether laminar flow ventilation continues to have a significant impact on reducing post-operative wound infection is a matter for some clinical debate, given that most patients receive modern prophylactic antibiotics (Holton and Ridgway 1993, Babb 1995, Fitzgerald 1992, Madeo 1996, Marotte et al 1987).

In general, the literature tends to reflect a difference in clinical opinion regarding the effectiveness of laminar flow ventilation and use of prophylactic antibiotics between practice in the United Kingdom and the United States of America (Babb 1995). The results of most recent comparative studies suggest that laminar flow ventilation does not contribute to the reduction of post-operative wound infection in a significant manner (van Griethuysen et al 1996, Kelly et al 1996). While well-designed randomised controlled trials may provide stronger evidential findings, well-designed prospective studies, such as these, still provide strong evidence (Level III) as to the validity of outcomes (NHMRC October 1995).

In Australia, no current standards or guidelines indicate that laminar flow ventilation must be adopted in any operating theatres, however in instances where laminar flow ventilation is installed, standards prescribe the operation and testing of such ventilation (AS 13861.1- 1386.7 1989, AS 1807.0 - 1807.24 1989, NHMRC April 1996).

## CONCLUSION

The randomised control trial conducted in the 1970s provided evidence that laminar flow ventilation had a significant impact on post-operative wound infection at that time, however the study did not control for the use of prophylactic antibiotics.

Current literature indicates a lack of scientific evidence to support the use of laminar flow ventilation in operating theatres, given more modern approaches to patient treatment regimes. Benefits to be gained in installing laminar flow ventilation in orthopaedic operating theatres appear to be only at the margin and then, only when laminar flow ventilation is installed in conjunction with the wearing of body exhaust suits.

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