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Airborne contamination and surgical site infection: Could a thirty-year-old idea help solve the problem?

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A B S T R A C T

Surgical site infection (SSI) is a most serious postoperative complication, associated with increased morbidity and mortality, as well as extended therapy and elevated healthcare costs. In open clean surgery, e.g. orthopedic and cardiothoracic operations, the risk of SSI is strongly correlated with the amount of airborne bacteria being present in the operating room and the surgical field. The source of these bacteria is the surgical team itself, as we all emit thousands of bacteria-carrying skin particles every minute into the air. Although the risk of airborne contamination has decreased over the years, thanks to modern surgical clothing and advanced operating room ventilation, airborne bacteria are still detected and cause SSI. However, during the past thirty years there has been a simple and potentially effective preventive method waiting to be noticed. In 1986 Hall, Mackintosh and Hoffman found in a controlled experimental study that the application of regular unperfumed skin lotion to a person's body reduced the emission of airborne bacteria-carrying particles by approximately 90%. Moreover, the effect lasted at least 4 hours, which corresponds to a major surgical procedure. Thus, in the light of those results the present paper puts forth the hypothesis that this method can decrease the incidence of airborne bacterial contamination and SSI in open clean surgery. The paper also discusses the rationale and advantages of the method, and questions why it has escaped scientific attention for so long. In healthcare, difficult problems rarely have a simple and cheap solution. However, the use of ordinary skin lotion in open surgery may just be one, as it could potentially help prevent surgical site infection, and thereby increase patient safety and reduce healthcare costs.

Introduction

Airborne contamination in open surgery

Each year millions of people undergo a major surgical operation, and with a growing and ageing population this number will increase rapidly in the near future [1]. Regrettably, in orthopedic and cardiothoracic operations, i.e. open clean surgery, about 1–2% of the patients contract surgical site infection (SSI) [2,3]. It is a serious postoperative complication, as it may ruin an otherwise successful operation and could be disastrous for the patient. Deep wound infections may not only cause sepsis, organ dysfunction, wound dehiscence and bone instability [3]. They could also necessitate reoperation and debridement, where the surgeon may have to remove ever-larger sections of infected tissue in order to improve wound healing. Because of all this, SSIs are associated with increased morbidity and mortality [3,4]. As a result, they also entail elevated healthcare costs, mainly due to the extended treatment and prolonged hospitalization [5]. In addition, the subsequent increased use of antibiotics promotes the emergence of antibiotic-resistant bacteria, which poses a serious public threat.

For several decades, clinicians have been aware that a main cause of SSI in open clean surgery is airborne bacteria swirling around in the operating room and the surgical field. Already 35 years ago, Lidwell et al. found the incidence of SSI in joint replacements to be correlated with the presence of airborne bacteria [6]. At the same time, Whyte et al. found confirming evidence that the majority of the bacteria that were washed out from contaminated wounds actually came from the ambient air [7]. These conclusions were later supported by other scientists' findings of a strong correlation between the air counts of bacteria-carrying particles and the surface counts of colony forming units in the surgical wound and the instrument area [8].

The mechanism of airborne contamination is well understood. During open surgery airborne particles may either fall down directly into the surgical wound, or settle on surrounding surfaces and then be transferred indirectly into the wound by the surgeon's hands and instruments [7]. Unfortunately, the source of these bacteria is the surgical team members themselves. The reason is that we all shed thousands of microscopic skin scales every minute into the air, and a significant portion of those carry bacteria [9]. Accordingly, the most common bacteria found in SSIs are *Staphylococci* that form part of our resident and transient skin flora [4,10,11]. Even more troubling is the fact that

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scientists have identified strains of these bacteria that are resistant to potent antibiotics, such as methicillin and vancomycin [12–15], which makes it even more important to prevent airborne bacterial contamination during surgery.

Current preventive measures

Over the years the increasing awareness of the problem with airborne contamination has fuelled the development of different countermeasures, including covering surgical clothing and advanced ventilation systems. The idea to ventilate the operating room with a downward, ultraclean and laminar airflow (LAF) has become standard, since Charnley in the 1960s [16], as well as Whyte [7], Lidwell [17], and Howorth [18] in the 1980s, presented convincing proof of the method's effectiveness. In those days the introduction of LAF systems no doubt helped to make clean surgery cleaner. However, in recent years the increasing requirements on patient safety have put the LAF systems under scrutiny. As a result, an increasing number of studies begin to question the efficiency and cost effectiveness of those systems [2,19,20], particularly since they in some cases seem to have increased the risk of SSI when compared with conventional ventilation systems that provide turbulent ultraclean airflows [20]. Some researchers have therefore suggested that "decision makers, medical and administrative, should not regard laminar airflow as a preventive measure to reduce the risk of SSIs" and that "this equipment should not be installed in new operating rooms" [20]. In fact, already a quarter of a century ago Taylor and Bannister managed to shed some light on the possible disadvantage of LAF systems [21]. They observed that when the surgeon leaned into the downward laminar airflow above the surgical field, airborne contamination increased 27-fold. Apparently, when the laminar airflow was obstructed, it lost its protective effect and instead helped to convey airborne particles into the wound.

Since many hospitals now have LAF-systems installed in their operating rooms, there is a need for a simple and reliable solution. Admittedly, several new methods have recently been presented to help improve the air quality during surgery, including different types of additional in-situ ventilation systems, such as mobile bedside ventilation [22] and local wound ventilation [23,24]. However, as it turns out, during the past decades of research and development of elaborate techniques to prevent airborne contamination, there has all along been a very simple and potentially effective method waiting to be noticed.

A new idea from the past

In 1986 Hall, Mackintosh and Hoffman published an experimental study entitled *The dispersal of bacteria and skin scales from the body after showering and after application of a skin lotion* [25]. Their data showed that application of regular unperfumed skin lotion to a person's body reduced the dispersal of airborne bacteria-carrying particles by approximately 90%. Moreover, the protective effect lasted at least 4 hours, which corresponds to a major surgical operation. Additional control measurements indicated that this effect was not due to some chemical action on the bacteria themselves, but to the lotion's adhesive effect on loosely attached skin scales.

The study also showed that showering had little effect, and that wearing surgical clothing (shirt, trousers, mask, cap and gloves) only slightly decreased the number of bacteria-carrying particles in the air. However, when lotion had been applied to the body, those numbers were greatly reduced, and they remained low throughout the four-hour sampling period, despite the fact that the volunteers were intermittently performing exercise, i.e. walking on the spot. Notably, such physical activity would normally increase the number of airborne particles due to the clothes' abrasive effect on the skin [26]. With these results at hand, Hall et al. finally made the unconventional suggestion that the use of skin lotion *"could provide a simple and inexpensive alternative to an ultraclean air system or uncomfortable operating clothing during surgery"*.

Hypothesis

The work of Hall et al. implies the following clinical hypothesis: *If the surgical team members apply body lotion prior to an operation, there should be significantly fewer airborne bacteria-carrying particles present in the operating room, and therefore a lower incidence of airborne contamination and surgical site infection in open clean surgery.*

Evaluation of the hypothesis

Since Hall et al.'s study was experimental the next logical step would be a randomized clinical trial. However, if their method shall be investigated properly, any clinical study should be preceded by a few additional laboratory experiments. First of all, it would be necessary to reproduce Hall et al.'s thirty-year-old measurements to test and possibly verify their results. Secondly, it would be advantageous to evaluate different types of lotion, as to their efficiency and comfort. Of particular interest would be to study lotions with different contents of oil, since it was assumed to be the effective component of the solution.

A subsequent *prospective* clinical trial, which could test the method's effect on the *incidence of SSI*, would be very demanding. Since the SSI rates in open clean surgery are already at relatively low levels, thanks to existing techniques and antibiotic prophylaxis, a clinical trial of this sort would require a "very large sample size to have enough power to detect a significant difference and would be very expensive" [19]. In fact, for all statistical and practical reasons, such an investigation would have to include tens of thousands of patients, and be arranged as a multicentre study involving many hospitals. Consequently, as today's SSI rates are historically low and since the proposed method does not really constitute an innovation, such a costly venture would probably attract little support.

Usually, another option would then be to use nationwide databases as a source for *retrospective* studies. But for that to work the method must have been used clinically and documented in patient files, which is clearly not the case. However, to find support for clinical implementation, it might suffice to test the method's effect on the number of airborne bacteria-carrying particles in the operating room. After all, previous studies have already established the correlation between airborne bacteria, wound contamination, and SSI, respectively. Furthermore, since surgical team members may use unperfumed body lotion for personal comfort and prevention of dry skin, the decision to use it for prevention of airborne contamination should be mainly academic. Hence, after a few years of documented clinical use there will eventually be enough data for retrospective evaluation of the method's effect on SSI rates.

Discussion

Reasons for the apparent unawareness

The question arises why the idea to use skin lotion to avoid airborne bacteria has escaped scientific attention for more than thirty years. Why has this not been further studied and already incorporated into clinical praxis? It might be tempting to suspect that the method has been regarded as being too simple, and by some maybe even too effective and too inexpensive. But as it turns out, when asking experienced experts in surgery and infection control, surprisingly few have ever heard of Hall et al.'s idea. Maybe the consistent focus on operating room ventilation has diverted scientists' attention all these years. However, this would still not explain the general unawareness of Hall's paper. Therefore, a more probable explanation for the many years of silence may simply be that the paper was not read, at least not initially and not by sufficiently many authorities. A possible reason could be that the publishing journal, *Journal of Hygiene*, ended its activity shortly after Hall et al.'s study was published. Since there was no Internet around in those days, this may have impeded the paper's circulation and left it unnoticed for a

Table 1
Comparison of different methods to prevent airborne contamination during open surgery.

	Operating room ventilation	Mobile bedside ventilation	Local wound ventilation	Surgical clothing (gown, hood etc.)	Skin lotion
Rationale	Induce ultraclean air into operating room	Induce ultraclean air near operating table	Induce ultraclean air near/ into surgical wound	Enclose body with covering fabric	Treat skin with fatty adhesive lotion
Usage	Electric supply, reusable filter	Electric supply, reusable filter	Air supply, disposable filter and ventilation devices	Disposable fabrics	Lotion container for multiple use
Installation	Yes	No	No	No	No
Maintenance	Yes	Yes	No	No	No
Cost	High	Medium	Low	Low	Very low

considerable time. These kinds of "blind spots" have occurred before in science due to poor dissemination of scientific knowledge. For example, more than 150 years ago Charles Darwin and his contemporary colleagues famously failed to notice Gregor Mendel's discovery and publication of the basic principles of inheritance. In that case the journal's distribution was indeed very limited, and more than three decades passed before his work was finally recognized.

The method's rationale and advantages

Hall et al.'s proposed method is in many ways a sound approach to solve the problem with airborne contamination in open surgery. First, unlike other methods to prevent airborne contamination (Table 1), skin lotion targets the actual source of airborne bacteria, i.e. the surface of the surgical team members' skin. Intuitively, this makes more sense and should also be more effective than trying to handle the difficult secondary effects of airborne bacterial dispersion and wound contamination. Second, according to Hall et al. the mildly fatty lotion acts as temporary glue on loose skin scales, which prevents them from shedding into the air. The lotion thereby creates a natural barrier against skin bacteria without the involvement of any active chemicals that might bring unwanted side effects after repeated use. Therefore, since we use skin cream and body lotion regularly in everyday life, we should be able to use it in clinical practice as well. Third, skin lotion is discreet. During surgery the applied lotion would not occupy space in the operating room or the surgical area, and would not require any attention or adjustments. Last, but not least, the method is inexpensive as it has a negligible acquisition cost, does not require installation, and is maintenance-free.

Implications

All in all, if proven effective, skin lotion should be considered as a sensible method to prevent airborne contamination in open surgery. However, in contrast to what Hall et al. suggested, the method would not have to be considered as an *alternative* to other measures. In order to realize the vision of complete prevention of airborne contamination, skin lotion should rather be regarded as a *complement* to currently applied techniques, since they all tackle the problem from different angles (Table 1). Finally, it should be noted that the potential application of Hall et al.'s method may not only be limited to operating rooms for prevention of SSI. In principle, the method could be useful to prevent airborne contamination in any cleanroom environment.

Conclusion

In healthcare, difficult problems rarely have a simple and cheap solution. However, the use of ordinary skin lotion in open surgery may just be one, as it could potentially help prevent surgical site infection, and thereby increase patient safety and reduce healthcare costs.

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