Chapter 10

Valorisation

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The results of the studies presented in this thesis are helpful for improving UDF systems, reducing the amount of potentially microorganisms carrying particles at the critical positions in an operating room and instrument lay-up room, as well as realizing a more efficient design process of these facilities. These results may be important to design teams and to hospitals because they will help to use air distribution systems more efficient and a design based on these results will reduce the costs (operational and maintenance) of UDF systems. The results can easily be implemented and are already frequently used in new designs and refurbishment of air distribution systems in operating rooms and lay-up rooms in The Netherlands. This thesis also contributes to the discussion on the effectiveness of air distribution systems. It is clearly indicated that well-functioning air distribution systems in operating rooms will reduce the amount of potentially microorganisms carrying particles at critical positions in operating rooms and instrument lay-up rooms resulting in a reduced number of SSI caused by exogenous sources, and so a reduced risk of postoperative infections.

During the design process of operating rooms, the lay-out is often subject of debate. Some of the questions that have to be answered by the design team during this process are often: 1) what should be the size of the operating room? 2) what type of air distribution system should be used? 3) what should be the size of the protected zone? 4) should we use a supply bridge and what should be the height? 5) what is the best position of the patient access door and door towards the instrument lay-up room?
In chapter 2 it is demonstrated that an area of 3 meter square is sufficient to contain the surgical team, the wound area and the instrument tables in about 95% of the procedures performed at an academic hospital setting.[1] It is also demonstrated that in the case of larger dimensions of the operating room the unidirectional downflow canopy should not be positioned centrally in the operating room for optimal layout.

The remaining space inside the operating room should preferably be situated on the side of the corridor, rather than being equally divided around the clean area. Positioning of the anaesthesia section on the side of the clean area also offers a better logistical layout of the operating room than in the traditional set-up where it is situated between the clean area and the entrance. In the anaesthetic working zone the activity level often is high and related to door openings resulting in a high local source of pollutants. Whether the suggested position has a negative effect on the number of microorganisms carrying particles at critical locations (surgical wound and instrument tables) in the operating room has not been investigated yet.

To improve the UDF air flow a skirt around the canopy with a supply bridge was considered in the design used in the study for this thesis.[2] The supply bridge was positioned 2.05 meter above floor level. In the Dutch situation, a supply bridge at a height of 2.05 meter provides a good balance between collisions with used medical equipment and for making connections in the slanted part of the supply bridge by employees and guiding the air flow as much as possible.

These results should be used as a starting point by the design teams when designing a system for an operating room. For comparable situations, the results may be used directly by hospitals and consultants to prepare the program of requirements. For types of operations and conditions not investigated in this study, the method described must be used to determine the minimum required size of the area to be protected by the air distribution system. Due to the availability of this information and method, the design team does not need to determine this in advance so that a design process is faster and more effective.[3,4]

Selecting new operating lamps is a difficult task. The amount of light, colour of the light and way to control the operating lamp are often the most important criteria for selection. Another aspect to be considered is the influence of the operating lamps on the air flow in the operating room.

With modern operating lamps with LED lighting, the temperature of the lamp is often less of a problem, provided that the control gear is not integrated in the lamp. Especially when UDF systems are used the air flow may be negatively affected, reducing the ability to discharge microorganism containing particles. Chapter 3 addresses the impact of using operating lamps with an open structure versus operating lamps blocking the air stream and the effect of a skirt around the canopy.[5] Using operating lamps with an open structure and using a skirt around the canopy improves the effect of UDF systems. These results may be used to improve the performance, protection against entrainment of potentially microorganisms carrying particles, of the UDF system.[6-9] The best operating lamp with respect to the influence on the air flow is an operating lamp that is positioned outside the air flow of a UDF system. The development of operating lamps should focus more on the design of systems that negatively influence the UDF air flow as little as possible. With modern high capacity and low weight batteries and LED lighting, it may be possible to develop portable lamps that are worn on the surgeon's head, that are comfortable and have sufficient light output, which could lead to redundancy of conventional surgical lamps. Systems could also be developed that are fully integrated into the ceiling where the light follows the field of vision of the surgeon.[10] To get enough light in the body parts deep in the body, a combination of the abovementioned possibilities can offer a solution that minimally influences the UDF air flow.

This research also demonstrates that using a skirt may have a positive effect on the effectiveness of air distribution systems in operating rooms. If a skirt is used, in combination with a supply bridge or not, the disturbance of the UDF air flow can even be limited further improving the performance of air distribution systems in operating rooms. If a supply bridge is combined with a skirt, special attention should be paid to the connection between the supply bridge and the skirt, which must be seamlessly transferred on the side of the air flow.

Hospitals have a big challenge to reduce energy consumption as required by the European energy regulations.[11,12] The easiest way to reduce energy is to switch of systems when not in use like lights, medical equipment, heating and cooling systems etc..
The ventilation system in operating rooms also has periods of prolonged inactivity e.g. during nights and weekends. However, because of the limited research performed on this subject responsible duty holders are hesitant to do so. Chapter 4 shows that switching off the ventilation system during prolonged inactivity (during the night and weekend) has no negative effect on the air quality in operating theatres with UDF systems during normal operational hours.[13] In this way not only energy will be saved but also the service life of filters may be extended. This will lead to reduction of operational cost (energy and maintenance). Switching of the ventilation systems of operating rooms contributes to the European goals for energy saving.[11,12] Design teams should develop systems that are able to be switched of easily and will restart at short notice. During long periods of inactivity (during the night and weekend) precautions should be taken to prevent heating up the operating room due to internal load caused by e.g. medical equipment.

When considering the possible contamination of sterile instruments during the lay-up process it is way to perform these processes in separate instrument lay-up rooms with a proper air distribution system. In the Netherlands vertical UDF systems are often used in these instrument lay-up rooms. Vertical UDF systems may however have some disadvantages when applied in such setting. The disadvantage is that vertical UDF systems are not easy to install in an existing lay-up room or existing building because of limitations in the space above the false ceiling and often need cooling of the air flow to support the down flow of the UDF system. Chapter 5 demonstrates that horizontal UDF systems protect sterile instruments during the laying-up process against aerogenic contaminations. In this study it is concluded that a horizontal UDF system offers at least the same protection against aerogenic contamination as down flow systems for the laying-up process.[14]

In comparison with downflow systems, horizonal UDF systems use less air and generate the same and even better results (level of particles and microorganisms carrying particles close to the sterile instruments). Other advantages of the horizontal UDF systems for laying-up instruments are that temperature difference is not needed to increase the air speed of the UDF system and the system is easier to install and maintain. With a reduction of the systems energy and maintenance cost as a result. After publication of this study more and more horizontal UDF systems for laying-up instruments have been implemented in the Netherlands. A potential risk is that these systems are not optimally attuned to the height of the instrument tables used e.g. the top of the table is positioned too high in relation to the position of the air supply system.
New operating rooms in the Netherlands are in most cases equipped with large UDF systems, typically 3 x 3 m. These systems are designed mainly for surgical processes that need several instrument tables and a Mayo stand. For local surgical procedures in a small area and a small number of sterile instruments e.g. eye and hand surgery the use of large UDF systems seems to be overdone. For these type of surgical procedures smaller UDF systems may be used. Chapter 6 shows that for intra-vitreal injection mobile UDF systems can safely be used.[15] These types of systems are not only suitable for intra-vitreal injection but also for surgical procedures in a small area and a small amount of sterile instruments and medical equipment. This may reduce the number of operations that are performed in operating rooms with large UDF systems freeing up the operation room for the intended surgical procedures with large operating areas and many sterile instruments. More research and product development is needed to prove and optimise the effectiveness of these mobile UDF systems.

This thesis concludes that the performance of an air distribution system in operating rooms should be expressed in the potential to discharge microorganisms carrying particles. The better the system is capable to do so, the lower the chance of microorganisms carrying particles depositing on instruments or in the operation wound.

At rest this should be demonstrated by technical measurements with a predefined source strength of particles and during real surgery this could be determined by measuring the number of CFU/m^3 or CFU/(m^2.h). Both strength and weakness of using CFU/m^3 or CFU/(m^2.h) as an indicator of the systems performance is that the outcome not only depends on the characteristics of the air distribution system in the operating room but also on the processes performed in the operating room.
These processes affect the source strength (CFU/m^3 or CFU/(m^2.h)) that the system has to eliminate, this applies in particular to diluting mixing systems. The more robust the air distribution system, the more limited the effect on the source strength will be.

Future directions of research are presented in this thesis that should be conducted on the topic of aerogenic contamination control in operating rooms and instrument lay-up rooms.

References

1. Traversari R, Goedhart R, Schraagen JM. Process simulation during the design process makes the difference: Process simulations applied to a traditional design. *Health Environments Research and Design Journal*. 2013;6(2):58-76.

2. Whyte W, Bailey PV. Effectiveness of a partial-wall laminar-flow system with special regard to air supply temperature. *J Soc Environ Eng*. 1978;17(4):29-32.

3. Bayramzadeh S, Joseph A, Allison D, Shultz J, Abernathy J. Using an integrative mock-up simulation approach for evidence-based evaluation of operating room design prototypes. *Appl Ergon*. 2018;70:288-299.

4. Stichler JF. State of the science in healthcare design. *HERD: Health Environments Research & Design Journal*. 2017;10(2):6-12.

5. Traversari AAL, Bottenheft C, Louman R, van Heumen SPM, Böggemann J. The effect of operating lamps on the protected area of a unidirectional down flow (UDF) system. *Health Environments Research and Design Journal*. 2017;10(3):40-50.

6. DIN 1946-4:2008. Ventilation and air conditioning - part 4: VAC systems in buildings and rooms used in the health care sector. *DIN*. 2008.

7. Departement of Health. *HTM 03-01 part A: Heating and ventilation systems health technical memorandum specialised ventilation for healthcare premises.* The Stationery Office (TSO); 2007.

8. Önorm H 6020. Lüftungstechnische anlagen für medizinisch genutzte räume - projektierung, errichtung, betrieb, instandhaltung, technische und hygienische kontrollen. *Österreichisches Normungsinstitut*. 2015.

9. VCCN Richtlijn 7. Methode voor testen en classificeren van operatiekamers en opdekruimten in rust. *Vereninging Contamination Control Nederland*. 2017:1-36.

10. Luntsford PK, inventorSurgical Lighting system. patent 5,093,769. Oct. 4, 1990, 1992.

11. EU. Directive 2010/31/EU of the european parliament and of the council of 19 may 2010 on the energy performance of buildings (recast). *Official Journal of the European Union*. 2010:13-35.

12. EU. Directive 2012/27/EU of the european parliament and of the council of 25 october 2012 on energy efficiency, amending directives 2009/125/EC and 2010/30/EU and repealing directives 2004/8/EC and 2006/32/EC. *Official Journal of the European Union*. 2012;55:1-97.

13. Traversari AAL, Bottenheft C, van Heumen SPM, Goedhart CA, Vos MC. Effect of switching off unidirectional downflow systems of operating theaters during prolonged inactivity on the period before the operating theater can safely be used. *Am J Infect Control*. 2017;45(2):139-144.

14. Traversari AAL, Goedhart CA, Dusseldorp E, et al. Laying-up of sterile instruments in the operating theatre: Equal or superior protection by using a horizontal unidirectional air flow system. *J Hosp Infect*. 2013;85(2):125-133.

15. Lapid-Gortzak R, Traversari R, van der Linden JW, Lesnik Oberstein SY, Lapid O, Schlingemann RO. Mobile ultra-clean unidirectional airflow screen reduces air contamination in a simulated setting for intra-vitreal injection. *Int Ophthalmol*. 2017;37(1):131-137.