Total and viable airborne particulates during orthopaedic surgical procedures

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Study participants

**Surgeons**
- Dr Richard Verhuel – Newcastle
- Professor Warwick Bruce – Sydney
- Dr Michael Solomon – Sydney
- Dr Broe – Sydney

**SORL**
- Rema Oliver, PhD – SORL
- Ms. Emma Walsh – SORL
- Mr. Nathaniel Bradford – SORL
Annual direct hospital cost of treating healthcare-associated infections (HAIs) in the United States

- Costs estimated in 2007 as high at $35.7 - 45 billion USD
- Benefits of prevention
  - 20% prevention cost savings .... $5.7 to $6.8 billion USD
  - 70% prevention cost savings .... $25.0 to $31.5 billion USD

R. Douglas Scott II, Economist
Division of Healthcare Quality Promotion
National Center for Preparedness, Detection, and Control of Infectious Diseases
Coordinating Center for Infectious Diseases
Centers for Disease Control and Prevention
March 2009
Financial Impact of Surgical Site Infections on Hospitals
The Hospital Management Perspective

John Shepard, MBA; William Ward, MBA; Aaron Milstone, MD, MHS; Taylor Carlson, BS; John Frederick, BS;
Eric Hadazy, MS; Trish Perl, MD, MSc

Figure 2. Equation to Determine Change in Profit Due to a Single Surgical Site Infection (SSI)

\[
\text{Change in Hospital Revenue} = \sum_{i=1}^{n} \left( \frac{\text{Change in ICU LOS if 1 SSI is Prevented}}{\text{Revenue per ICU Day}} - \frac{\text{Change in Non-ICU LOS if 1 SSI is Prevented}}{\text{Revenue per Non-ICU Day}} \right) \times \left( \frac{\text{Change in Daily Hospital Cost if 1 SSI is Prevented}}{\text{LOS for a Patient With an SSI}} - \frac{\text{Cost to Obtain Backfill Patients}}{\text{Cost of Intervention That Prevented SSI No. of SSI's Prevented by Intervention}} \right)
\]

The equation is used for all SSI's. The results must be summed for all SSI's to derive the total change in profit for the health system or hospital due to SSI's. ICU indicates intensive care unit and LOS, length of stay.
Surgical site infection: Incidence and impact on hospital utilization and treatment costs

Gregory de Lissovoy, PhD, MPH, a Kathy Fraeman, SM, a Valerie Hutchins, BS, a Denise Murphy, RN, MPH, CIC, b David Song, MD, c and Brian B. Vaughn, MPA, MBA d

Fig 1. Impact of surgical site infection on length of stay.

Fig 2. Impact of surgical site infection on cost of hospital stay.

American Journal of Infection Control, Volume 37, Issue 5, June 2009, Pages 387-397
Surgical Site Infection (SSI)

- Contaminating microorganisms may be endogenous or exogenous
  - Skin, surgical preparation

- Exogenous microorganisms are vectored by airborne particles

- The patient’s skin is the direct source of contamination in only 2% of cases, leaving 98% of cases related to airborne particles
SSI

- Surgical-site contamination by airborne particles

  - 30% of cases to direct settling of the particles on the wound
  - 70% of cases to settling on the instruments and surgeon’s hands followed by transfer to the wound

Multidisciplinary problem

Medical

Surgical

Device

Environment
- Operating environment and what is happening
- Traffic within the theatre and potential cross contamination
- Equipment etc

Understand the variables

Endpoints

Study design

Solutions ....
Studies

- Airborne particulate during different surgical procedures
  - Newcastle, Sydney

- Effect of technology to influence operating theatre environment
  - Newcastle, Sydney

- Models to study airborne particulates
  - Lab based
Intervention

A. HEPA FILTER AIR
B. QUALITY MONITOR
C. VARIABLE SPEED CONTROL
D. ULTRAVIOLET REACTOR
E. BLOWER/MOTOR
F. PREFILTER

Contaminated Air → Prefilter → HEPA → Treated Air
Objectives/Hypothesis

**Objectives**

- To monitor total and viable particle count during a knee and hip replacements
- To compare total and viable particle count across different hospitals and surgical procedure

**Hypothesis**

- Orthopaedic surgery and movement in the theatre contributes to overall particle load during the surgery. This has the potential to increase the risk of infection for the patient as well as cross contamination between theatres.
Monitoring conditions

Study A
Biotrak – 90 min cycle, 28 L – **No Illuvia**
Case 1 – THA - uncemented
Case 2 – TKA - cemented

Study B
Biotrak – 90 min cycle, 28 L
**One theatre with Illuvia, One theatre without**
4 cases in each theatre ,..., mix of hips and knees
8:03 am – Biotrak system initiated – 4 staff in the theatre at this time preparing for the patient.

8:05-8:35 am – Set up the theatre with numerous door openings that had access to the corridor of the theatre.

8:35 am – Patient brought into theatre. During this period door openings into the corridor and store room continued.

8:42 am – 9 staff in the theatre as well as the patient.
  - Surgeon gloves taped as per Professor’s technique.

9:00 am – Skin incision – scalpel and diathermy – 3 fellows and 1 surgical assistant.

9:10 am – Broaching the femur

9:13 am – Reaming

9:18 am – Suctioning

9:20 am – Broaching

9:22 am – Reaming – 12 people in the theatre

9:28 am – Definitive acetabular implant placed in the patient, people still moving around the theatre

9:32 am – Preparing of the femoral stem site

9:40 am – Femoral preparation – 10 people in the theatre

9:49 am – Implant placed and closing started

9:58 am – Closing continued – 7 people in the theatre

10:10 am – Patient removed from the theatre – lots of movement

10:35 am – Doors open and staff “mopping theatre” and wheeling out the bed and set up starting for next case – 8 people in the theatre.

10:50 am – still “mopping”
Incision – 9am ...

9:10 am – 9:22 am
Lots of “action”

Clean up ...

Case 1: THA
Incision – 12:27 pm … to close 2:39 pm
**Particles & Illuvia - Aerobiotix**

<table>
<thead>
<tr>
<th>Theatre 1</th>
<th>Theatre 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>◦ 4 cases</td>
<td>◦ 4 cases</td>
</tr>
<tr>
<td>◦ With Illuvia</td>
<td>◦ Without Illuvia</td>
</tr>
</tbody>
</table>

Bacteria plates as well in the hallway and the theatres
Bacteria counts in the hallway – Baseline
No Illuvia Present

<table>
<thead>
<tr>
<th>Location</th>
<th>Time Tested</th>
<th>Bacteria</th>
<th>Mould</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hallway 1</td>
<td>04:30am</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>Hallway 1</td>
<td>11:10am</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Hallway 2</td>
<td>05:30am</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>Hallway 2</td>
<td>11:20am</td>
<td>440</td>
<td>5</td>
</tr>
</tbody>
</table>

Bacteria is present
Theatre 1 - Illuvia Aerobiotix system present

Illuvia Aerobiotix system present ...

Bacteria counts are lower than the Hallway and low all day
Particles are generated throughout the procedure however the Illuvia Aerobiotix system reduces airborne particulates.
No Illuvia treatment

Table 1: Bacteria and Mould counts in theatre 3. This theatre did not have the Illuvia Aerobicix system running.

<table>
<thead>
<tr>
<th>Location</th>
<th>Time Tested</th>
<th>Bacteria</th>
<th>Mould</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Theatre 3</td>
<td>04:30am</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>06:30am</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>07:00am</td>
<td>180</td>
<td>5</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>07:45am</td>
<td>75</td>
<td>5</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>08:00am</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>08:25am</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>09:40am</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>10:00am</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>11:30am</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>Operating Theatre 3</td>
<td>11:40am</td>
<td>65</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 9: Airborne concentration of Bacteria and mould throughout Operating Theatre 3 during the course of 3 cases. This theatre did not have the Illuvia Aerobicix system running and served as the control room.
With Illuvia – “dirty” air in, clean/sterile air out

Figure 10: Bacteria counts in the Hallway, Theatre 1 and Theatre 3. Theatre 1 had the Illuvia Aerobiotic system running.
Particles during surgery ....

- Lots!
- Many sources

- Environment can be controlled
  - Reduce airborne particulate
    - Reduce SSI
Controlling airborne particles during surgical procedures using a novel device: A laboratory based study

Walsh WR, Davies GS, Bradford N, Oliver R,

Surgical and Orthopaedic Research Laboratories,
Prince of Wales Clinical School, University of New South Wales
Sydney, Australia
SSI

Surgical-site contamination by airborne particles

- 30% of cases to direct settling of the particles on the wound
- 70% of cases to settling on the instruments and surgeon’s hands followed by transfer to the wound

SSI

- Surgical-site contamination is chiefly attributable to airborne particles
- Measures to control air quality deserves serious attention

Airborne microbes → Wound contamination → Surgical site infection
Multidisciplinary problem

- Medical
- Surgical
- Device

- Environment
  - Operating environment and what is happening
  - Traffic within the theatre and potential cross contamination
  - Equipment etc
The problem

• Huge variation in microbial load
• Difficulty quantifying the effect of an intervention

• Overcome this → controlled laboratory environment
  • Controlled particle source – *diathermy of tissue.*
  • *PC2 environment*
  • *Traffic from people or doors opening, etc.*
Intervention – continuous system

A. HEPA FILTER AIR
B. QUALITY MONITOR
C. VARIABLE SPEED CONTROL
D. ULTRAVIOLET REACTOR
E. BLOWER/MOTOR
F. PREFILTER
Model & methods

Set up

• 60s Diathermy (30cm/min) on pig skin
• Diathermy set to ‘cut’ at 50w
• Measurement at 0.5m and 3m
• 20 minute intervals
• 10 repetitions with and without Aerobiotix Illuvia
Results: Distance from the source

Total particles measured using diathermy to provide the source was influenced by the distance from the particle counter.
Results

0.5m With and Without Aerobiotix

3m With and Without Aerobiotix
Status

Baseline significantly lowered at both 0.5 and 3m with ADRS active

Figure 1  Mean baseline of airborne particles in thousands (± 1 SD) measured at 0.5m and 3m from site of diathermy with and without ADRS active.
Results – Area under the curve
AUC for total particles significantly reduced for 0.5 and 3m with ADRS active
Conclusions

• Diathermy can provide a controlled means to introduce particles to study with effect of technology that filters the air.

• Illuvia system
  • Faster clearance of airborne particles
  • Lower baseline particle count

• Reduces particle contamination