The Physicians of the Future are Engineers!

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Taylor Healthcare Consulting, CEO
Hospitalization is the third leading cause of death in the US!
Healthcare Associated Infections (HAIs) are the main cause
How is the hospital building involved in this sad statistic?
Humans and buildings
- Many diseases are on the rise
- The “new” human environment
- Current building design goals

Indoors
- We see what we look for
- New tools revolutionize our knowledge

Indoor climate and our health
- Studies on the indoor environment and health
- Indoor air, microbes and humans

Change is in the air
- Financial impact of proper IAQ management
- Next steps
Presentation Summary

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Examples of emerging and re-emerging infectious diseases
In USA, 2017-18 was one of the worst flu seasons in the history of CDC surveillance.
We spend 85% of our time indoors

- Open dwellings
- Unobstructed outdoor air exchange
- Tight building envelopes
- Mechanical air ventilation systems

“We shape our buildings, then they kill us!” Dr. Dickerman
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Thankfully, we have new tools to study our bodies and our environments.
A closer look at our indoor spaces
We now know that each of us are ecosystems, more microbial than human!

Don’t worry, most of these microbes are good for us, helping our:

✓ digestion and metabolism
✓ mental health
✓ immune system

Microbial imbalances, however, are associated with:

✓ inflammatory diseases
✓ obesity
✓ neurological disorders

Microbial cells ~ 100 trillion

Human cells ~ 30 trillion
Building design and ventilation determine which microbes survive inside.

Occupants send microbes into buildings, and buildings send microbes back to us.
The invisible communities living in our buildings are called “The microbiome of the built environment”.

- **by naked eye**, we see nothing!
- **by microscopy**, thousands of microbes are visible.
- Genome sequencing has uncovered that trillions of microbes inhabit our buildings.
The indoor microbiome is less diverse than outdoors.
Microbes in mechanically ventilated buildings are more closely related to pathogens.

- **Mechanically ventilated**
  - *Low* bacterial diversity
  - *High* average pathogenicity

- **Outdoor Air**
  - *High* bacterial diversity
  - *Low* average pathogenicity
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Criteria for designing our “new” human environment

✓ Construction budget
✓ Energy consumption
✓ Appropriate for contained indoor "goods“ (data server, paper, food, etc.)

Occupant comfort
✓ Occupant health

✓ Fuel consumption
✓ Sound system
✓ Paint color and interior materials

✓ Driver and passenger safety in case of an accident
What data will tell us if building design and operation truly support human health?

Moving beyond LEED ratings
One year-long study to evaluate the patient room environment and HAIs

**Patient room data**  VS.  **Patient HAIs**

- Staff & visitor hand cleaning
- Temperature
- Room pressurization
- Lux
- CO₂ level
- Relative humidity, Absolute humidity
- Room traffic
- Room air changes
- Outdoor air fractions
Lower relative humidity (RH) in patient rooms correlated with more patient HAIs

Average RH for all patient rooms

Healthcare-Associated Infections in 10 monitored patient rooms

<table>
<thead>
<tr>
<th>Coefficients²</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average RH</td>
<td>-9.060</td>
<td>-2.396</td>
<td>0.020</td>
</tr>
<tr>
<td>Avg Temp</td>
<td>2.593</td>
<td>2.383</td>
<td>0.021</td>
</tr>
<tr>
<td>Avg Hum Ratio</td>
<td>-7.563</td>
<td>-2.386</td>
<td>0.021</td>
</tr>
</tbody>
</table>
Patient events:

Infections
- respiratory (viral & bacterial)
- GI (Noro. & Notovirus, C. diff)
- urinary tract
- conjunctivitis
- cellulitis

Cognitive and behavioral
- scheduled antipsychotic meds
- PRN antipsychotic medication
- falls, pressure ulcers

External measurements:

Outdoor climate
- temperature
- relative humidity
- flu outbreaks

Indoor conditions
- temperature
- relative humidity
- visitors
- staff absenteeism
Respiratory & GI infection rates were lowest when indoor RH 40-60%

avg # of infections

Indoor RH

- Respiratory
- GI (ex. Noro-virus)
- UTI
- Cellulitis
- Eye

Respiratory & GI infection rates were lowest when indoor RH 40-60%
### Independent group t-test - all patient events and RH

#### Monthly incidence rate

<table>
<thead>
<tr>
<th></th>
<th>RH &lt;40% Mean (SD)</th>
<th>RH 40%-60% Mean (SD)</th>
<th>RH &gt;60% Mean (SD)</th>
<th>T-test comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RH &lt;40% to 40%-60% RH</td>
</tr>
<tr>
<td>Events</td>
<td></td>
<td></td>
<td></td>
<td>T-test (p-value)</td>
</tr>
<tr>
<td>Falls</td>
<td>49.63 (13.72)</td>
<td>41.57 (16.26)</td>
<td>29.20 (19.20)</td>
<td>1.31 (0.20)</td>
</tr>
<tr>
<td>Antipsychotic medications</td>
<td>33.08 (4.00)</td>
<td>34.14 (4.45)</td>
<td>29.60 (9.02)</td>
<td>-0.60 (0.55)</td>
</tr>
<tr>
<td>PRN antipsychotic medications</td>
<td>4.04 (2.76)</td>
<td>4.29 (1.80)</td>
<td>2.80 (2.05)</td>
<td>0.60 (0.83)</td>
</tr>
<tr>
<td>Pressure ulcers</td>
<td>4.67 (4.19)</td>
<td>1.71 (1.38)</td>
<td>2.40 (0.89)</td>
<td>1.82 (0.08)</td>
</tr>
<tr>
<td>Infections</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urinary tract infections</td>
<td>2.29 (1.57)</td>
<td>3.14 (2.34)</td>
<td>2.60 (1.67)</td>
<td>-1.13 (0.27)</td>
</tr>
<tr>
<td>Upper respiratory infections</td>
<td>3.13 (2.86)</td>
<td>0.57 (0.79)</td>
<td>0.80 (1.30)</td>
<td>2.31 (0.03)</td>
</tr>
<tr>
<td>Gastrointestinal infections</td>
<td>3.67 (2.84)</td>
<td>0.29 (0.49)</td>
<td>0.00 (0.00)</td>
<td>3.10 (&lt;0.01)</td>
</tr>
<tr>
<td>Cellulitis</td>
<td>2.17 (1.49)</td>
<td>1.00 (0.82)</td>
<td>0.60 (0.55)</td>
<td>1.97 (0.06)</td>
</tr>
</tbody>
</table>

SD=Standard Deviation  
RH=Relative Humidity
Humidity as a non-pharmaceutical intervention for Influenza A

January 25 – March 11 (32 days)

Half of the classrooms were humidified, the other half were not

<table>
<thead>
<tr>
<th>RH of classrooms</th>
<th>% Airborne particles carrying virus (PCR)</th>
<th>Virulence of airborne virus (% cells infected)</th>
<th># children absent due to influenza illness</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>49%</td>
<td>75%</td>
<td>22</td>
</tr>
<tr>
<td>45%</td>
<td>19%</td>
<td>35%</td>
<td>9</td>
</tr>
</tbody>
</table>
“Dry air may be the most important environmental factor influencing the survival of airborne microbes.”

Dr. Dimmick, Naval Biological Laboratory, Univ. CA, Berkeley, doing research on anthrax spores
Why is dry air so powerful?

Dry, thirsty air steals moisture from wherever it can – a universal law of physics.
Will this cough infect others?
Infectious droplets shrink and travel in dry air

**Droplet diameter in microns (um)**
- 0.5
- 1
- 3
- 10
- 100

**Float time**
- 6 seconds
- 1.5 hours
- 41 hours – 21 days

**Distance travelled:**
- 1m
- 10m+
RH of 40% quickly inactivates 80% airborne influenza A
Diseases/Pathogens Requiring Airborne Infection Isolation

• Anthrax
• Avian influenza
• Varicella disease (chickenpox, shingles)
• Measles (rubeola)
• Severe acute respiratory syndrome (SARS)
• Smallpox (variola)/Varioloa virus
• Tuberculosis (TB)
Diseases/Pathogens Requiring Droplet Precautions

- Diphtheria
- Epiglottitis, due to Haemophilus influenzae type b
- Haemophilus influenzae Serotype b (Hib) disease
- Influenza, human (typical seasonal variations)
- Meningitis & Meningococcal disease sepsis, pneumonia
- Mumps (infectious parotitis)/Mumps virus
- Mycoplasmal pneumonia
- Parvovirus B19 infection (erythema infectiosum)
- Pertussis (whooping cough)
- Pharyngitis from Adenovirus, Orthomyxoviridae, Epstein-Barr virus, Herpes simplex virus

New news

- Pneumonia (Adenovirus, Haemophilus influenzae Serotype b, Meningococcal Mycoplasma)
- Streptococcus Group A
- Pneumonic plague/Yersinia pestis
- Rubella virus infection (German measles)/Rubella virus
- Severe acute respiratory syndrome (SARS)
- Streptococcal disease (group A streptococcus)
- Viral hemorrhagic fevers due to Lassa, Ebola, Marburg, Crimean-Congo fever viruses
This is the most startling news of all...

"Antibiotic Resistance Can Spread Through The Air, Scientists Warn, And Yes You Should Be Terrified",

*July 26, 2018*

Dry conditions increase **horizontal** transfer of antibiotic resistance genes
Vertical vs. horizontal gene transfer

**Vertical gene transfer**

*slow-*
mutation and reproduction

**Horizontal gene transfer**

*fast-*
genomes inserted sideways
Indoor air with RH < 40% promotes pathogen transmission in tiny aerosolized droplets

Pathogens circulate through the ventilation system

Infectious droplets are expelled into the hospital environment and dry rapidly

Re-contaminate hands and surfaces

Recirculate in turbulent flow

Infectious droplets spread disease to in-patients (HAIs)
With healthy RH of 40%–60%, infectious droplets settle out of the airborne environment.

**Disinfection benefits of proper air hydration:**

- Bedrails and other frequently touched surfaces are more effectively cleaned.
- Hand hygiene is maintained.
- Settled infectious droplets are not re-suspended.
Enough about microbes. Do humans do well in dry air?
NO! Even mild dehydration causes health problems

Sitting in room air with 20% RH, the average person becomes clinically dehydrated in 8 hours, before thirst begins

- dry eyes & blurry vision
- skin cracking, decreased wound healing
- impaired brain function
- more infections & asthma attacks
- dangerous blood clotting
Dry air harms respiratory defenses

Dry inhaled air causes:

- Increased susceptibility to infections
- Increased wheezing from allergic disease
Bacteria spread through the air when the outdoor humidity is low

“Once the humidity exceeds 40%, the epidemic ends”

Dry weather reliably predicts meningitis outbreaks
Mild (1%) dehydration impairs our brain
Mild (1%) dehydration impairs our brain.

Results in decreased:
- ability to think
- short-term memory
- concentration
- reaction times
- visual-motor tracking

*Explored in vivo by 1H-MR imaging and spectroscopy*
Dry air impairs our vision

6 hours later with 20% RH
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The great indoor air RH debate!

 Protect the building

Buildings *don’t care* about humidity

Facility managers often think:

- The drier the air the better
- Easier to dry the air than fix the envelope construction

 Protect the occupants

Occupants *need* RH between 40% and 60% for health

- Decreased infections
- Fewer allergies
- Improved organ hydration
- Improved wound healing
- Increased work performance
Hello, are you listening?
Humidification **IS** used when the financial impact is quantifiable.

- National Institute of Health animal facility
  - Replacement cost of a primate: $22,000
  - RH 40%–60%

- NASA spacecraft
  - Cost to train an astronaut: $50 million (in 2006)
  - RH 40%–60%

- Louvre
  - Mona Lisa value: $780 million
  - RH 40%–60%
Do humans have a dollar value?
When are humans worthy of humidification?

“Arrrghh, Why didn’t we humidify our air sooner?!?”
There is a financial reason to decrease HAIs, 250 bed hospital’s losses from these infections

<table>
<thead>
<tr>
<th>Infection Type</th>
<th>Total Infections</th>
<th>Total Excess Costs</th>
<th>Total Excess Hospital Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urinary Tract Infections</td>
<td>1,296</td>
<td>$1,435,968</td>
<td>2592.0</td>
</tr>
<tr>
<td>Surgical Wound Infections</td>
<td>365</td>
<td>$7,042,464</td>
<td>4378.0</td>
</tr>
<tr>
<td>CRBSI</td>
<td>148</td>
<td>$4,990,636</td>
<td>2509.0</td>
</tr>
<tr>
<td>VAP</td>
<td>15</td>
<td>$401,369</td>
<td>170.0</td>
</tr>
<tr>
<td>MRSA</td>
<td>120</td>
<td>$927,162</td>
<td>646.0</td>
</tr>
<tr>
<td>CDIFF</td>
<td>122</td>
<td>$500,200</td>
<td>733.0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2,066</strong></td>
<td><strong>$15,297,799</strong></td>
<td><strong>11,028.0</strong></td>
</tr>
</tbody>
</table>
Projected financial benefits of humidification in a 250-bed hospital

<table>
<thead>
<tr>
<th>BENEFITS - Year One</th>
<th>Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Revenue</td>
<td></td>
</tr>
<tr>
<td>Maximize per day bed value by decreasing LOS</td>
<td>$1,310,126</td>
</tr>
<tr>
<td>Decrease non-reimbursable HAI costs</td>
<td>$764,890</td>
</tr>
<tr>
<td>Cost Avoidance</td>
<td></td>
</tr>
<tr>
<td>3% CMS penalty</td>
<td>$91,787</td>
</tr>
<tr>
<td>CMS Quality in</td>
<td>TBD</td>
</tr>
<tr>
<td>Joint Commission</td>
<td>TBD</td>
</tr>
<tr>
<td>Employee absence</td>
<td>TBD</td>
</tr>
<tr>
<td>HAI litigation</td>
<td>TBD</td>
</tr>
<tr>
<td>Quarterly total</td>
<td>$2,166,803</td>
</tr>
<tr>
<td>Cumulative value</td>
<td>$2,166,803</td>
</tr>
</tbody>
</table>

INVESTMENTS

| INVESTMENTS | | |
|-------------|----------------|
| Gas         | Installation & Integration of New System |
|             | $ (1,198,500) |
| Maintenance | $ (23,850)    |
| Operating Cost | $ (34,573) |
| OR & PT Room Down Time | $ (10,000) |
| Quarterly total | ($1,266,923) |
| Cumulative investment | ($1,266,923) |

1st Quarter 500.97%
1985 ASHRAE Sterling et al, Optimum relative humidity ranges for health = 40%–60%
35 years later….. Taylor Chart in 2019
The divide between medical and building professionals is a huge problem, and offers an equally huge opportunity.

**Medical professionals**
- Better patient outcomes
- Do what is familiar
- Avoid lawsuits
- Make a profit

**Building professionals**
- Reduce energy consumption
- Real estate values
- Stay within budget
- Beauty of the building

**Improve occupant health**
- Fewer infections and chronic diseases
- Improved wellness, productivity and learning
Where are you?

**STAGES OF RESISTANCE TO CHANGE**

What do you need to move forward?

1. _______________
2. _______________
3. _______________
4. _______________
Biology is a guide...

Evolution and RH

skull of the grassland Saiga antelope
A large cranial air cavity increases ambient RH, preventing dust particles and parasites from entering delicate lung tissue.

the African desert first cousin
Conclusions

1. We need to manage indoor climates to support occupant health, not just occupant comfort.

2. This is a different priority, and will require a new mindset of both building and medical professionals.

3. Specifically, the humidity level in many buildings is harmful to humans and is associated with serious illnesses and decreased overall wellness.

4. **People need to be in an indoor environment with the relative humidity between 40–60%. This is essential!**
Thank You!

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• Tropical Medicine & International Health. 2008., Volume 13, Issue 12, pages 1543-1552, 6 Oct.


Influenza A outbreaks

Seasonal distribution
Decrease building energy use with proper humidification

Hospital indoor air change rates (ACH) are kept high because of a mistaken perception that high ACH will yield better IAQ.

- Although counterintuitive, reducing room ACH in hospitals decreases the spread of infectious droplet nuclei.
- Hospitals can save up to 70% HVAC fan and reheat energy costs by reducing ACH by 10%.
The OR sterile field is affected by room temp, air velocity & RH
The sterile field was less contaminated at OR with RH 35% vs 20%

**Bacterial CFUs** in the sterile field were significantly lower at RH 35% and 50% compared to RH 20%

No statistical difference was found between RH 35% and 50%

*=p<0.0167 v. 20RH*