

**Safety & Quality in a Highly Engineered Environment**

**Healthcare-Associated Infection (HCAI) & the Environment, Many Questions, Few Answers**

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**Declaration I**

I am recently in receipt of research funds from Pfizer, 3M, Cepheid, Inov 8, Steris Corporation & GSK

I have recently received consultancy or lecture fees from Novartis, 3M & Astellas

**Declaration II**

The views expressed are in a personal professional capacity & are not necessarily those of the RCSI or Beaumont Hospital

I am a medically, qualified & trained microbiologist. I am not a designer, engineer, architect or planner!



**Outline**

1. HCAI, prevalence & impact
2. The physical environment & HCAI
  - intensive care units
  - operating theatres
  - other
3. Conclusions

**HCAI Prevalence & Impact**

**Historical Perspective - Hospitals**

1<sup>st</sup> Hospital, Baghdad in 9th century  
Monasteries, in 15th century  
Gothic hall style, light & crowding

Wellcome Library, London



## What is HCAI?

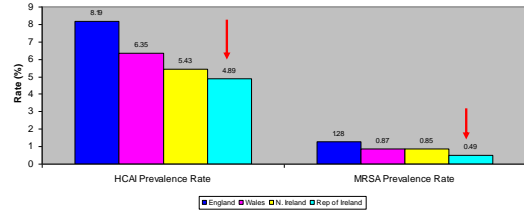
Infection acquired in hospital (wards, Emergency Department, outpatients) & usually 48 hours or more after admission

&

Infections acquired in other healthcare facilities such as nursing homes, day centres, etc.

## Hospital Infection Survey of HCAI, 2006

Prevalence Rate of HCAI and MRSA



## Why is HCAI Important?

**Patient** death  
patient illness & suffering

**Costs** patient  
health system  
society

## Healthcare Costs

USA - \$6.8b in 2004

Lautenbach & Woeltje, 2004

Ireland - €10 - 20m in 2001

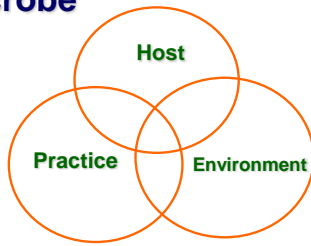
Humphreys & O'Flanagan, 2001

Canada - \$42-59m in 1996/97 for MRSA only

Kim & Simor, 2001

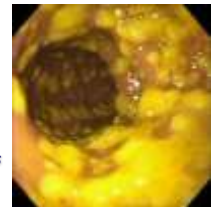
## Healthcare-Associated Infection (HCAI)

### Microbe



## The Bugs

- Bacteria are everywhere; replicate every 20 minutes. Viruses change quickly
- Some bacteria, e.g. *S. aureus* can survive on the skin, despite dryness & salt
- Bacteria can adapt & produce toxins, e.g. toxic shock syndrome toxin
- 30% of the population carry *S. aureus* in the nose, some of us carry *Clostridium difficile* in the intestine



## HCAI & the Environment

<b>Immediate area</b>	ward, bed
<b>Instruments</b>	surgical, endoscopes
<b>General</b>	cleanliness building work water, air

## *Clostridium difficile*

Increasingly recognised infection  
Cause of antibiotic-associated diarrhoea  
Elderly at particular risk  
Ribotype 027 emerged in last 3-4 years,  
with more severe disease, associated  
with certain classes of antibiotics



### *Maidstone/Tunbridge Wells Report*

"Overall, from Oct. '05 to Sept'06 more than 500 patients developed the infection, & we estimate that there were - 60 deaths where *C. difficile* was definitely or probably the main cause."



## Preventing HCAI

- Education & knowledge
- Improved professional practice
- Personnel; specialist & general
- Better facilities, e.g. single rooms
- Hygiene, hand & the environment

**Q.** What is the evidence that the environment directly impinges on HCAI rates?

**A.** There is little direct or incontrovertible evidence. Circumstantial evidence & common sense tell us it is important, but it is difficult to quantify.

## Hospital Architecture & HCAI rates

<b>Methods</b>	databases from 1975-2001
<b>Results</b>	382 articles, 178 included e.g. ICUs (41), surgical depts (83) Four studies failed to show an improvement when facilities updated One showed that 5 patients not 4 on ward leads to increased HCAs
<b>Conclusion</b>	Confounding factors such as poor facilities associated with poor compliance Studies on hospital design required

*Infect Control Hosp Epidemiol* 2004; 25: 21-25

## The Physical Environment: The Intensive Care Unit

## ICU – Key Principles

(Health Building Note 57, 2000)

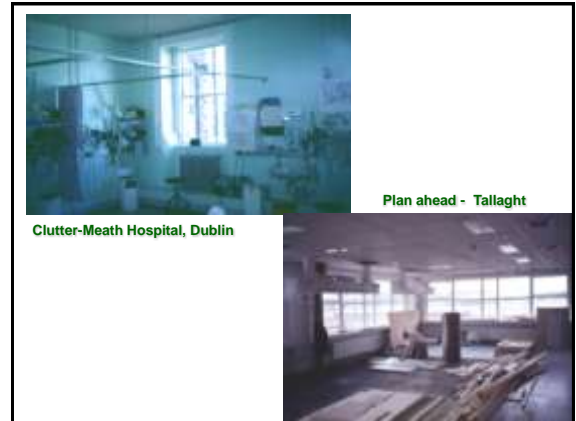
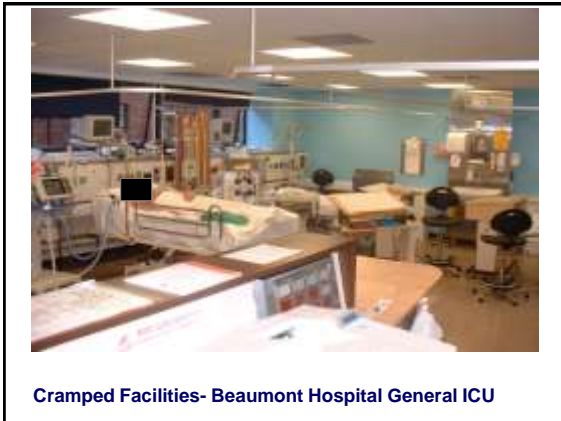
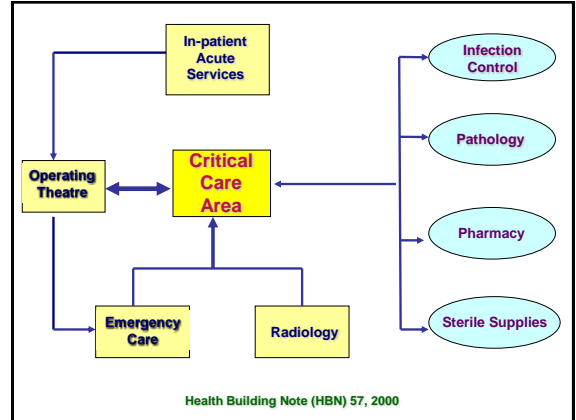
“The ICU should be large, airy, offer privacy, be located close to admitting areas, have easy access to imaging, be quickly evacuated and allow patients to be observed at all times.”

Consider the current & future demands; ideal occupancy of ~75% & admission refusal rate of no more than 5%

At least 50% of beds as cubicles, with + & -ve pressure ventilation

Each bed 25.4m<sup>2</sup>, additional 7m<sup>2</sup> for ‘air-lock’ rooms in cubicles

*Surgery 2009; 27:190-194*



## Isolation Rooms & *Acinetobacter*

- French ICU converted from 7 isolation rooms and 2 x 4 rooms to 15 enclosed isolation rooms in 1994
- Lung carriage reduced from 9/1000 days before to 0.5/1000 days
- 12% of patients positive before & 1% afterwards

*Infect Control Hosp Epidemiol 1997; 18: 499-503*

## Persistence of *Acinetobacter baumannii* in the ICU

- Periodic outbreaks in ICU, Nottingham
- 18% of patients positive when screened during a non-outbreak period
- Using molecular techniques, isolates in '94-'95 indistinguishable from 1982-'83
- Although not detected, probably persisted in the environment over 10 years

*Eur J Clin Microbiol Infect Dis 1998; 17: 171-176*

# The Physical Environment: Operating Theatre

## Historical Perspective

- 18th Century** dedicated room for demonstration purposes
- 1846** anaesthesia
- 1930-'50** artificial ventilation to prevent airborne bacteria
- 1960-'70** ultraclean theatres & body exhaust suits



Boston, USA, 1846  
(Wellcome)



Middlesex Hospital,  
London, 1927 (Wellcome)

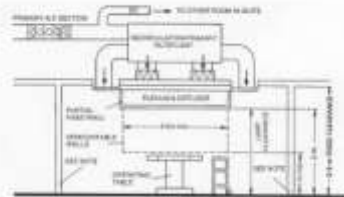


UCV Theatres (HIRL, Birmingham, UK)

## Theatre ventilation

- During walking,  $10^4$  skin scales shed per minute; 10% with microbes
- Air supply should be free of dust & particles; air intake distant from weather, sources of dust
- ~ 20 air changes per hour
- Pressure gradients from sterile areas to other parts of the complex

## UCV or 'Orthopaedic' Theatre



HTM 20

- Prevent airborne prosthetic joint infection
- Larger area of diffusion & air volume, more air changes
- HEPA filtration & air re-circulation
- 'Partial walls' or canopy

## Surgical Site Infection (SSI) & Orthopaedic Surgery

- Active SSI surveillance from 55 hospitals

Factors (OR)	Hip prosthesis	Knee prosthesis
Laminar flow ventilation	1.44	2.38
>600 beds	1.11	1.10
>75th percentile frequency	0.94	0.96
University hospital	0.57	1.36

- Possibly due to inappropriate position of surgical team or low temperatures

Ann Surg 2008; 248: 695-700

## Minimally Invasive Surgery (MIS)

### What is it?

- Laparoscopic surgery, e.g. cholecystectomy
- Interventional radiology, e.g. inserting vascular stents
- Invasive cardiology, e.g. angioplasty, pacing line insertion, pacemaker implantation
- Anaesthesiology & ICU, e.g. tracheostomies

## Cardiology MIS

Ventilation	Hospital type	% in category
No ventilation	DGH (29)	30
	University (11)	16
Treatment room	DGH (34)	38
	University (21)	41
<20 air changes	DGH (10)	12
	University (10)	18
>20 air changes	DGH (16)	19
	University (14)	25
UCV	DGH (1)	1.5
	University (01)	-

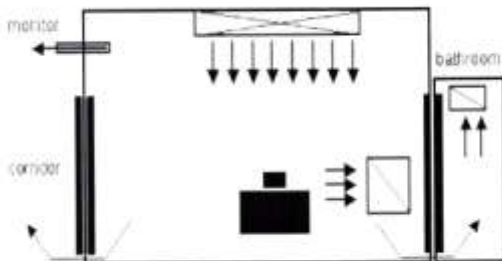
## The Physical Environment: Elsewhere

### Protective Isolation

A category of isolation for patients with an increased susceptibility to infection and where such patients need protection from the hospital environment

- immunodeficiency
- burns patients

Also referred to as 'protective environment,' 'positive pressure rooms'



+ve pressure room (CDC, HICPAC 2001)

## Risk Factors for Aspergillosis

### Patient

Neutropenia, transplantation, radiation, corticosteroids, etc.

*J Hosp Infect* 1998; 39: 95-109

### Environment

Improperly functioning systems

Air filters

Backflow

False ceilings

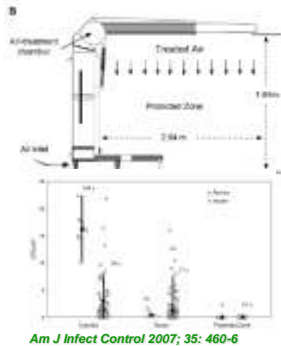
Open windows

HICPAC, 2001



## Mobile HEPA Filtration & Aspergillosis

- Mobile decontamination unit Immunair assessed in 2 children's hospitals
- Dry cleaning raised fungal counts & total counts to 400 cfu/m<sup>3</sup> & 300 cfu/m<sup>3</sup>
- Unit maintains fungal counts <1 cfu/m<sup>3</sup>

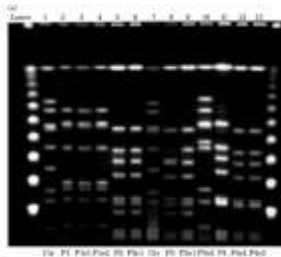


*Am J Infect Control 2007; 35: 460-6*



## Environmental Reservoirs of MRSA in Beaumont Hospital

- 25 patient isolation rooms
- 56% of surface, 28% of air & 41% of settle plates positive
- 70% of linked patient & environmental isolates similar



*J Hosp Infect 2006; 62: 187-194*

## The Physical Environment: Priorities

### Design - Common Sense

- ✓ Self-sealing doors
- ✓ Adequate light
- ✓ Sealed windows
- ✓ Good surfaces
- ✓ Rounded edges
- ✓ Adequate storage
- ✓ Staff facilities
- ✓ Safety & fire regulations

### Quality Processes & the Agri-Food Industry

Well documented procedures & training

Division of duties

Regular inspections

- customers
- accreditation



## HCAI & The Netherlands

**Healthcare**    140 hospitals for 16m  
                          7 university hospitals

**One Hospital**    8,000 employees for 1300 beds  
                          70-80% bed occupancy  
                          No 6-bed rooms; all 4, 2 or 1 beds  
                          100 ventilated rooms

                         9 Infection Control  
                          Practitioners/Nurses  
                          (excluding Microbiologists)



## HCAI - Environment

*(J Hosp Infect 2006;64:63-68)*

<b>Number of hospitals surveyed in Ireland</b>	<b>66</b>
<b>Number with single rooms for isolation</b>	<b>63</b>
<b>Ratio of isolation rooms to total</b>	<b>1:16</b>
<b>Hospitals with en-suite facilities for single rooms</b>	<b>43/55</b>
<b>Hospitals with negative pressure ventilation rooms (NVR)</b>	<b>9</b>
<b>Total number of NVR rooms</b>	<b>52</b>

## MRSA & Portable HEPA Unit

- 2 IQ Air Clean units (60-235 m<sup>3</sup>/h) air filtration
- 3 MRSA patients in single rooms
- Settle plates to assess MRSA in air
- Rate of air filtration correlated with MRSA counts

*J Hosp Infect 2006; 63: 47-54*

**Simple things are important**

