Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Are infection control measures helpful in reducing paediatric ward infections?

Yvonne Beuvink
Scott Hackett

Abstract
As the majority of children on paediatric wards, especially in winter, have infections all paediatricians will be involved in infection control and prevention (ICP) without realising it. ICP measures include decisions on isolation of patients, which can be difficult with small numbers of cubicles. Children, who are highly infectious, have potential severe infections and those who are more at risk of developing severe infections (e.g. immunocompromised) should be isolated. Handwashing/decontamination is the central and most essential part of ICP measures. It should be actively encouraged and regularly monitored to ensure adherence. The ward layout will influence how we manage ICP. This includes placement and number of alcohol dispensers, sinks, bathrooms, equipment storage and the number of cubicles. It is also worth reviewing ward cleaning policies to assess whether these can be streamlined, potentially freeing up beds/cubicles earlier and leading to cost improvement without putting patients and staff at risk. We encourage all our staff to be fully vaccinated (including seasonal influenza vaccines and MMR). Paediatricians need to be closely involved in antibiotic stewardship and act as role models for all aspects of infection control, particularly proper handwashing.

Keywords antibiotic stewardship; handwashing; infection control and prevention

Introduction
The following review will cover if general paediatricians can influence paediatric infection control and prevention (ICP) issues, highlighting where there is evidence and what strategies should be employed to promote this. We will not specifically be covering Paediatric and Neonatal Intensive Care Units (PICU & NICU) unless stated, however in general the methods for ICP will be similar.

The biggest difference between paediatric and adult wards, especially during the winter months is that the majority of children are admitted because of infections. ICP should therefore concern every general paediatrician. It is not uncommon for children at home compared to those in medical settings from the few studies identified. Controversially this may mean that for common paediatric infections, for ‘normal’ children in hospital, we may be able to worry less regarding ICP issues. We will discuss this as we progress through this review remaining pragmatic about where we use this evidence.

Figure 1 shows some of the ICP issues and contamination risks that are commonly encountered in paediatric wards in the UK. The full list of potential risks is given at the end of the article.

History
ICP is not a new topic. It has caused controversy throughout time and still does today. Some of the earliest ICP measures are mentioned by Hippocrates and Galen in the context of plague “leave, go far away and come back slowly”. Reducing contact between infectious patients and healthy individuals remains a mainstay of ICP today.

Handwashing/cleansing
Simple handwashing was shown to be effective in reducing infection rates as long ago as the mid-19th century. Ignaz Semmelweis, a Viennese doctor, noticed that more women died from puerperal sepsis after having been examined by doctors or medical students compared to midwives. This was attributed to the fact that the doctors and students had performed dissections/autopsies just before gynaecological examinations. It was a common belief at the time that puerperal sepsis was either transmitted through the air or was an autoinfection from “unclean” woman in childbirth.

As a consequence of this observation Semmelweis recommended strict handwashing, regular changes of bed linen and thorough cleaning of gynaecological instruments. Unfortunately Semmelweis’ was ridiculed at the time by scientists and other doctors and his theory was only accepted into clinical practice after his death in 1865. Today we have moved these principles forward so that all of us should be universally employing the 5 moments of hand hygiene and the 6 steps of hand washing technique.

The 5 moments for hand hygiene, when we need to disinfect our hands are:
1. Before touching a patient/entering their bed space/cubicle
2. Before clean/aseptic procedures
3. After body fluid exposure/risk
4. After touching a patient
5. After touching a patients’ surroundings

The 6 steps to hand washing or alcohol rubbing technique are shown in Figure 2. Alcohol rubs, which can be carried by
Figure 1 Identify the potential infection control risks lurking in these picture from a paediatric ward (answers at the end of this article).

Figure 2 The 6 steps to hand washing or alcohol rubbing technique.
individuals, should be applied only to unsoiled (previously washed) hands. Many alcohol rubs are wall mounted electronic units activated by a non-touch technique, eliminating any recontamination of the device.

Reinfection/contamination of hands from others surfaces needs to be minimised (see equipment section later) but to prevent clothing becoming contaminated in all clinical situations we need to enforce bare below the elbows, no ties, name badges not on lanyards, no watches etc. Ensuring that correct handwashing is enforced is the lowest hanging fruit to improve your ward ICP.

How are infections transmitted?

Routes of transmission can differ between pathogens. The knowledge of how different infections are spread influences which ICP measures we should be employing. Routes of infection include direct contact with the infected person, bodily fluids or contaminated surfaces, faecal-oral transmission and droplet or airborne transmission.

Viral infections

Viral respiratory tract infections are the commonest paediatric infections. Viral particles are often spread via droplets. These were thought not to be spreadable over significant distances (but see later discussion), but settle on surfaces where they can survive for prolonged periods. They can later be passed on through contaminated hands of patients/parents and health care workers. This route of transmission would be prevented by adherence to strict handwashing policies.

New data on airborne viral particles may change ICP measures. RSV particles can stay aerosolised and are detectable, albeit in significantly reduced levels at 5 m from a patient at head height. There are no particles detectable at 10 m. Other viral particles that have been documented in aerosols include influenza, adenovirus, coronavirus and rhinovirus.

Practical measures to prevent spread of viruses between children

Separating patients by over 5 m is usually not practical in most units. Moveable curtains/screens (floor to ceiling) can be used to reduce spread, especially if they can easily be cleaned between patients. However, we must ask, is this necessary? As we have said there is some evidence that children in hospital do not acquire infections (viral) more commonly than those in the community.

We propose where possible children with infections should be separated as much as possible. If you are involved in the re-design or plans for a new unit then the distances stated above should probably be taken into account or you should consider building more cubicles. However, if patients are ‘normal’ and facilities do not permit this separation it is not clear to us that you need to strictly adhere to these distances. Moreover children and parents are mobile and restricting their movements may neither be practical or desirable.

A recurrent theme later in this article is that the ‘at risk’ children are the ones who should be isolated. Common sense should apply to other children.

Which ICP measures can be effective?

Patient to patient transmission

With no evidence that hospital acquired ‘viral’ infections harm children do we need to worry about this? We consider a common scenario in Box 1 (below).

A common scenario

You are the middle grade, looking after a paediatric High Dependency Unit (HDU) where there is a 40 week old ex-preterm infant who has severe hypoplastic lung disease. This child has required variable high flow oxygen and intermittent CPAP over the last week. The unit has 3 open beds and one cubicle. The patient is nursed in a cot. An 8 year old patient with a severe myopathy is admitted to HDU with a significant ‘chest infection’. You are asked by the senior sister whom should be admitted to the cubicle? What would you do?

Box 1

We decided the child with hypoplastic lungs warranted the cubicle. The child with the myopathy is older, has siblings and has spent longer at home. We therefore assume that they have been exposed to more viruses and have coped with these. We have, as a department elected, if possible to protect at risk children by putting them into cubicles. This makes little sense when we have just said that hand washing etc. can prevent the majority of respiratory viral transmissions. However, cubicles with yellow infection risk signs on the door and an insistence that medical staff wear plastic gowns etc. reinforces the ICP policy of the unit.

There is little if any concrete evidence for this position but we feel that taking a position where we ‘protect the most vulnerable child’ helps to encourage better ICP policies especially as we are not constantly present on the wards. Our nursing colleagues support this policy. We base our decisions pragmatically upon the patients in front of us which includes the risk of them developing severe disease due to co morbidities, their infectivity risk and the number of cubicles available.

The question often becomes more complicated in reality as pressures on beds and resources mount. What do you do if you have limited resources and are faced with 2 patients that both should be protected? Do you put at risk patients in the cubicle or the most infectious ones? Patients likely to be more infectious are those producing aerosols. These include those with productive coughs, those needing CPAP or those vomiting.

Space, a vital but limited commodity in children’s wards

In PICU there is evidence that patients with bronchiolitis can be safely managed in open areas providing that good ICP measures are strictly adhered to. In most UK PICUs individual patient areas are separated physically by distance (maybe more than 5 m) and individual patient areas are sometimes delineated by a reminder tape on the floor. We encourage a similar approach on our HDU.

Cohorting patients — is it reasonable and is it right?

Many of us will have been told that during winter, RSV positive bronchiolitis patients should be cohorted together on an open
ward, thus relieving some of the pressure on cubicles. Does this make sense and is there any evidence for this? There are a number of reasons that we think that this is the wrong approach.

1. In the past immunofluorescence on NPAs gave us a rapid result and if positive this meant that RSV positive children were cootted together. Now that PCR techniques are routinely available, significantly more children demonstrate different viruses; some have multiple viruses detected. These individuals cannot be differentiated clinically.

2. Many older children and parents on the paediatric wards will have the same viruses, causing ‘colds’; they are not usually being isolated.

3. Infant with bronchiolitis are non-mobile so are unlikely to infect others unless there is direct physical contact or poor ICP and hand washing (see discussion re distances above).

Do younger children need special treatment?

It is currently accepted practice in the UK to isolate infants in a cubicle until they have had their ‘immunisations’. However, if parents and professionals strictly adhere to ICP guidelines do non-mobile children require such precautions?

Historically, we were particularly concerned that younger children who were, ‘pre-immunisation’ had increased risks from infections, in particular pertussis. Now that most mums in the UK have been vaccinated against pertussis during pregnancy can we relax our concern over whooping cough in infants?

Young infants remain at an increased risk of complications from bronchiolitis compared to older children. When determining how best to allocate our limited cubicle spaces it seems reasonable to take all of this into consideration with need for isolation being based upon possible disease severity which relates to age (<3 months or even < 1 month), risk factors (e.g. chronic lung disease, heart disease etc.) and maternal vaccination history rather than as we currently do relying on the number of vaccines the infant has received?

In our clinical practice we try to isolate all our small infants, especially those with risk factors but if this is not possible e.g. in HDU then we ensure that ICP procedures are strictly adhered to and monitored. Individual situations are reviewed at each ward round. (see Box 2)

Face masks

Surgical face masks offer little, if any, protection for staff. They are often used for infectious patients to move around a hospital e.g. smear positive non-drug resistant TB cases.

If staff do need to wear masks for protection then FFP2 or 3 masks should be used. FFP2 masks are used for staff protection and FFP3 for high risk procedures e.g. aerosolisation during intubation, NG tube insertion (risk of vomiting). It is important that before staff use both FFP2 and 3 masks the correct fit testing training has been provided. It is best that it is rolled out to staff at risk as soon as possible. If time does not allow early roll out then a rapid upskilling for staff needs to be achieved so that no one is exposed unnecessarily. How to wear these effectively needs to be periodically reinforced.

Measles. A fly in the ointment or a wakeup call

When we started writing this article active transmission of measles had been eliminated in the UK. However in Birmingham, along with a number of other major UK cities, measles has re-emerged. It is the most infectious disease in the world so ICP protocols are essential to prevent nosocomial spread. How can we achieve this? There are four important steps: recognition, isolation, contact tracing and protection of high risk individuals.

1. Recognition.

We need to actively educate team members on what clinical measles looks like as the majority will not have seen measles for many years, if at all.

2. Isolation of suspected or confirmed cases.

Staff must isolate patients with measles from other children as soon as it is suspected, especially if they have fever, rash and conjunctivitis. This means that full protective measures should be initiated including wearing face masks, protective fluid shields and ensuring all staff strictly follow the 5 and 6 stages of hand hygiene.

3. Contact tracing.

A complete list of patients and staff exposed needs to be compiled so that vaccine status can be checked and MMR administered within 3 days if necessary.

4. Patient and staff with risk factors need to be identified.

Risk factors include age less than 6 months, immune deficiency, received less than 2 doses of MMR or pregnant. In these cases intramuscular immunoglobulin should be given within 6 days.

Need for extra caution

Some patients require special attention. Patients with lifelong conditions such as Cystic Fibrosis (CF) require extra vigilance in health care settings as the clinical outcome for these patients is significantly affected by infection with certain bacteria especially *Pseudomonas aeruginosa* and *Burkholderia cepacia*. Some strains of *P. aeruginosa* and *B. cepacia* can be transmitted between CF patients, and these transmissible strains are commonly resistant to many antibiotics.

Therefore during outpatient visits and hospital admissions patients need to be strictly isolated from each other. Care also needs to be taken not to transfer bacteria from staff or contaminated lung function testing equipment.

There are some exceptions to this blanket rule of ‘no contact’ between individuals with cystic fibrosis. It is not practical to isolate close family members (e.g. affected siblings or less commonly affected parents) but in principle individuals with cystic fibrosis should be kept apart whenever possible to minimise the risk of cross-infection. This has significantly changed the way in which CF care is delivered in the UK.
The principle risk to individuals with CF is not other children, but other children or adults with CF or chronic suppurative lung disease. If cubicles for highly infectious patients are not available and providing there are no other risk factors we sometimes move individual CF patients onto the open ward. This situation is reviewed daily with the plan to place them back into a cubicle as soon as possible or send them home on IVs. The parents and clinical team are kept fully involved in these decisions.

Antibiotic resistance, a growing concern

Multidrug resistance is increasing in healthcare settings. On paediatric wards there is often no admission/active screening for colonisation as the risk for multidrug resistance is low. Most children admitted to paediatric wards have had no or only short stays in hospital. If patients are admitted from another higher risk facility, NICU or PICU, where colonisation with drug resistant organisms is higher there needs to be a clear handover regarding which drug resistant organisms if any the child is colonised with. Children colonised with a multidrug resistant organism need to be isolated with strict hand hygiene and ICP enforced. There are limited data on how long isolation and contact precautions should be continued. Colonisation can continue for long periods. Decolonisation for patients with MRSA with a five day course of anti-bacterial nasal cream and whole body wash is often successful. However there are reports of further carriage after initial clearance. For vancomycin resistant bacteria three negative swabs is accepted as a marker of clearance but re colonisation (recurrence) can occur after further antibiotics. (see Box 3)

What about the parents?

A case of suspected pulmonary TB in a 5 year old is admitted to your ward and placed in a negative pressure isolation cubicle. Are there any special ICP procedures that need to be considered in this case? Most young children even with active pulmonary TB are unlikely to be significantly infectious. They do not expectorate sputum, swallowing it instead. However any procedure that leads to potential aerosolisation such as a NG tube placement (vomiting) or hypertonic saline nebuliser are risks and merits staff wearing a FFP3 face mask and visor.

The child is unlikely to infect anyone else on your ward but they will have contracted TB from an infectious source, most likely a family member. So before adults and children over 12 years can come onto your ward, without wearing a surgical mask, you need to ensure they do not have active TB. This usually requires them to have a chest X-ray. In this case his mother, the source, had denied any symptoms until she had a chest X-ray. She was smear negative therefore significantly less infectious. Nonetheless this real-life cautionary tale reminds us that it is important to think outside the box to prevent potential spread of TB.

Box 3

Staff

In a hospital setting where infants are non-mobile it is still likely that a significant cause of cross infection is by direct inoculation from doctors or nurses as well as parents. Contaminated hands are the most likely source which is why all staff need to be vigilant and enforce good hand hygiene for themselves and others, without fear of recrimination. This does suppose that all soap and or alcohol dispensers are filled, work correctly and are placed in easily accessible/convenient places. We should insist that the 5 moments of hand hygiene the 6 stages of hand cleaning are complied with. Compliance with hand washing should be taught at induction, encouraged, audited (covertly if necessarily) and results fed back to all.

As a unit we had variable audit results which have improved. For instance where alcohol rub dispensers are not working we open them and insert a card saying please do not close until fixed (empty or broken) so everyone knows they do not work. Informally this has increased the number of working units especially as staff are proactively reporting them when broken. The ICP policies re dress code, ties, bare below the elbows, badges not on lanyards etc. need to be strictly policed.

Is it time for compulsory vaccination of health care workers?

To protect patients and reduce staff sickness should we make Influenza vaccination for all staff compulsory? There is evidence in adults who acquire influenza in hospital, that both length of stay and mortality are increased. There is no data on the effect of nosocomial viral infections in normal children but this lack of evidence should not stop us preventing this if we can. Influenza vaccination of staff should be actively encouraged even though there is limited evidence that this prevents transmission to patients. These data are complicated by low vaccine up take in staff and in recent years suboptimal efficacy. A positive often unrecognised aspect is that vaccinated staff have less sickness. We actively encourage all staff to have the yearly ‘flu’ vaccination.

Equipment/environment

It is often said that a ‘hospital is cleaner than your house’, especially the kitchen sink or bathroom. Whilst this is likely to be true, organisms that you can transmit in a hospital are potentially more pathogenic coupled with the increased vulnerability of patients. Sites of contamination include any impervious surfaces. Paper, unless soiled, is much less likely to be contaminated with micro-organisms. Contaminated surfaces need to be regularly cleaned; these include bed frames and mattresses, door handles, taps, stethoscopes, aurosopes, monitoring equipment, badges, phones etc. There is little evidence that these objects transmit infections, however many studies have demonstrated that these objects often carry pathogens on their surface.

We performed surface swabs from our consultant hotline phone (uncleaned) and inoculated them onto blood agar. Whilst we found few pathogens we did isolate a gram negative Enterobacter cloacae (not multi-resistant) (Figure 3 below). Simple surface decontamination with and a universal soap based cleaner virtually eliminated these bacteria.

Stethoscopes

Whilst there is emphasis on hand decontamination, disinfection of equipment is often a lower priority. In some reviews greater

PAEDIATRICS AND CHILD HEALTH 28:6

© 2018 Published by Elsevier Ltd.
than 80% of stethoscopes were colonised with bacteria. Although usually only a minority of isolates were pathogenic, rates varied widely; MSSA 1.9–100%, MRSA 1–37%, VRE 3 –31%, Pseudomonas 0–72% (highest if never cleaned) and *Clostridium difficile* (4 in an outbreak situation). Whilst there is evidence of transmission to skin we can find no evidence of a link between infections and contaminated stethoscopes. However, it makes sense to ensure that a greater emphasis is placed on their decontamination. This should also include other equipment following patient contact/contamination. Education programmes with reminders on when and how to clean stethoscopes have been trialled but have had only limited success. Patient specific stethoscopes might be a solution to this problem.

**Playrooms and toys**

Whilst hospitals are there to primarily treat sick patients, paediatric wards also need to promote playtime and enjoyment for children. How can this be achieved in a playroom where potentially many children will have an infection? We have to remember that children mix with others outside the hospital who have ‘viral illnesses e.g. at school, nursery etc. Therefore we believe that generally if a child is well enough to play they should be encouraged to mix with other children.

There are obvious times when this is not the correct approach e.g. the child is highly infectious or immune suppressed that will put them or other children at risk. Pragmatically all toys and playrooms are cleaned daily. In clinics we have moved from plastic toys to paper colouring books.

**Cleaning**

Do you know what cleaning procedure is instigated for a cubicle or bed space when a child with an infection goes home? We thought we did but when we checked the team’s understanding in our own unit staff were often unsure which level of clean was required for different scenarios.

We suspect this confusion also occurs in other trusts. We have a cleaning matrix with green for non-infectious patients, to amber, then red and finally platinum for severe infections. What we had not realised is that the list of infections in the matrix is...

### Our local cleaning matrix

| Cleaning request | Infection control info, required following the discharge of patients with:- | Nursing info | Important info | Cleaning time from start | Description of works to be completed and responsibilities |
|------------------|-----------------------------------------------------------------------------|--------------|----------------|--------------------------|----------------------------------------------------------|
| **Green** (ward staff duty) | None infections to be done by ward staff | All items below must be done by nursing staff prior to clean to avoid cleaning delay please | Bed space discharge (ward staff duty) | 30 mins | Bed space discharge (ward staff duty) | Chlor clean of bed space, bedside cabinet, bedframe, floor area and medicine cabinet | Curtain change if damaged or soiled | Nursing equipment clean |
| | Symptomatic MRAS colonisation e.g. nosed or skin Non-Pulmonary TB e.g. lymph nodes RSV Shingles Chicken pox Multi resistant organism Scabies | Bed linen to be stripped | | | | | |
| **Amber** | | Contact the Helpdesks. During peak periods priority will be decided by SITE office and infection prevention teams | 1.5 hours | Steam and Chlor clean of bed space, bedside cabinet, bedframe, floor area and medicine cabinet | Curtain change | Nursing equipment clean |
| | Norovirus Acinetobacter Pulmonary TB including MDR TB Group A streptococcus including invasive GAS Confirmed MRSA infection e.g. purulent wound, sputum in actively coughing Salmonella Carbapenemase Producing Enterobacteriaceae (CPE) Unknown diarrhoea If hydrogen peroxide cannot be carried out due to structure continue with amber cleaning | As above | | | | |
| **Platinum** | Viral haemorrhagic fever (VHF) Long stay (over 1 month in patient with known infection) Planned ward deep clean | As above | | | | | |

Table 1
limited and the level of clean required did not always make sense. The clean imposed a lot of extra work on staff (some of which is not needed), took the cubicle out of action for hours (amber clean 1.5 h, red over 3.5 h, if staff can be found to clean) and has significant cost implications (amber clean £250, red over £500; Cleaning Matrix; Table 1).

We are reviewing the matrix to populate with more paediatric infections and the specific level of cleaning needed for these. We are discussing if reducing levels of cleaning for specific infections is safe, which could be part of our cost improvement and importantly free up beds quicker. We encourage someone in your department, with nursing support to take on this task as well.

**Antibiotic guidelines**

The high level of senior supervision in paediatrics means we are better able to implement antibiotic stewardship which is one of the pillars of ICP. We should use the ward rounds to teach how these guidelines and their implementation make patient management simpler, more understandable (explaining the rational for which antibiotic and the organisms we are treating), targeting where antibiotics can be stopped early and educating where there were not indicated in the first instance. We should be involved in antibiotic guideline development and review. Whilst this is unlikely to have an immediate effect on infections in a general paediatric ward they can ultimately reduce antibiotic resistance in your patients.

**Take home messages**

1. All paediatricians need to be pragmatic ICP advocates.
2. The children that need isolation are those with significant or potential severe infections, those who are highly infectious and those at risk of developing severe infections.
3. Hand washing, central to ICP, should be encouraged, monitored and enforced where it is an issue.
4. We should review the layout of our wards ensuring that ICP is considered including placement and number of alcohol dispensers, cubicles, sinks, bathrooms, equipment storage etc.
5. Paediatric teams should be involved in their ward cleaning policy.
6. We should encourage staff to be vaccinated against influenzae and MMR.
7. We need to deliver good antibiotic stewardship.

**Answers for Figure 1, the hidden infection control risks lurking in the photographs.**

- a. Soap and or Alcohol rub, may be empty/not working. We need to ensure they are maintained.
- b. Sink, potential source of infection especially if water directly falls into the waste plug, allowing bacteria to be splashed up onto hands, surfaces etc.
- c. Waste bin, often used as a convenient shelf for notes or even a seat.
- d. Stethoscope, as well as other equipment, a source of cross infection for both bacteria and viruses.
- e. Badges on lanyards a potential source of resistant organisms.
- f. Open cubicle door, isolation protocol not being adhered to.

**Conflict of interest**

No conflict of interest for either of us.

---

**READING LIST**

Antibiotic stewardship: start smart then focus. Public Health England, November 2011.

Kulkarni H, Smith CM, Lee Ddo H, et al. Evidence of respiratory syncytial virus spread by aerosol - time to revisit infection control strategies. *Am J Respir Crit Care Med* August 1 2016; 194.

Healthcare-associated infections: prevention and control in primary and community care. NICE, March 2012.

O’Flaherty N, Fenelon L. The stethoscope and healthcare-associated infection: a snake in the grass or innocent bystander?. The Healthcare Infection Society, 2015.