Abstract

In this paper we undertake an innovative analysis of infection prevention and control (IPC) activities in hospitals, using non-representational theory of space (2005). We deployed video-reflexive ethnography in three wards in two metropolitan teaching hospitals involving 252 healthcare workers as participants. We analysed our data iteratively using non-representational theory, which showed hospital space being *constantly produced* from varied, intersecting, and sometimes competing trajectories of hospital work, objects and people. The approach enabled multiple material factors impinging on routine IPC (including objects such as rolls of surgical tape), and habitual or prioritised actions (such as safeguarding patient privacy) to be included in analysis. The analysis also included the role of *time* which has been absent from other discussions of IPC, highlighting the transience of spaces produced through IPC practices and the need to continually re-make them. We found many situations in which the complexity of practice, rather than failures of compliance, contributed to potential microbial transmission. We show how inconsistency and confusion about IPC practice often can only be resolved through action. Our findings suggest that further reduction in preventable hospital infection rates will require better integration of IPC with other work trajectories; a shift in emphasis from compliance monitoring to collaborative practice; and greater use of in situ risk assessment and judgment.

Introduction

Where in a hospital are the pathogens, the viruses and bacteria that produce healthcare-associated infections (HAIs)? On what people, or things, do they enter the hospital; via what routes do they transfer to vulnerable patients? These questions are components of a bigger question: how can we prevent pathogens from being moved around hospitals in tandem with the movement of hospital staff, equipment, patients and visitors (Umscheid, Mitchell et al. 2011, Bearman, Munoz-Price et al. 2018)? This question is challenging to answer because pathogens are (mostly) invisible and their movement difficult to 'see' or to represent.

In this paper we therefore take up non-representational theory (NRT) (Thrift 2008) to provide a novel spatial account of infection prevention and control (IPC) activities. Specifically drawing from Doreen Massey's approach as set out in her book *For Space* (Massey 2005), we offer new insights into why it is so difficult to consistently prevent HAIs (Umscheid, Mitchell et al. 2011, Bearman, Munoz-Price et al. 2018), despite IPC protocols, increased hand hygiene compliance, and new technologies to track pathogens and identify transmission (Quainoo, Coolen et al. 2017). We argue that using non-representational theory allows us to show how hospital space is *constantly produced* from various trajectories of hospital work, objects and people. Characterizations of spaces and surfaces as 'clean' or 'dirty' are temporary and unstable, and must be constantly established and reproduced (McAlearney and Hefner 2014). We show that the complexity generated by the intersection of multiple trajectories means that reductions in HAI rates will require a change in emphasis - from the implementation of rules, to the integration and performance of IPC principles in complex and emergent clinical activities.

Our analysis extends previous work (Mesman 2009, Mesman 2012, Hor, Hooker et al. 2016) that analysed the spatiality of IPC activities, and is developed from empirical data gathered during video-reflexive ethnographic research in two metropolitan teaching hospitals in Australia. High rates of HAI are often explained in terms of policy or compliance failures (e.g. (Mendel, Weinberg et al. 2014, Pink, Morgan et al. 2014). Offering a complex dynamic

account of practice, we show how Massey's theory allows us to transition to a clearer, more strategic approach to IPC.

Our aims for this study were:

1: To show that non-representational theory can illuminate features of IPC absent from previous accounts, extend previous spatial analyses of IPC (Mesman 2009, Mesman 2012, Pink, Morgan et al. 2014), and help develop practical solutions.

2: To provide a hybrid, *more-than-representational* analysis of IPC. We consider representations created and used by IPC , which often intersect with those created by, and put to use in, other hospital work. Examples range from written policies and guidelines to the physical configurations of boundary work (Hor, Hooker et al. 2016). We then discuss examples of how the spatiality of IPC work can *exceed* such representations, and how confusion and inconsistent practice may result, which may not be easily resolvable.

3: To show how this approach enables analysis of how space is enacted dynamically over *time*. Time (i.e., the transience of space), is critical to reducing infection transmission, but absent from other accounts of IPC.

Background

The serious problem of HAIs

HAIs are a common adverse effect of hospital care. Often resulting from drug-resistant organisms, such as methicillin-resistant *Staphylococcus aureus* (MRSA), they can have serious consequences, including lengthy periods of illness and possible death (World Health Organisation 2012). HAIs add billions of dollars to direct healthcare costs, in the USA alone, and even more in indirect loss-of-productivity costs (Allegranzi, Nejad et al. 2011, Marchetti and Rossiter 2013).

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Although much is accomplished by routine hospital IPC, and by specific interventions and programs that have immediate local impacts, it has proven challenging to consistently lower the incidence of most HAIs, over time (Umscheid, Mitchell et al. 2011, Marchetti and Rossiter 2013, Al-Tawfiq and Tambyah 2014, Mendel, Weinberg et al. 2014, Bearman, Munoz-Price et al. 2018).

Hand hygiene and IPC activities

Although IPC practices in routine hospital care are prescribed in national protocols, they vary between hospitals. In many Western countries, over the past decade, there has been a focus on frequently-audited hand hygiene (Allegranzi and Pittet 2009, Hor, Hooker et al. 2016), as a prominent strategy for lowering HAI rates (Erasmus, Daha et al. 2010). Discrepant compliance rates between healthcare professional groups – specifically doctors' consistently relatively low rates - is of ongoing importance and concern (Gilbert 2014).

However, greater hand hygiene compliance does not straightforwardly correlate with lower HAI rates (Jumaa 2005); and there is limited understanding of what other IPC activities contribute to HAI prevention or how they intersect with hand hygiene. A broader view of IPC is required (McLaws, Pantle et al. 2009, McClung, Obasi et al. 2017, Bearman, Munoz-Price et al. 2018).

IPC is inherently a spatial accomplishment

Jessica Mesman has shown previously that 'sterility' (her term, meaning 'asepsis') is an intrinsically *spatial* accomplishment. Mesman's 'topical' analysis identified how IPC activities, such as the safe insertion of a central venous line or an unplanned admission to a neonatal intensive care unit, require, and produce, spatial orderings of varying kinds; including the construction of a 'standard operating configuration' of equipment and people, and with it, an 'infrastructure of attention' needed for a procedure, and the construction of temporary boundaries and buffers that produce 'sterility' (Mesman 2009, Mesman 2012). We note that an 'infrastructure of attention' is a significant example of the importance of

'affect' (Thrift 2004, Thrift 2008), a concept from NRT, for clinical practice; though Mesman did not analyse it as such.

Mesman's analysis understood space as being *created* by actions – in contrast to the conventional representations of space in IPC literature as consisting of solid, preferably cleanable, surfaces (such as the floor, or a hospital trolley), on which human actors (and microbes) move; or as an empty container (such as a corridor) in which furniture, fixtures and people may be present or absent (eg (Ulrich, Zimring et al. 2008)). Mesman argued instead that clinicians actively *order* space and *use* the temporary structures thus created to achieve IPC goals. We have found this approach (which shares some ideas in common with non representational theory (Andrews 2017)) productive; and, like Mesman, analysed IPC as boundary and trajectory work. We also observed that IPC activities exceed the routine precautions that currently define hospital IPC (Hor, Hooker et al. 2016).

Although Mesman's spatial analysis provided novel insights into a highly-orchestrated procedure and ward, it did not fully account for, nor provide clues for how to improve, the porous, complex and messy IPC activities we observed in our study of three very different wards (Hor, Hooker et al. 2016, Iedema, Jorm et al. 2018). To account for these complex dimensions – the active 'present moment of practice' (Jones 2011) of 'what happens' in IPC (Andrews 2014, Andrews 2018), and the less-than-fully-intentional performances that dynamically emerge (Andrews, Chen et al. 2014) - we used non-representational theory, NRT (Lorimer 2005, Thrift 2008).

The value of non-representational theorising of IPC work

Non-representational theory, a plurality of approaches with the same style of thinking (Andrews 2018, Andrews and Duff 2019), aims to open up the complexity of the present (Thrift 1999) by engaging with the world as ongoing raw performance (Andrews 2014, Andrews 2017). Where sociologies of healthcare have traditionally provided descriptions and interpretations of human action – for example, analysing the meaning of what humans represent through language (eg in discourse) and the resulting consciously acted phenomena (eg ideas, policies) - NRT analyses the many wordless, contingent, human and

non-human acts that produce the world (Andrews 2017). This invited us to consider the less-than-fully-conscious aspects of IPC activities as they occurred, and likewise, to include ordinary, everyday disruptions to flows of practice.

Our study is more accurately called '*more-than-representational*' (Lorimer 2005). This is partly because since any phenomenon *becomes* representational once researchers notice and observe it, employing their cognitive judgment and conveying it in language. Our hybrid analysis deliberately includes parts that are representational alongside those that are non-representational (Andrews 2017), in order to make better sense of our data (as we explain below).

NRT treats human and non-human actors equally and explores the productive and disruptive potentialities of material objects, drawing from and engaging with approaches from neomaterialism (Pink, Morgan et al. 2014, Buse, Martin et al. 2018), Actor Network Theory (see also (Mol 2014), and complexity theory (Thrift 1999). We investigate how the trajectories of kidney dishes, trolleys, gloves, surgical tape, curtains, and many other objects, produce the complex and transient spatiality of microbial transmission, and hence, of IPC. These material entities *affect* emergent in-situ practice (Thrift 2004).

Most importantly for us, NRT is centrally concerned with rethinking space, since everything is spatially distributed, and every space is dynamically enacted (Thrift 2004), that is, *is space-time*. Our interest is to explore how the quotidian IPC activities captured in our data come to 'make up' space, from moment to moment. NRT appreciates the potentiality and multiplicity of space-time, facets relevant to the production and ordering of spaces in relation to where microbes might potentially move, or at least are feared to move. Much of this analysis reveals confusion, contestation, incompleteness and mess, in contrast to Mesman's descriptions of well-controlled, spatially discrete IPC work (2009, 2012).

A non-representational spatial analysis of IPC activities

To attempt a non-representational study of the spatiality of IPC, we turned to Doreen Massey's theorisation of space as set out in her book *For Space* (2005). Massey's approach –

often termed 'relational geography' (Werner et al 2018) – critiques representations of space as the (static and closed) negative opposite of (dynamic) time (see also Massey 2006).

Massey presents three intertwined propositions of space, as:

1) produced through multiple interrelations – between human actors, certainly, but also between humans and non-humans;

2) as always 'under construction', never finished and closed; and

3) as spheres of 'coexisting heterogeneity', that is, of being diverse and multiple (Mol 2014) in character and content. Space is constructed through multiple, heterogeneous trajectories.

Massey's three propositions articulate a non-representational approach that explores (1) human and non human mutual construction, (2) *space-time*, the immediacy of the world's ongoing (Andrews 2014), and (3) distributed causation, constant flow and (hence) complexity (Massey 2006); how space and time are non-fixed and multiple (Andrews 2014).

We applied Doreen Massey's theory through a process of 'thinking with theory' (Jackson and Mazzei 2012). These three propositions about space captured the transience and instability of the IPC activities that we observed in our study. IPC spaces were constantly reconfigured, and manifested shifting boundaries and hotspots. They encompassed multiple human and non-human actors, and intersecting activities and activity trajectories. They did not 'contain' IPC practice, but were changed by imbrications of people, rules, tools and actions.

This paper, therefore: complements and extends Mesman's ground-breaking spatial analysis; sets out how a non-representational approach such as Massey's can extend our understanding of IPC activities; and explores the implications for improving IPC practices.

Methods

Video-reflexive ethnography (VRE) is a methodology based in learning theory and contemporary understandings of patient safety and complexity (Iedema 2019). VRE researchers collaborate with participants to create visual recordings of their work practices for reflexive inquiry and improvement. The insights that participants develop, through scrutiny of routine practices embedded in a real-world context, represent a highly effective mode of learning (Iedema, Hor et al. 2015). Participant scrutiny can be developed, through discussion, into changes in previously taken-for-granted work assumptions about and habits of practice (Iedema 2009, Hor, Iedema et al. 2014, Iedema, Carroll et al. 2018).

The study's aim was to illuminate the full complexity of IPC practices, in order to increase frontline practitioners' awareness of risk and fine tune their responsiveness to it. Methodologically, VRE was well suited to a non-representational study of IPC, because it offers both a means of 'witnessing' non representable forms of action, and of 'acting into' the world (Andrews 2017, Andrews 2018). It fits calls from NRT for methods that experiment with close relationships between the researcher and what is happening in the world (Andrews 2018). This is the first project in which VRE has been applied to IPC, specifically.

Ethics and consent

Ethics approvals for this study were obtained from the University of Technology, Sydney, and the respective Local Health District Human Research Ethics Committee. Study information was distributed through face-to-face information sessions between researchers and staff, one-page handouts on information boards, and via email. Researchers obtained written consent for observation, interviews and videoing from individual participants; consent was treated as an ongoing process, with verbal permission sought from participants at each stage of the research process (e.g. before and after videoing, and before showing the footage to others).

Study design

VRE was deployed in three wards in two metropolitan teaching hospitals and involved 252 healthcare workers as participants: 87 in a mixed surgical ward in hospital A (50 nurses, 21

doctors, 6 allied health practitioners, 3 clerical staff, 1 cleaner, 2 general services staff and 4 patients); 90 in an intensive-care unit (ICU) in hospital B (57 nurses, 23 doctors, 5 allied health practitioners, 2 wardsmen, 1 data manager, 1 cleaner and 1 Patient Service Assistant); and 75 in a renal unit in hospital A (57 nurses, 11 doctors, 3 administrative staff, 2 cleaners and 1 pharmacist). A nested PhD project using VRE to research patient perspectives of IPC was also conducted during this time (Wyer, Iedema et al. 2015, Wyer, Jackson et al. 2015). Video-recording and reflexive feedback sessions took place over periods of approximately 3 months in each ward. A total of 34 reflexive sessions were conducted, in which selected video footage was shown back to participants for discussion. As part of the VRE methods, ward observations and semi-structured field interviews were also conducted.

Analysis

Our 'thinking-with-theory' approach (Jackson and Mazzei 2012) involved testing the capacity of Massey's theory (Massey 2005) to describe the breadth and multiplicity of our data – interview transcripts, field notes, video footage of routine practices and transcripts of reflexive sessions, in which clinician participants themselves led an initial analysis of our data through reflexive commentary on the footage. Like Mesman (Mesman 2012), and in keeping with hybrid methodological approaches for non-representational studies (Andrews 2017, Andrews 2018), we did not use formal coding, identification of themes or saturation. Instead, our goal was to determine the degree to which Massey's theorisation of space could be used to analyse data that could not be sufficiently described by Mesman's model of the spatiality of patient safety. Here, we present the analyses, insights and new questions opened up by this approach; their implications are explored in the Discussion.

Findings

(1) *The Present Moment of Practice (Thrift 2004, Jones 2011)*

We begin this section with a detailed recounting of an everyday activity – a routine wound dressing procedure – that was captured in our footage, and presented back to nursing staff for discussion at reflexive sessions. This vignette was chosen not only because it describes a

routine and frequent activity in the ward, but also because it demonstrates, in spite its ordinariness, the complexity of IPC considerations in everyday clinical practices that healthcare workers are tasked to grapple with. The narrative below is interspersed with commentary, to highlight how Massey's three propositions can be used to attune us relational, always-incomplete and entangled production of the spaces involved in this activity, in contrast to thinking of them as neutral and stable surfaces and containers. We then explore transience and messily intersecting trajectories in IPC work more generally, using examples from our video-reflexive ethnographic data and fieldwork experiences.

A nurse, Sarah (a pseudonym), in her first year of nursing, has agreed to be videoed doing the routine dressing, although she is tired, and it is nearly the end of her shift. The video begins in the equipment room, where she gathers materials she needs (dressing pack, sterile scissors, bandages, saline, creams and cleaning agents, forceps, sterile gloves, etc). Sarah walks out of the room and locates an empty trolley. With one hand (the other holding her equipment), she cleans the top and bottom shelves of the trolley, with disinfectant and paper towels, and places her materials on the bottom shelf. She returns to the equipment room for a roll of surgical tape, then pushes the trolley to the patient's room.

Trolleys are used frequently to transport medications, patient folders and notes and equipment during nurses' and doctors' rounds. For the wound dressing procedure, the trolley will not only transport dressing items between the equipment room and the patient's bedside, but also to act as part of a spatial set up and 'buffer zone' (Mesman, 2009; Hor et al, 2016), to enable aseptic cleaning and dressing of a wound. The trolley is transformed for this purpose by being cleaned. Although both shelves are arguably equally clean at that point, later the bottom shelf is made less clean than the top by the action of placing unopened dressing items on the bottom shelf, and leaving the top untouched.

On the way, two pieces of equipment (in their packaging) fall onto the floor. Sarah picks them up and puts them back on the bottom shelf of the trolley. A physiotherapist exits the patient's room with a wheeled walking frame, and Sarah then enters with her trolley.

The trolley does not move smoothly over the floor, which causes the packages to fall on the floor, become contaminated and potentially contaminate the bottom shelf (and other items) when replaced. This creates a distinction between the top (clean) shelf and the now-possibly-less-clean bottom shelf of the trolley. When this footage was viewed by other nurses, they debated whether the potentially contaminated items should have been discarded (which would have been wasteful), or cleaned (with unknown efficacy), *and whether or not it mattered*. As we will see, the packaging of *all* dressing items on the bottom shelf would soon be made, through actions, as 'less clean' than their contents.

The physiotherapist leaving the room with the walking frame reminds us that multiple people, objects, activities and trajectories, intersect in this environment. The patient's room was a site of physiotherapy, which is now about to become a site for a dressing change. The possible trajectories of microbes are different for each activity. The patient's room is heterogenous, being constantly constituted by multiple activities, including IPC:

> *As the physiotherapist removes her gloves and cleans her hands with alcohol-based hand rub (ABHR) next to the door, Sarah takes a set of gloves and a gown from boxes on the wall just outside the room. After donning her gown, she cleans her hands with the ABHR and puts on her gloves.*

Both the nurse and physiotherapist are here activating a 'boundary' between the patient's room and the rest of the ward by performing hand hygiene and donning or removing (non-sterile, blue) gloves, actions that produce a distinction between the surfaces *inside* the room, which are identified as 'dirty' (contaminated with the patient's germs – in this case MRSA), and the rest of the ward (which may or may not be contaminated). Sarah further demarcates the surface of her uniform from the patient's room by donning personal protective equipment (PPE) - a long-sleeved impervious gown - prior to entering. This 'boundary work', demonstrated by hand hygiene and PPE, are examples of the spatial work that characterises most prescribed IPC practices (see Hor et al 2016).

> *Sarah's patient is a middle-aged man, his right leg amputated above the knee, sitting on a wheelchair next to his bed and waiting for her. They chat, briefly, then he asks if a*

particular dressing item was 'available this time', which she realises she has forgotten.
As she is already gowned and gloved and should not leave and re-enter the room without
removing and replacing her PPE, she asks the researcher (who is not gowned or gloved)
to retrieve the item from the equipment room.

Sarah's movements here are constrained by the boundary she has constructed between the patient's room and the rest of the ward, since it would waste time and resources to discard them, retrieve the missing item and then reconstruct the boundary. If the researcher had not been available, she may have asked a passing colleague for assistance (as was commonly observed). This reminds us that the smoothness and flow of IPC work can also depend on the timely coincidence of other HCWs' trajectories, and also complicates narratives of IPC work as centred solely on individual HCWs' actions.

Sarah starts to lay out items she needs on the top surface of the trolley. She first opens a
'dressing pack', which unfolds as a blue waterproof sheet with a basic set of items
within it. She is careful about not touching the inside of this dressing pack with her
gloved hands. For subsequent items that she retrieves from the bottom shelf and opens,
she touches only the outside packaging, allowing the contents to fall upon the blue
sheet. If needed she retrieves the contents using sterile blue forceps (see Figure 1).
Likewise, she uses only the forceps to move items around on the blue sheet.

<<Figure 1, image and caption (at end of document) inserted here.>>

Here, we see how the dressing trolley is transformed, by Sarah's actions, into distinct spaces. The field constructed *on top of* the blue sheet contains only sterile items, through the careful 'no touch' technique Sarah employs to open dressing items.

When she has opened all the items she needs, Sarah opens a packet containing white
sterile gloves and leaves them open, untouched, on the bottom shelf of the trolley. She
then removes and discards her blue gloves into the bin, pushes up the sleeves of her
gown, and thoroughly washes her hands up to the elbows, with soap and water, at the

sink in the room, turning the tap off with her elbow. She puts on the sterile gloves. The
patient removes a dressing pad from his right leg and tosses it onto the bottom shelf of
the trolley. Sarah uses forceps to remove remaining layers of dressing from this wound,
and discards them, on the bottom shelf, with the discarded sterile glove packaging.

Now, the sterile 'field' has been extended to her hands, carefully cleaned and gloved with sterile gloves - as opposed to the non-sterile gloves, which are not necessarily particularly clean, taking into account their likely previous trajectories. For instance, extra gloves often fall out of their boxes onto the floor and are replaced in their boxes; and their contents are also regularly touched by potentially contaminated hands, to check whether they need to be restocked. Nevertheless, they are considered 'clean enough' (or at least, still used) for many care activities.

It is noteworthy that, when reviewing footage of this and other dressing changes, not all nurses believed that sterile gloves were necessary for dressing changes, especially if a 'no touch' technique with forceps was used (WOCN, 2012). Some argued that it was a waste of scarce resources and time (including an extended hand wash), during the busy nurses' shifts. They also referenced the state of the wound – less complex dressings, or wounds that were mostly healed or healing well, might not require sterile gloves. Others acknowledged that a 'no touch' technique without sterile gloves might be easier for an experienced nurse, whereas sterile gloves allowed more room for error by someone less-experienced. They also generally accepted that the use of sterile gloves would be safer for patients.

The policy in this unit, not known to all nurses, was for sterile gloves to be used for *all* wound dressings. The policy is a representation; what it *does* is to encourage stabilisation. It represents the space of the wound dressing set-up (equipment and nurse's hands) *as if* it were possible to determine their status as clean: i.e. by always using sterile gloves for wound dressings. By contrast, the video data, including commentary from nurses, demonstrates that, in *practice*, the status of a space is *not* always pre-determinable; it is always made by action. This is because of the complexity of hospital work, which emerges from the multiplicity of intersecting trajectories involved in work schedules and embodied expertise (Thrift 1999). Each dressing change is a unique event, involving a more or less

complex procedure; a more or less healed or healing wound; more or less clean gloves; a more or less experienced nurse; and a trolley, with different items set out in more or less specified ways, each item with its own previous trajectories. These intersecting trajectories temporarily produce spaces, whose status - as clean, 'clean enough' or not clean - is made by and is *only resolvable* through action. In this vignette, the space of the sterile field is *made* (and kept) clean by the actions of the nurse, through cleaning, and her deft no-touch technique.

Of course, these space-times are also made by the actions of microbes, and especially by their potential to move and grow. We see how easily a sterile object loses its sterility by contact with other objects. For instance, the forceps are no longer clean, having touched the old (dirty) layers of dressings, all of which are discarded onto the trolley's bottom shelf, which is now distinctly 'unclean'. Human actions must remake space that has been made (or potentially made) unclean by microbial action. In reviewing this footage, Sarah reflects that she could have brought a bag to use as a bin for the unclean materials, rather than leaving them exposed on the bottom shelf - at risk of contaminating other surfaces.

Next, Sarah faces a conundrum.

> *Sarah uses a new pair of forceps to pick up gauze swabs from the top shelf to clean the wound on the patient's right leg, discarding the swabs on the bottom shelf. Then, she realizes that she also needs to clean a wound on the patient's other leg. She pauses, then proceeds to use the same forceps to clean this other wound as before. When both wounds are cleaned, Sarah uses her gloved hands to apply new layers of clean dressing to both and covers them with fresh bandages and tape.*

Here, faced with a second wound site on the same patient's body, Sarah was unsure whether it was acceptable to use the same forceps as for the first wound. The risk was that pathogens from the first wound could be transferred on the forceps to the second wound, potentially causing infection. To avoid this risk, however, would have necessitated her leaving the room and removing her PPE, to get a new dressing pack, and repeating the

laborious process of donning PPE and set-up. So she decided to treat the forceps as 'clean enough' for this purpose, and did not distinguish between the two wounds.

At a later reflexive discussion, this became a point of contention amongst nurses. Should the two wounds be regarded (and treated) as totally separate spaces or, since they contained "*the patient's own bugs*", could they be considered as one space?

> *NURSE 3: She's fine to use the one forceps on the wounds. Because it's the patient's own bugs.*
> *NURSE 1: Same, same patient. […]*
> *NURSE 3: You can't cross-contaminate.*
> *RESEARCHER: What if the patient has MRSA outside, on his skin, but not in the wound?*
> *NURSE 2: Depends on where the organisms stay.*
> *NURSE 3: […] on the skin?*
> *RESEARCHER: Do you often know? Obviously you know if…*
> *NURSE 2: Yeah, yeah, they swab it…*
> *NURSE 1: They do the swab to find out…*
> *NURSE 3: Yeah, we know where the MRSA is. It's on the wound […]*
> *NURSE 3: [The report] doesn't actually even say which wound.*
> *RESEARCHER: Yeah.*
> *NURSE 3: It just says 'the wound'.*

Spaces, and this includes the wounds, the surface of the dressing, the skin, the room, the trolley, the floor – are constantly reconfigured through the temporally unique ways in which agents (humans, instruments, boundaries, results, microbes) intersect and impact on one another (Mol 2014).

> *After Sarah finishes applying fresh bandages and tape, the sterile area on the trolley is cleared; all items are discarded in a waste bin or a special bin for cleaning; her gown and sterile gloves are removed and discarded and she puts on new blue gloves from the box outside the room, to clean the trolley from top to bottom with disinfectant and*

paper towels. She then exits the room, leaving the trolley in the corridor outside the equipment room.

This vignette reveals many occasions when the *in-situ* complexity of sterility work is more than representational: it exceeds the reach of the protocols that govern the wound-dressing procedure. The present moment of hospital practice frequently also reveals more complexity than Mesman's description of its organised spatiality: items fall from the (cleaned) trolley to the (unclean) floor and are returned to the trolley; the patient needs to find a way to remind the nurse of a needed item; hitches occur, and questions arise about the status of gloves and how two different wound sites on the same patient should be treated.

We see here how the messiness, the complexity, and the unresolved spatial work of IPC – the space-time *event* of sterility - is accurately captured by Massey's propositions:
(1) the constructedness of space is evident: trolleys are cleaned; the sterile surface is created by moving items in particular ways. In an earlier analysis we also showed how staff made distinctions, in different situations, between 'clean', 'less clean', 'clean enough', and 'dirty' spaces (Hor, Hooker et al. 2016);
(2) these space-events are produced by multiple interrelations, including those of humans and unseen pathogens;
 (3) the intersecting trajectories of trolleys, researchers, physiotherapists, patients and microbes co-exist and intersect in a space of coexisting heterogeneity, demonstrating IPC activities as *ad hoc*, messy and entangled in other hospital work.

Our analysis also highlights issues not accounted for in IPC in protocols, which represent care spaces as stable: the work space is labelled 'sterile' and the patient simply 'isolated'. But we have demonstrated that, because of the multiplicity of factors, actors, goals and trajectories, this can only be achieved transiently, through action. NRT allows us to see that the spaces constructed and used by IPC activities need to be constantly ascertained and reproduced.

(2) Transience

If we understand hospital spaces as continually being constituted through multiple interrelations and trajectories – if, in short, we understand space as an event - then one obvious corollary is that whether a space is clean or contaminated is always *in process*. A space may be *made* clean, but that status lasts only so long as nothing touches it. In other words: NRT adds a crucial facet to a spatial analysis of IPC: that of *time*. If we think of spaces (like wounds or trolley surfaces) as *events* and the environment as multiple *'space-times'*, an alternative conception of IPC work emerges. IPC work becomes, not so much compliance with protocols *per se*, as the *constant creation of transiently safer spaces*, as *never complete*, and *always part* of *all* healthcare work.

Time as well as space clinically defines infection: the time a microbe is on a surface, or whether it is on the skin or inside the body (contaminating, if temporarily introduced; colonising, if established in/on a person; or infecting, if causing disease). The categories used in practice are representational: they represent the status of a space: this patient 'is colonised', that room 'is contaminated'. Our research shows how this status is actually transient and unstable, produced by the movements (or not) of microbes and the activities of patients and healthcare workers. As our fieldwork progressed, we (and our participants, including patients) observed that the significance of these categories varied according to situation and were differently constituted through different clinical practices.

For instance, the renal unit consisted of three functional spaces: the inpatient ward, dialysis (day-only) ward and outpatient clinic, which were connected by a long corridor, and staff often moved between wards. In the inpatient ward, patients who were colonised with MRSA or vancomycin-resistant enterococci were placed in isolation rooms with contact precautions (gowns and gloves). However, in the dialysis ward, there were fewer isolation rooms and many colonised patients were nursed in spaces demarcated by closed curtains, or identified by the presence of a PPE trolley beside the bed. Staff generally wore PPE for their own protection anyway, because their work involved blood; so fewer dedicated practices were needed to configure space safely in relation to colonised patients. The outpatient clinic space, by contrast, was considered as 'low risk', because patients were in the clinic only briefly, generally not acutely ill, and any procedures were relatively non-

invasive. Thus, in the clinic, a patient's colonised status could go unnoticed because it was not usually acted upon. These various circumstances could at times seem incongruous and confusing to patients who, like staff, also moved back and forth through the corridor between these different wards over time as they became more or less well with chronic kidney disease. Whether or not they were colonised was differently foregrounded in less-than-fully-conscious performed IPC actions in different rooms along the same corridor.

Our study also shows the gap between representations in IPC (such as policies) and the lively, immediately detail of what is 'taking place' in IPC. IPC practices are embodied; they have rhythm and choreography; they can be somewhat habituated, and, as our dressing-change example illustrated, are often less than fully conscious (Andrews 2015). *What happens* in IPC are many actions performed in the moment to achieve trajectories of IPC work in intersection with other hospital work (such as wound care, clinical monitoring or patient privacy). We saw that when these activities were brought into representation, through discussion in the reflexive sessions, that staff watching our video clips disagreed in their interpretations of what had happened or should occur. We found many instances in our video data where IPC work was *more* than representational; that is, that it *exceeded* its various representations.

For example: microbes produce space through their trajectories, by moving and by growing in places hospitable to them. IPC practices made hospital space in relation to microbial potentiality: in relation to the *potential* for microbes to be present, and to move. We observed that some IPC activities configured space in ways that then represented where targeted microbes (such as MRSA) were located, others configured space to stop potential microbial movement *in particular directions,* and still others configured space around microbial potentiality - the microbes *might be anywhere*. For example, in some wards, but not others, patients were swabbed to discover who was colonised with an MRO; staff were rarely tested. Patients identified as colonised or infected were isolated or grouped together; then IPC practices were concentrated on preventing MROs moving in one direction: from *leaving the room*. This justified use of the gloves by staff entering the room (to prevent a patient's MRO contaminating HCWs' hands).

Other IPC activities produced hospital space as always potentially contaminated by MROs. For example one ward (ICU) had, for a while, instituted blanket contact precautions (i.e. requiring gloves and gowns) for all patients. Instead of depending on routine testing, this resource (and time)-intensive strategy assumes that any patient and therefore any surface, at any time, could be carrying MROs. This, as with cleaning or the 'no-touch technique', *ordered space* around where potential pathogens *were not* (e.g., on a cleaned hand), rather than around where they *were*. The task of IPC became the creation of clean spaces (hands, bodies, trolleys) amid a potentially contaminated environment in order to accomplish a goal, such as a safe dressing change.

Interestingly, due to a MRSA-outbreak in another ward, coincident with our study, a set of environmental swabs was collected (not usually done). The swabs identified MRSA on many surfaces (such as at workstations) that were not usually the focus of IPC practices. This made spaces that were often treated as 'background' by being left out of practice, into the remit of IPC activity. Swabbing also produced hospital space in which MROs might be anywhere.

Our video data collection also created the effect of bringing what was 'background' into conscious awareness. When we played clips from video footage, the physical environment often became the subject of commentary in reflexive sessions. For instance, in one clip, a patient, colonised by MRSA and potentially infectious, is moved in her bed by a team of two nurses, a doctor and a wardsperson (porter). They push the bed through a crowded corridor with gloved hands, through an ICU to the lifts outside, heading towards the radiology departments for tests. As they do so, the staff encounter numerous impediments - trolleys, computer workstations, bins - all left or placed by other people for other reasons - and move them, despite having handled the patient's (potentially-contaminated) bed, without intervening hand hygiene. Likewise, they touch door handles and lift buttons. As ward staff viewed this clip, the corridor could no longer be seen as a closed, fixed and neutral background surface for a patient's trajectory, but rather a contested site of multiple trajectories of objects and equipment from past and ongoing clinical activities. This complexity created several potential new microbial trajectories (i.e. cross contamination) through the staff's actions.

In viewing this clip and others, participants frequently commented on the need to reorganise space: to move items out of the way, to reduce interactions with curtains, beds and objects on furniture and workstations, and to develop different practices in relation to equipment in IPC activity, for example, rolls of surgical tape, which were frequently kept in use by patients' bedsides after being contaminated during procedures.

(3) Co-existing heterogeneity

In hospitals, multiple trajectories – e.g. of tests, medications, diagnostic tests, visitors, patients, data collection, monitoring machines, ward rounds, wound-care etc. – constantly intersect or collide. Our videos and participants' comments identified numerous examples of how this heterogeneity extends, undoes, or complicates IPC protocols and practices. Most obviously, there are innumerable small interruptions to practices that follow IPC protocols (or try to). A trolley, not yet cleaned and left outside a ward room by one nurse for a few minutes (trajectory 1), becomes an obstruction to be moved away from the potentially contaminated bed of an MRO-colonised patient on the way to radiology (trajectory 2). Or questions from a patient or family member (trajectory 1) interrupt the careful choreography of IPC (trajectory 2) in the process of checking wounds or monitoring machines (trajectory 3).

The coexisting heterogeneity of trajectories means that IPC concerns may be either invisible or not prioritised by HCWs who are primarily focused on another task. Patient beds are large and difficult to handle and can be left in hallways, sometimes with patients still in them. These may be patients who were previously isolated in single rooms, due to their status as MRO-colonised or infectious, but they might remain in the hallway for hours, waiting for transport that has been delayed by other imperatives. This makes the representation 'colonised patient' less prominent (invisible, in fact) to numerous staff who may move the bed slightly to accommodate their own trajectories, unintentionally multiplying possible trajectories of unseen pathogens.

The intersections of IPC and other clinician trajectories similarly produce complexity. For example, a doctor might examine (and touch) a urine drainage bag, which is likely to be contaminated, before touching a wound site, which *should* be kept clean, because her primary focus is on the patient's urine output. Similarly, trajectories producing patient privacy could circumvent IPC trajectories. Our footage included clips of clinicians using newly-cleaned hands to close a (potentially contaminated) curtain to produce privacy, and then touching (and potentially contaminating) a previously uncontaminated patient. Such less-than-fully-conscious actions provide new trajectories for pathogens.

When brought into representation, these circumstances create confusion for clinicians, as revealed by questions raised in reflective sessions. For example, ideas about 'patient space' were particularly contentious. Clinicians debated whether the patient's body, their bedding, the curtain and/or the room surfaces should be regarded – that is, represented - as 'the same' with respect to the presence or absence of pathogens, or whether IPC practices should produce differentiated spaces. Should hand hygiene occur between touching the curtain and the patient, for example, and did this differ between single, and four-bedded, rooms?

Intersecting trajectories created even more confusions for patients. Their comments on videos of dressing changes, collection of swabs and other quotidian patient care, revealed that patients observed multiple apparent inconsistencies in IPC practices: e.g. they witnessed items that fell on floors or were forgotten, or curtains or light switches being touched with gloved hands that then touched 'clean' surfaces; they wondered whether ABHR should be used on gloves or before putting them on and whether it should be positioned beside the bed for multiple use; they noted the inconsistency of MRSA-colonised patients being isolated in the renal inpatient ward, only to have their MRSA status ignored when they attend the clinic. They noticed, in effect, that the spatio-temporal complexity of IPC dynamics exceeded representations of space from IPC protocols (Wyer, Iedema et al. 2015).

Discussion

Doreen Massey wrote that she wished to 'uproot space from the constellation of concepts in which it is embedded (stasis, closure, representation) and to settle it in other ideas (heterogeneity, relationality, coevalness)' (Massey 2005).

We have applied this approach to the spatiality of IPC, which enabled us to extend Mesman's analysis of sterility as a spatial accomplishment. We grappled with the 'messiness' of healthcare practice, that is, with the dynamic reconfigurations of relations among space, microbes, people, resources and time (Iedema, Hor et al. 2015, Hor, Hooker et al. 2016, Iedema 2019).

Our video-reflexive fieldwork showed us (and our participants) that space is not a neutral background to healthcare work. Rather, space is a multitude of complex dynamic events produced by multiple factors, including what we do and say. Hospital space is 'of coexisting heterogeneity', that is, constructed from numerous intersecting, and sometimes competing, imperatives, including clinical examination, patient privacy and IPC activities. Analysing space as produced by multiple trajectories, including those of non-human objects, brings many circumstances that might enable microbial trajectories into consciousness and makes them available for incorporation into practice.

A second and related point we have made is that *time* is of central importance to an analysis of IPC activities. Sterility is not simply a spatial achievement, as Mesman outlined, it is a space-time *event*, and it is transient – for example, a wound dressing is sterile only until it is applied, even with aseptic technique, to the wound (which may be cleaned but not sterile).

Precisely because hospital work is so complex, routine practices and strategies (including protocols) are used to simplify it. As representations, these 'stabilise' particular time-space constructions and make them available for use. But nothing remains stable for long; everything needs to be constantly reproduced. Our data showed: that clinicians may not consciously consider the role of objects (like curtains) or directions of potential microbial spread that are not specifically addressed by routine practices; that protocols that cannot be followed exactly and must be constantly adapted; and that protocols may hinder efficiency, e.g. by requiring the use of PPE when it is unnecessary or restrictive. This

reinforces our previous observations (Iedema, Jorm et al. 2018, Iedema 2019), that IPC practices not only often fall short of, but may also *exceed,* those prescribed in protocols (Iedema, Jorm et al. 2018, Iedema 2019).

Our account explains why staff frequently expressed confusion, in reflexive sessions, about IPC practices that exceeded their representation in protocols. Although a question such as 'when are gloves necessary in addition to hand hygiene' may seem straightforward, the answer is not always obvious and certainly not always agreed upon (Iedema, Jorm et al. 2018). Our analysis suggests that the heterogeneity and transience of hospital space imply that some questions *cannot* have fixed or stable answers, other than 'it depends'. When a HCW should use gloves and/or hand hygiene depends on, *inter alia*: what she touched just before; how she conceives of, (and produces, through her actions), the patient in relation to the cleanliness of his bed curtains; how she judges the status of a surface *at this moment in time*; or simply on the less-than-fully-conscious activities through which she performs the objectives of privacy or clinical routine. Our argument here is that these questions arise, in part, because of tensions between different imperatives of hospital work and/or different representations of IPC, and hence are, in some sense, empirically unresolvable ahead of time.

Additionally, because it enables us to incorporate so many factors not captured by other approaches to IPC, one implication of our non-representational approach is that we have new insight into the apparent 'failures' of IPC. In fact, the analysis reveals that 'failures' are mostly not failures at all, and not accurately described as lapses in compliance (Pink, Morgan et al. 2014). Rather, they result from disruptions to IPC activity due to other trajectories and different priorities; our assessment is that microbes were often moved around the hospital as a result of the inevitably heterogenous and intersecting characteristics of hospital work. This perspective fits with strengths-based approaches (Mesman 2009, Pink, Morgan et al. 2014) that aim to examine the resources and resourcefulness inherent in 'how things work *in situ'* (Iedema, Carroll et al. 2018, Iedema 2019) – and makes it doubtful that strategies involving increased staff surveillance or auditing of processes, such as hand hygiene, will produce significant reduction in HAI rates.

A third implication is that space can be analysed as a non-trivial *actor* with effects relevant to IPC. Previous VRE research has shown that video makes sociality visible: actors can see they are part of social formations, and that individual actions alone fall short of explaining how hospital work is accomplished (Iedema 2019). Here, we have demonstrated that video also makes *space* visible because footage can be 'hologrammatic' when shown to those familiar with the activities videoed (Iedema 2019). VRE is a useful methodology for non representational research because allows for studies that are part representational and part non-representational. In this case, it allowed participants to consider the potential past and future trajectories of microbes, objects and people. For example, if, while watching a clinician entering an isolation room, participants are asked 'are the gloves clean', they can envisage previous clinicians' space-time interactions with the glove box and judge that the gloves may be *not* clean or perhaps 'clean enough'. Or they might consider the possible future trajectory of a roll of surgical tape stuck onto the bed rail, and consider whether it might create a pathogen trajectory as it is moved around the ward.

Finally, we note that this study contributes to and extends the application of NRT to health geography and clinical care (Andrews 2015, Andrews 2017, Andrews and Duff 2019). Our study indicates the utility of insights into how non human actors such as pathogens are in complex networks with people and objects, and how their trajectories are configured by these networks. Our account indicates that we need to better understand how the knowledge and skills gained in clinical education and training are enacted in the quotidian, less-than-fully conscious actions of healthcare staff (Andrews 2017). Future non representational research theorising *affects* in IPC (Thrift 2004, Thrift 2008) (for example, as an achievement of the transient infrastructure of attention noticed by Mesman), which we did not have room to pursue here, could provide more insight into habits and responses to IPC .

Conclusion

What can a non-representational theory of space offer clinicians who simply want to know what to change, in order to do their work better? Four propositions for practice change arise from our analysis:

(1) *All* hospital work is also IPC work - we suggest it should be taught and practiced as such. Representing IPC as completed by following specific protocols, limits the capacity of staff to see and disrupt other potential avenues of infection transmission.

(2) IPC work is never complete - likewise we suggest that teaching and practice should emphasise what needs to be cleaned and kept clean and that cleanliness needs to be *made* constantly. A sign on the wall identifying an isolation room is a representation that implies that things are different inside and outside, but actually, staff need to *make* it so each time.

(3) The counter-intuitive construction of spaces as *processes* may help staff call to attention how the status of a space depends on other people and objects. This helps managers and staff recognise that IPC practices often exceed individuals' compliance with protocols, and their messiness arises from the disruptions and intersections of multiple trajectories in hospital work.

(4) That IPC knowledge translation and training could productively involve nurse educators and their trainees practicing together and actively creating new realities; and then consciously retrospectively reviewing these new realities, as suggested by Gavin Andrews (2017), using techniques like VRE. Ward environments could be altered to make wanted, repeated (or habituated) clinical behaviour more achievable (for example by installing more bedside brackets for ABHR, as occurred in our study).

Because it is heterogenous, multiple, and temporary, we argue that IPC can never be fully known at a distance and what we term 'situated responsiveness' will need to be constantly enacted to achieve lower rates of HAI. We suggest that situated responsiveness can be developed by drawing on what is already *performed well.* Although our study showed that overloaded attention was an issue that needs to be addressed in modern healthcare, we also observed multiple situations, in every video session, where IPC work was accomplished successfully, because of the capacity of staff to respond reflexively to unpredicted events. Situated responsiveness enabled items accidentally forgotten to be retrieved, patient questions to be addressed, helping hands to pull curtains for gloved and gowned clinicians. During the course of our study, the reflexive engagement of staff with researchers' use of VRE enabled several local improvements to be made (such as different team configurations) that suited the work routines and needs of the ward (Iedema, Hor et al. 2015).

Teamwork, collaboration, the cultivation and use of clinical judgment (perhaps through semi codified risk assessment processes), and periodic opportunities for reflexive group learning, already provide for great achievements in IPC and are necessary for further improvements. These implications fit with the frequent calls in IPC research for strategies that encourage 'healthcare organizations to adopt or adapt the best interventions in reduction of HAI in their routine practice' and to 'change the culture of … healthcare organizations' (Jumaa 2005, Al-Tawfiq and Tambyah 2014, McAlearney and Hefner 2014, Bearman, Munoz-Price et al. 2018).

HCWs are strongly motivated to prevent the suffering caused by HAIs (McClung, Obasi et al. 2017). This commitment may become effective through strategies that support situated responsiveness. The constant, transient production of clean and sterile spaces, within the multiple and complex spatiality of the hospital, requires strategies that represent IPC as they emerge from the *collective* work of all staff and collaboration with patients (Wyer, Iedema et al. 2015), as much as those that represent successful IPC as simply the outcome of individual compliance.

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Figure 1. A trolley with items needed for a dressing change.