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Air care: an ‘aerography’ of breath, buildings and bugs in the cystic fibrosis clinic

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Abstract With significant relevance to the Covid-19 pandemic, this paper contributes to emerging ‘aerographic’ research on the socio-materialities of air and breath, based on an in-depth empirical study of three hospital-based lung infection clinics treating people with cystic fibrosis. We begin by outlining the changing place of atmosphere in hospital design from the pre-antibiotic period and into the present. We then turn to the first of three aerographic themes where air becomes a matter of grasping and visualising otherwise invisible airborne infections. This includes imagining patients located within bodily spheres or ‘cloud bodies’, conceptually anchored in Irigaray’s thoughts on the ‘forgetting of the air’ and Sloterdijk’s immunitary ‘spherology’ of the body. Our second theme explores the material politics of air, air conditioning, window design and the way competing ‘air regimes’ come into conflict with each other at the interface of buildings, bodies and the biotic. Our final theme attends to the ‘cost of air’, the aero-economic problem of atmospheric scarcity within modern high-rise, deep-density healthcare architectures.

Keywords: aerography, ventilation, lung infections, antimicrobial resistance (AMR), transmission, cystic fibrosis

Introduction

As this paper went to press in April 2020, the world had entered the early phases of a global viral pandemic without precedent in living memory. In a few short months and weeks, Covid-19 had ushered in a historically radical transformation in how we move, travel, interact, breathe, work, live, heal, die and mourn. The paper that follows was written ‘BC’, in a time when the terms ‘social distancing’ and ‘self-isolation’ would have been unfamiliar to most of us. And yet for some, those susceptible to serious respiratory infections, the ‘two metre rule’ or ‘six foot rule’ has long been a way of life. That includes people with cystic fibrosis (CF) and other conditions who are vulnerable to lung infections increasingly resistant to antibiotics (antimicrobial resistance [AMR]). AMR is, we are now beginning to learn, potentially a contributory factor in Covid-19 deaths from secondary infections, largely pneumonia (Zhou *et al.* 2020). Breaking the global chain of Covid-19 transmission has come to depend on a new biopolitical spatiality of the body, of all bodies. For most people, these are entirely new

etiquettes of spacing, of imagining the invisible, of envisioning aerosolised dangers, of picturing airborne threats encircling the bodies of oneself and others. The profound state of emergency once inhabited by the very few, has now come to enfold the entire world.

This paper documents an ‘aerography’ of respiratory life building on an in-depth empirical study of three UK hospital-based respiratory lung infection clinics treating people with CF.¹ In this context the air has become materially spatialised in ways that call into question the ecological life of building design and layout. Cystic fibrosis is characterised by lifelong chronic respiratory infections where breathing is not to be taken for granted but becomes a matter of conscious effort and atmospheric management. Here, the implicit nature of breath is made explicit, surfacing above the taken-for-granted. Lung infections may temporarily be alleviated through antibiotics delivered intravenously or nebulised and inhaled. Nevertheless, residues of infection evolve, genetically selecting for resistance. Lungs become ‘reservoirs’ of ‘resistome’, organisms inhaled and exhaled, settling on surfaces or lingering in the air.

The atmospheric biotic focuses attention on the mutually implicated microbiomes of buildings, bodies and respiratory tracts. Recognised as a global healthcare challenge, the problem of AMR is greatly magnified in those illnesses characterised by persistent long-term microbial colonisation. This includes CF and conditions in which the microbial load of the lungs is much greater than would normally be the case, and where pathogens are far likelier to be expelled during coughing to circulate as mucoid vapour. The sharing of airs in this way naturally results in cross-infection and the evolutionary adaptation of resistance to antimicrobials.

Much of the policy engagement with AMR has focussed on aspects of human ‘behaviour’ especially prescribing and patient ‘compliance’ (Chandler 2019, Will 2018), while less attention has been directed at the socio-material nature/s of healthcare architectures (Brown *et al.* 2019, Martin *et al.* 2015). We respond to this aspect of AMR by focussing on the built environment of clinical space, taking into account changes in contemporary healthcare buildings and the layered atmospheric histories of ventilation and ‘air hygiene’. This includes a detailed consideration of localised practices where air is both a focus for microbial anxiety, but also infection management. Our research maps the real-world pathways, journeys and flows of bodies and bodies of air through clinical space, including the way atmospheric interactions are configured by the spatial dimensions of respiratory care. Until the 1990s, people with CF would routinely meet in open hospital wards, adjoining games rooms, waiting areas and on residential holidays. This emphasis on interactional intimacy changed fundamentally with the identification of resistant bacteria traced to cross-infection through interpersonal contact (Conway 2008). Living with CF has increasingly come to depend upon a hygienic regime of spatial and atmospheric segregation, ritualised etiquettes of social distancing and a keen acuity to infection risks carried on the air. Median survival for CF now typically sees adults living over a decade longer (mid 40s) than would have been the case in the 1990s (Keogh *et al.* 2018), with greater implications for the configuration of the spaces in which they are treated. The body of the CF patient has been transfigured into a vaporous source of infectious transmissibility to be isolated, imposing new self-pedagogies of hygienic prudence (Lowton and Gabe 2006) and containment within what Fox (1997) has called ‘circuits of hygiene’ (see also Mesman 2009 on ‘sterility as a product of spatial ordering’, 1705).

Conceptually, to take an aerographic perspective reverses a hierarchy of the senses privileging visible solids (Irigaray 1999). Instead of an afterthought, an aerography asks, ‘why not begin with air’ (Jackson and Fannin 2011), with the immaterially intangible? Air is, as Sloterdijk (1998) notes, a matter of ‘sphereology’, of being located ‘in’ some definite atmosphere, prompting us to think about life enveloped in contrasting spheres of relative exposure and protection, endangerment and safety. Our discussion here is conceptually anchored in emerging aerographic perspectives across a number of disciplines (Ingold 2012, Lowe 2010).

In what follows, we begin by outlining a broader historical perspective making connections between aerographic reflections in medical humanities work on hospital architecture, but also a corresponding 'turn to the air' in the clinical sciences. We suggest that AMR has focussed interest in these fields on the atmospheric attributes of healthcare architectures across time ('pre-to-post-antibiotic').² Then, having outlined our methodology, we turn to the first of three aerographic themes in our data on the way air becomes a matter of doubt and guesswork in the CF clinic. We reflect on the role of the imagination in visualising the invisible, including imagining patients located within bodily spheres, or 'cloud bodies'. This is conceptually anchored in Irigaray's thoughts on the 'forgetting' of the air, and Sloterdijk's immunitary thinking on the spherology of the body. Our second theme explores the material politics of air ventilation, air conditioning and window design, and the way competing air regimes conflict with each other, becoming flashpoints or 'airquakes' (Sloterdijk 2004) at the interface of buildings, bodies and the biotic. Our final theme attends to the 'cost of air', the aero-economic problem of atmospheric scarcity within high-rise, deep density modern healthcare architectures. We conclude by speculating on responses to the AMR crisis by critically questioning contemporary healthcare atmospheres.

From pre-to-post antibiotic atmospheres

Air, Connor writes, fragments the borders of bodies and buildings, rendering space 'produced and dynamic, rather than absolute and given' (2006: 121). Buildings lend bodies metaphorical sturdiness while bodies give buildings their liveliness and frailty. 'This contrast is at its most intense', he suggests, '... when the physical processes in question are least material ... those carried on or in the air' (*ibid.* 118). The disassembling of the building is nowhere more acute than in the world of infections interacting between hosts through the medium of the air. For our purposes, we might usefully think about the shifting place of air in hospital architecture from the 'pre-antibiotic' into the 'post-antibiotic'. Prior (1992) traces the way miasmatic theories of contagion became architecturally embedded in the classic 'fresh air wards' of the nineteenth century (see also Adams *et al.* 2008). *Maladies* are seen to arise from zymotic gaseous chemical processes, the decaying decomposition of plant and faecal substances, the putrefaction of flesh and mephitic fermentation. Torpid air must not fester. Resulting vapours and stagnating fumes must move, be dispersed, circulate and refresh. Buildings mirror bodies in their need to respire.

The architectural expression of miasmatic discourse is the 'pavilion' (Forty 2003), *papilio* or *papillon* (C13th), the 'butterfly' tent. The pavilion ward inverts internal and external space, detached from the main building, sometimes having a radial tent-like cylindrical shape, preventing air lingering in dark corners. Ventilation separates the bodies of the sick into neatly divided atmospheres, each patient apportioned a volume of air not less than 1500 cubic feet and each bed an area of 100 square feet (Nightingale 1859). The pavilion ward 'spatially isolated everything from everything by oceans of fresh natural air' (Kisacky 2005: 20). A central fireplace would draw air in to be evacuated up and out at the apex of a vaulted roof. Beds would be wheeled outside to surrounding balconies and gardens for 'air bathing' (Gauvain 1933). The classic Nightingale ward would be south facing, glazed floor to ceiling. Well into the mid-twentieth century, 'fresh air cure' architectures were the mainstay of tuberculosis treatment in the 'pre-antibiotic age' (Blundell Jones 2016: 267).

The paradigm shift from miasma to germ theory and later the widespread use of antibiotics from the late 1940s corresponds with fundamental changes in the configuration of clinical space, reflected in a movement of disease from the environmental to the internal and pathogen-centric. Hospital design '... shifted from the pavilion-ward ideal of keeping everything spatially separated to the functionalist ideal of interconnecting spaces in the service of

operational efficiency' (Kisacky 2005: 3). Adams *et al.* (2008: 912) similarly note how '... lasting until the age of antibiotics ... architecture (or more generally the patient's immediate environment) served explicitly as an active physical agent'.

Antibiotics made possible new concentrations of healthcare delivery within ever more efficiently compact architectural designs (Bud 2007). Treating infections with chemical compounds rather than air and sunlight fundamentally changed the spatial and environmental dimensions of the biotic. Antibiotics became 'infrastructurally' (Chandler 2019) enmeshed in a way of life whereby infections became a matter for pharmacology rather than aerography. The '... introduction of drug therapy at the close of World War II' constituted a 'dramatic break' with any semblance of the pavilion atmosphere (Adams *et al.* 2008: 913). Indeed, 'by the 1960s, antimicrobial treatment had rendered sanatoria, [and] the rest cure ... obsolete' (*ibid.*). Antibiotics arguably meant that hospitals '... turned away from Nightingale's principles, closing their windows and shutting out the sun' (Swain 2013: 35). Openable windows and the external environment itself were seen to threaten the fragile technology-dependent integrity of high-rise, deep-density, hermetically sealed, air-managed atmospheres (see also Gissen 2014).

AMR now prompts more critical thinking on the interdependence of hospital architecture and antibiotics, and in turn, a renewed attention to the air. A recent Swedish hospital architectural commission (completed in 2011) is described explicitly as an architecture for the 'post-antibiotic era', incorporating spacious isolation rooms and wrap-around fresh-air balconies to maximise ventilation and minimise cross-infection (Holmdahl and Lanbeck 2013). Air is undergoing a renaissance in the interplay of historical memory and impending dystopian doom. 'Perhaps we can prepare for the looming post-antibiotic era' writes Swain, 'by taking some lessons from the pre-antibiotic age?' (2013: 35). Kembel *et al.* (2014) point out the relatively ignored inter-connectedness of architectural design and microbial ecology, reframing the buildings as 'multi-species ecosystems'. Natural ventilation through windows turns buildings inside out bringing the external biotic life of the environment into the internal space of the building. But rooms with mechanical air conditioning preserve or capture the interior life of the building. Hospital airs now 'deserve special attention' affecting 'the rate and direction of bioaerosol transmission to sensitive respiratory mucosal surfaces' (Kelley and Gilbert 2013: 202).

There is a growing interest therefore in microbiology on external fresh air as a beneficial means of 're-wilding' indoor atmospheres. Windowless air-conditioned hospitals, it is argued, are over-populated with pathogens, compromising the healthy biodiversity of building ecology, allowing resistance to flourish uncontested (Smith *et al.* 2013). Perhaps, suggests one commentator, we're coming 'full circle in hospital design' by revisiting pavilion architectures (Escombe *et al.* 2007)? In what follows, these overlapping turns towards the aerographic, frame our attempt to 'follow the air', or 'air care' in the real world materialities and practices of respiratory clinics. In our concluding discussion, we want to return to the way AMR potentially creates an imaginative historical space with which to rethink the shared atmospheres of human and biotic bodies.

Methods

As discussed below, hospital architectures are differently patterned in their affordances and how they shape and are shaped by the bodies navigating them. Our study develops insights from three outpatient CF clinics, each having a different architectural history and scale of delivery. Site 1 treats outpatients within a 1970s-built hospital located in a small provincial city treating around 35 adult CF patients. When first built, it gained repute as an example of

highly economical building design. Today, staff talk of 'getting by' and 'making do' in a budget building. Outpatient CF treatment takes place in rooms within the busy ground floor outpatient department at the hospital, alongside other clinics. Inpatient services and 'ad hoc' (emergency) outpatient appointments take place in a general respiratory ward on the third floor. By contrast, outpatient services at site 2 (with 400 listed CF patients), takes place on the semi-rural margins of large urban conurbation in the 1990's wing of a 1904 infectious disease hospital. Indeed, it is possible to still see framed photographs of the original fresh air wards hanging on the walls. In contrast to the other sites, site 2 has a dedicated area of the outpatient department for CF. Inpatient services and 'ad hoc' outpatient appointments for site 2 take place in a specialist CF ward on the sixth floor of a busy teaching hospital. Site 3 has over three hundred CF patients, with outpatient services based within a large chest department built during the early 1990s. Inpatients are treated in segregated wards for patients with different 'bugs'.

Our research at each site included ethnography, archival research and face-to-face and walking interviews with 54 respondents (34 hospital staff, 15 patients, 2 family members and 3 architects). Architectural layout plans of the clinics were used in face-to-face graphic interviews with participants encouraged to annotate plans, using different colour markers indicating routes, cross-infection 'hot spots', design features, etc. We conducted 70 interviews, 45 graphic and 25 'walking interviews' with participants guiding us through buildings, taking photographs of spaces, objects, signage and using the built environment as a prompt for discussion. Walking interviews followed routine journeys through the hospital space (including entrances, exits, corridors, treatment rooms, waiting areas, wards, etc.). Ethnographic observations were undertaken in CF outpatient clinics and inpatient wards with facilities for 'ad hoc' outpatient appointments. Incidental observations took place during visits to each site over a 9–10 month period, and we additionally conducted 72 hours of 'targeted ethnography' (Sage and Dainty 2012) involving focussed observations of clinic days designated for different infections at each site. Graphic and textual data have been analysed in dialogue with one another using NVivo to create links between different data types. Ethical approval was secured through the UK NHS. Names of participants and clinics have been replaced with pseudonyms.

Imagining atmospheres – the spherology of 'cloud bodies'

Caring for lung infections is a matter of constantly struggling to remember the forgettable and envision the invisible. 'Always there', Irigaray (1999) writes, the air 'allows itself to be forgotten'. Instead, an aerography prompts us to 'begin with' (Jackson and Fannin 2011) and 'take to' (Connor 2006) the air. Opening the window on air prompts us to ask questions differently and overturn the 'oblivion' of the air, uncoupling ourselves from an attachment to tangibility. The fact that the air doesn't easily 'show itself', as Irigaray puts it, is a constant preoccupation in respiratory care. Bergson suggests that, '... our logic is, pre-eminently, the logic of solids' (1984: ix). The air however is clouded in doubt. Latour (2004) points out that certain events move air from the implicit to the explicit. For Sloterdijk (2004), the gas attack on *Ypres* is an airquake that converts air into object of explication, to be understood. The respiratory clinic is, in just this way, an environment of aerographic uncertainty where air's movement becomes an epistemic problem of un/knowability.

In our interviews, both medical staff and patients talk of their anxieties about the air but are unsure whether and for how long bacteria 'linger in the air'. Changing the air, the rate of exchange, and its implications for infections in the air is, in most respects, a matter of guesswork. Envisioning aerographic risk is a question of having to speculatively 'imagine the

atmosphere' but without really knowing (Wagenfeld 2008). As one CF practitioner puts it to us, the atmosphere of a room is an acute source of doubt and uncertainty:

... how much you mitigate it by opening a window? I don't know whether there is less risk [in] big open spaces, and the air exchange is different, I'm not sure ... all the infections that we see largely is airborne, and I don't know ... having wipeable surfaces is a benefit, but does it reduce airborne transmission? I don't know. I doubt it ... the one thing I really worry about ... is when a patient's been in the same area for a few hours ... I just imagine the atmosphere in that room full of bacteria ... and then the next person goes in ... You go in and you breathe it all in ... it's this time between patients and better ventilation ... you don't know what they've breathed out. So, we normally just ... open all the windows ... let it get a bit of air. (Rachel, physiotherapist, site 1)

For people at risk of cross-infection, the air is imagined hydrologically as having a certain unruly leakiness, becoming an indeterminate source of liquid defilement and disorder. The fluid translucency of the air renders the atmosphere unclassifiable, neither one thing nor another. Always given to turbulence, clinical air is in a constant state of flux, threatening the orderliness of spatial boundaries and classificatory schema. Breath, exhaled moisture and especially mucous transgress the body's boundedness. As Classen notes in relation to scent, bodily odours borne upon the air become proxies for defilement and are concerning because they '... cannot easily be contained, they escape and cross boundaries, blending different olfactory wholes' (Classen *et al.* 1994: 4). Our respondents are threatened by contagion in air that is perceived to be 'claggy', 'humid' and 'saturated':

... some organisms are spread in the air ... if the patient's been in a room and is coughing, then the air is saturated with whatever they're growing, and then we might put somebody else into that room. (Irene, physiotherapist, site 2)

There are innumerable moments when uncertain questions of atmospheric transmission arise in the everyday life of the respiratory clinic, especially when patients are asked to provide sputum samples for microbiology diagnosis or to 'clear' their airways. This can include the administration of nebulised hypertonic saline inhaled to saturate the lungs before 'coughing up'. Specialist CF physiotherapists will usually be responsible for managing sputum sampling, assisting patients to 'produce' fluid from the lungs using direct physical contact. At these and other times, anxieties centre on being able to 'clear the air' and the necessary risks of simply being present 'in the room', thereby becoming an embodied surface upon which pathogens settle from the air:

Some [rooms] have windows ... the Friday physio room doesn't ... I'll open the windows, if I've been getting people coughing and clearing stuff or have done a nebuliser ... try and get the air flow through the room before I bring someone else in ... often ... you don't really have a lot of time to let any air flow through before you get someone else in (Mandy, physiotherapist, site 3).

We're in the room with them when they're nebulising ... we are potentially more of a risk in terms of cross-infection ... you're in the room ... when transmission is more possible ... *pseudomonas* we know should desiccate fairly quickly ... once it's been coughed out and is on a surface ... So the risk of cross-infection to someone else without those people coming face-to-face is less ... for bugs like nontuberculous *mycobacteria* ... they're getting unique strains passing from person to person, without those people ever coming into direct contact ... which suggests that there's someone or something in the middle. (Rachel, physiotherapist, site 1)

The air is also the bearer of nebulised antibiotics, inhaled and exhaled, often into the immediate atmosphere, interacting with the built environment, inevitably contributing to the evolution of resistance. The nebuliser is however an unstable dimension of respiratory life, its 'correct' use a contested aspect of 'patient compliance' (Prout 1996). Tina (CF patient, site 1) told us how she felt traumatised by the experience of nebulised antibiotic treatment in childhood. The device was, she said, a big noisy 'black machine'. It had long ventilation pipes trailing out of the window to disperse nebulised antibiotics breathed in and exhaled out. This remains a source of anxiety for her and the cause of ongoing friction with the clinical team. Today however, those window ventilation pipes have been replaced by filters that must be maintained by patients themselves. Clinicians however complain that patients fail to see the dangers of the antibiotic vapour surrounding them and the importance of filtering:

... from an antibiotic resistance point of view ... Some of the patients are a bit slack at using their filters ... And if we are doing any drug response assessments for those we would ensure that we have got the filters with them too ... sometimes they don't remember, and so it's having to re-educate them as well. (Anne, physiotherapist, site 1)

In the aerographic imagination of the clinic, the bodies of the infected are envisioned surrounded by a communicable mist, a personal 'cloud' of biotic life following patients through space. The metaphor of the 'cloud body' is coined in microbiology (Belani *et al.* 1986) to designate bodies that 'shed' bacteria and viruses in great quantities. The metaphor emerges in the context of mounting concerns about AMR in upper respiratory tract infections, exfoliative skin conditions, CF and TB. The very idea of 'the cloud' repositions the individual body as a transmissible bioaerosol, dispersed in clinical space, becoming '... more likely when there is increased people traffic or activities such as bed-making that precipitate air turbulence' (Hobday and Dancer 2013: 274). More importantly, the metaphor of the cloud becomes an imaginative way of grasping the otherwise unintelligible, making the air apparent. By loosely symbolising the patient as a volume of air, the cloud re-envisioned the unseen, whilst itself remaining invisible. This recently found cinematic expression in the film *Five Feet Apart* (2019) where a romance develops between two CF patients whose lives are '... full of routines, boundaries and self-control'. While maintaining 'a safe distance' the '... temptation to throw the rules out the window and embrace that attraction intensifies' (see plot summary, IMDb 2019). The title itself derives from the 'six-foot rule' (Cystic Fibrosis Foundation 2014), the two protagonists having daringly closed that distance by one foot.

Embodying CF connects to a spherological biopolitics in which one comes to conceive of oneself in the terms of a bounded atmosphere. Tina (CF patient site 1) spoke of the way she envisages her own 'personal bubble' choosing a seat in the waiting area some distance from others, spreading her personal belongings on the adjacent chairs to preserve her own discrete sense of space. This is partly a matter of protection from infection, but also of privacy. She likes to 'people watch' but she doesn't want to 'get involved'. In this way the 'cloud' or 'bubble' becomes an indefinite expression of both the biomedical mandate to avoid transmission through social distancing, but also the navigation of public space (Brown 2018, Brown and Nettleton 2017, Newman *et al.* 2016). Imagining and embodying 'clouds' or 'bubbles' repositions CF patients within the aerographic 'spatiality of biopoliticized flesh' as Esposito has put it (Esposito 2008: 160).

Sloterdijk suggests breathing occurs in foam-like spheres of co-isolated adjacency, within a given volume of immunitary defensibility. It is, writes Campbell, as if '... the former blood ties of family ... had been turned outward ... to now include the breathing space of those whose individual immunitary designs most closely match one's own' (2011: 97). Respiration

increasingly retreats from shared space, becoming more privately self-contained. Membranous living is the basic principle of immunity providing protection from without but requiring continual labour to maintain a thin defensive sheath easily disposed to collapse. Spherology questions the very possibility of isolated individualism since all spheres are composed of co-belongings, a pluralised dynamic foam of spheres.

The 'foam architectures' (Borch 2008) of the healthcare built environment arguably produces the very atmospheric pathogenicity it attempts to prevent. Such spaces are the consequence and cause of the immunitary work undertaken to 'co-isolate' bodies. Illustrating the contradictions of co-isolation in CF, one of our interviewees, an architect who had overseen the design of a bespoke CF hospital, pointed out the curious irony of designing a building for bodies that should not be brought together. Hospitals inevitably therefore become an awkward gathering of those bodies for whom adjacency is a danger, and yet whose absolute isolation is impossible. Another interviewee, a respiratory doctor, mocked the very idea of total atmospheric immunisation. 'To be absolutely safe' he says, '... we could all wear spacesuits ... refuse to touch the patient ... see them one at a time ... completely alienating the patient and making their care feel awful. And where's the balance?'

Air technics and window politics

As already evident, many of our interviews return to the question of windows, their presence and absence, their design, the ability to open a window, and frustration at windows that cannot be opened. As Connor (2006) writes in his reflections on the overlaps between the building of the body and the body of the building, windows disassemble the boundaries of the built environment. Having its etymology in the Norse *vindauga*, the 'wind-eyes' of the building, these once glassless openings, are semantically synonymous with the breath of the building. In modern buildings, windows and ventilation materially express unequal distributions of power, agency and control. Windows are tied into layered systems of governance and policy. They evolve through successive regulated design mandates linked to thermal efficiency, conceptions of comfort, privacy, visibility and security.

Illustrating these tensions, outpatient CF treatment at site 1 takes place on the ground floor of a six-story hospital built during the 1970s. The hospital estate is comprised of four tower blocks each having an internal courtyard allowing much of it to be naturally lit from large windows wrapping continuously around the building and facing inwards towards the central quads. When the hospital was originally built it was possible to fully open its sliding aluminium windows allowing for generous ventilation. However, safety legislation has since required window openings in public buildings to be restricted to ten centimetres. Interviewees responsible for the hospital estate described how this radically reduced airflow, resulting in an uncomfortably warm atmosphere, increasing the need for air conditioning and mechanical ventilation. Harry, a building manager, described how air quality had remained an intractable problem until the arrival of a new colleague, Adam, who had transferred from a nearby Victorian-built hospital. Adam and Harry described how the older hospital had inspired them to imagine ways of increasing natural ventilation.

After some trial and error, they designed discrete horizontal bars to be fitted to the general hospital's windows, allowing restrictors to be removed and the windows to be fully openable once again. This included the respiratory ward accommodating CF inpatients and ad hoc outpatient appointments take place. Harry spoke of the unpleasantly 'close atmosphere' on the wards before the redesign. Pointing to a portable air conditioner in his cluttered office, 'fresh air is best' he says, 'there's nothing better than real air'. Adam mentioned the Scottish New

Year tradition of 'first footing', the first person to cross the threshold, followed by opening all the windows, 'letting out the old air and letting in the new'. Both spoke nostalgically of the old hospital, its vaulted ceilings, full-height windows, its spaciousness compared to the more compact 1970s estate. They discussed its fixtures and fittings, the use of copper, now credited with natural anti-bacterial properties.

Many of our discussions have centred on these seemingly intractable historical and contemporary tensions between competing air regimes, especially the way windows come into conflict with air conditioning and heating systems. Cooper (2002) has written of the way ideas about 'healthy air' ricochet over time between contending registers of what counts as a healthy element within which to live. The 1900s campaigns extolling the benefits of external fresh air, give way in the twentieth century to industry-driven advertising promoting the modern advantages of air-conditioning for productivity and workplace output. Air 'conditioning' and 'air management' came to promise the conditioning of managed bodies and oversight of their activities in schools, hospitals and especially in offices and factories (Ackermann 2010, Hitchings and Lee 2008). Windows became contested ground between managerial and subordinate subjects. Following from our discussion above, in a walking interview, Harry shows us the original air ventilation system built into the very fabric of the hospital back in the '70s. Every ward has a single unassuming square vent, positioned close to the central reception desk. But in his 20 years at the hospital, he has never known the system to be operated and nobody is sure anymore where the 'master switch' actually is. It's simply more obvious to open a window, he suggests. The continual problem of having to maintain systems disposed to obsolescence and malfunctioning is a constant topic of discussion.

All outpatient CF treatment rooms at sites 1 and 2 have openable windows, although some rooms at site 3 are windowless. Inpatient rooms at site 2 are located immediately above the main entrance to the hospital where smokers gather below making it unpleasant to open the windows. Site 2 inpatient rooms can therefore become unbearably hot during the summer. However, even the use of air conditioners is impracticable because they require the hose to trail through an open window. The respiratory life of the clinic is therefore situated in an unsettled toing and froing between the contrasting benefits and dangers of 'fresh' and 'manufactured' air, open and closed windows, windows and 'managed' or 'conditioned air'. One healthcare assistant told us how she would switch the air conditioning off because of the 'risk of it blowing infection around'. And yet, many other interviewees are reassured by opening a window allowing breezy conditions inside the building. Air's movement is, in this way, bisected with reference to underlying registers of the natural and artificial, pure and dangerous perturbations of air:

... you don't know what they've breathed out. So we normally just, yeah, open the, open all the windows, and just let it get a bit of air ... we don't use air conditioner or anything like that anymore, just for the pure risk of infection prevention. Because obviously if you've got that blowing all around, you've no idea what ... viruses or bacteria or ... Is getting blown around with it. (Elizabeth, clinical support worker, site 2)

One patient spoke at length about how the tensions between fresh and conditioned air had become a dominating force in his occupational life and experience of the healthcare environment. Terry, a male CF patient in his 40s, felt unpleasantly hot in the outpatient waiting area for the CF clinic (site 3) and would normally try to sit close to the only window available, although sometimes it's locked or somebody else is sitting there. Like many of our respondents, he is unsure whether and how the internal space of the hospital is ventilated, tending to rely instead on the more visible verification of an open window. 'I assume' Terry says, ' ...

the hospital has a hole somewhere ... there aren't that many windows ... maybe it's just a perception thing ... I've convinced myself'. He recounted having a long-running conflict with his employers over atmospheric conditions in his office blaming air-conditioning for his chest irritation and migraines. His employers took some convincing but eventually he was moved to a different building and occupational role.

I've not done very well with air conditioning ... work wise I have had to move out to a completely different town and a different office ...

'... You find it drying, don't you ...? [respondent's partner]

... [to do with] the amount of oxygen in the air ... at work it was admitted that the fresh air intake was broken ... At home we like fresh air... I was off sick because of it. But proving that it was ... pretty difficult ... I don't have it when I sit in the other offices, I don't have it at home, I don't have it at weekends, and yet I'm running into a problem here ... Far too many people in the building ... it wasn't built with opening windows, so you couldn't just say ... let's open a window.

It is to these unifying and dividing aspects of atmospheric biopolitics that Sloterdijk also turns in his spherological theory of immunitary protection. In *Terror from the Air* (2009) he reflects on breath as a problem of technical mediation, an unavoidably necessary physiological imperative tied into the processing of the air's 'condition'. To breathe is to become dependent on the inter-related technics of filtration, purification and air conditioning (Latour 2004). Breath becomes a matter of uneven 'exposure' to particulates or organisms that collapse the borders and boundaries separating external atmospheres from internal somatospheres.

Costing the air

Healthcare building design necessarily raises pressing aero-economic questions pitching patient safety and comfort against affordability. For Irigaray, once forgotten, air has instead now become 'resource', a matter of scarcity, of economic measurability, appropriation, efficiencies of productivity and tradability. Air both levels and unifies, whilst also dividing and isolating. But 'without clean air, we have nothing' (Irigaray and Marder 2014). Air is now a 'trade-off' between competing mandates. To breathe freely and safely is an increasingly desperate matter of affordability, of longing and desire.

In addition to offering an alternative to the perceived risks of air conditioning, windows are also seen to provide a sometimes-necessary alternative to often prohibitively expensive infection-control air pressure management systems. Respiratory infection control is, on occasions, a highly technical and therefore economically expensive barometric problem of positive or negative air, channelling and filtering air to protect either those within a treatment room or protecting those without from those within. Some in-patient CF isolation rooms are fitted with negative air pressure systems in which the 'weight' of air inside the room is lower than that outside. In which case, airborne pathogens are prevented from flowing outside. Openable windows and air pressure management are therefore mutually exclusive. As such, pressure is a matter of regulating the quantity of atmospheres within space, preventing the rebalancing of internal and external airs. Indeed, staff and patients are known to complain of the difficulties of simply opening a door made heavy by 'negative air' pulling and resisting the efforts of those in 'positive air' (Holmdahl and Lanbeck 2013).

In a walking interview, one estates manager at site 1 (Harry) guided us onto the roof of the hospital and pointed to an immense tangle of oversized pipework, ducting, tubes, and control boxes. From this vantage point, Harry maps out the hospital below, by the atmospheric plant machinery on the rooftop above: operating theatres, pathology labs, endoscopy, and so on. There's very little roof space left to be able to accommodate further air handling. It simply can't be retrofitted to such a compact building with no ceiling voids, no spare volume. And in any case, it's too costly. Another estates manager at site 1 (Andy) also showed us the air 'infrastructure' and how it 'takes up the whole roof ... [it's] hard to add anything ... they seem to grow in size ... the newer they are, the bigger they are'. As a rule of thumb, he explains, the dimensions of any air handling system are roughly proportionate to the space to be purified. From here it's possible to see many of 'Adam's windows' below, the white horizontal bars flecked here and there across the outer skin of the hospital.

For clinical staff in respiratory care, negative air is therefore largely an atmospheric aspiration, especially in the treatment of CF outpatients. Only the individual inpatient rooms at site 3 have negative air pressure. Emma, a specialist CF nurse at site 1, puts it:

'... ideally we would need the negative pressure rooms. It's not [ideal], all we can do ... is open the windows to get some fresh air and cleaning it ourselves ... by no way perfect. They [windows] don't open very far, but yeah, they do open. So opening a window and trying to keep the door open for that half an hour, but logistically it can be quite difficult to keep a half an hour gap' [between patients].

Another interviewee, Ivor, a hospital-based microbiologist at site 2, has found himself 'in a difficult position' having to arbitrate between clinicians and the estates department in unsettled disputes over the clinical evidence and financial constraints of expensive air handling systems. He is not convinced of the evidence for negative pressure rooms but feels that he is letting the CF team down in their campaign for negative air. Highly dangerous pathogens like resistant non-tuberculous *Mycobacteria* and *Mycobacterium abscessus* may have many multiple routes of environmental transmission beyond the temporary purified world of a controlled pressure atmosphere. The 'evidence that it [air pressure management] will make a difference', he says, 'isn't really there ... it massively adds complexity ... and cost'. Ivor spoke of feeling uncomfortable at having turned into a 'clipboard-holding manager' interested in the 'bottom line'. As so often the case in our interviews, he went on to talk about Victorian buildings, fresh air wards, balconies, windows and the 'rate of air change':

'... we don't know how far [bugs] travel and how long they exist for ... they could be around for several minutes, anything up to ... 45 minutes, maybe an hour ... a normal room like this, with a door and a window, and if I open the window you might ... get five or six air changes an hour ... you would probably get 99% decrease in any organisms that you've coughed out ... It's not robust, but a feeling from the evidence ...'

Again, in these and other ways, the increased awareness of the dependence of life on competing air technics is suggestive of Sloterdijk's 'airquakes' (2004: 89). These are moments in which atmosphere and breathability become occasions for profound upheaval, a life-threatening collision of atmospheres, in which 'to breathe' can no longer be simply assumed but must be technically accomplished instead. In an atmospheric quake, air becomes vulnerable to mechanical, electrical and budget failure. Latour sums up Sloterdijk's thoughts on the technically mediated nature of air 'conditioning' writing: '... You are on life support, it's fragile, it's technical, it's public, it's political, it could break down – it is breaking down – it's being fixed, you are not too confident of those who fix it' (Latour 2004, 3). In an airquake, the

economically exorbitant complexity of immunitary atmospheric systems is given to contradiction, even autoimmunitary self-destruction. Efficiencies gained through the densification and concentration of the healthcare built environment come with unintended atmospheric costs. Airquakes are events and processes that fragment and disintegrate, unequally distributing protections and dangers, 'clean' and 'contaminated' airs. Whilst Sloterdijk tends to reflect on historically dramatic moments of life-threatening violence and subjugation, many such quakes are instead architecturally far more mundane and routine (Borch 2008). It is this unobservability that makes it possible for the hidden economic and design politics of atmospheric control to more usually go largely unquestioned.

Concluding discussion

This article highlights the profound significance and implications of an aerographic perspective in understanding the management of respiratory infections, but also the role of the built environment in the far broader context of the global AMR crisis. Taking our cue from Irigaray, we challenge the privileging of the tangible over that of the atmospheric. Our analysis also challenges the framing of AMR as a problem of human 'behaviour' (prescribing, medicinal compliance), showing instead how the materialities of competing 'air regimes' come into conflict with each other, thus shaping the biotic life of the contemporary healthcare environments in which most of us receive care and treatment. This is empirically evidenced through our engagement with the everyday interactions through which buildings are lived, resisted and reshaped in CF care. We have also been particularly keen to locate these tensions historically in a built landscape in which human bodies, infections and antibiotics have co-evolved with one another.

Our discussion here joins that of others in using the AMR crisis as an opportunity with which to critically reflect on the nature of contemporary healthcare buildings, and their historical relationship to the availability of antibiotics. As Dancer (2013) puts it, 'infection control in the post-antibiotic era' increasingly calls into question the antagonistic relationship to the microbial seen to be responsible for a 'proliferation' of resistance. Hospitals and the domestic environment are now being re-imagined as bodies having their own microbiome (see Adams *et al.* 2016, Smith *et al.* 2013). 'The idea', writes Sample (2012), 'mirrors that seen in the gut, where antibiotics can kill off the balanced and healthy community of bacteria, only to make way for hardier bugs that cause illness'. AMR has given rise to a new biopolitical opening with which to 'rethink' the implications of the sterility that has dominated the design of hospital environments throughout much of the twentieth century. Just as antibiotics have been seen to 'disrupt' gut ecology, they are also seen to cut 'a swath through the hordes of non-pathogenic microorganisms' within the built environment (Arnold 2014: 184).

As we suggest above, air is even becoming enfolded in a material discourse of atmospheric 'rewilding' not dissimilar to that happening in other contexts of 'going probiotic' (Lorimer 2019), dovetailing with mounting concerns around the bio-depletion of both the body and the built environment, reflected in attempts to mitigate resistance through restorative bio-diversifying interventions. The rigid spherological boundaries of the built environment are in this way being called into question. Such interventions are now of interest to healthcare design whereby '... altering humidity and ventilation systems, could help reduce the number of pathogens in the indoor environment. Architects are looking at such tweaks in the context not just of hospitals but also other public areas' (Arnold 2014: 186). There is increasing speculation on a future where 'we may well see architects, doctors, and building managers working together to ensure that we live and work in environments that take account of our microbial companions' (Swain

2013: 35). It remains to be seen whether the 'AMR debate' – and now the Covid-19 pandemic – will open the window of healthcare design to fresh perspectives on past, present and future hospital atmospheres.

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