Circulating blood:
Vital materialities and crisis mobilities

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I settled back in the cushy grey chair with my left sleeve pulled up.
The phlebotomist, needle in hand, asks, "Ready?"
Looking away I squeeze my eyes shut. "Ready."

Introduction

How do we move things when it really matters? This paper addresses a critical gap in knowledge about blood supply chains and their susceptibility to infrastructural breakdown. By undertaking an ethnography of one Canadian blood donation, this paper enables deeper understanding of the circulations and blockages inherent in health care delivery with the goal of enhancing proactive planning capacity. Blood is an exemplar of how challenges to other medical supply chains might be addressed.

Contemporary society relies upon the circulation of people, goods, information and services.[1] What happens when such circulations are disrupted? Sources of potential disruption are numerous, including worker action, technical failure and terrorist acts.[2] Here I focus on extreme weather events of the type projected to increase in frequency and intensity under climate change.[3] I am interested in goods for which transport is imperative, that is, with implications for one's life chances. Such a list might include, but is not limited to, blood, water, food, pharmaceuticals, shelter and fuel. Dematerialization is not, at this point an option, for these goods.[4] [5] Further, I focus scholarly attention on the movement of a vital material that is critical in crisis -- blood -- as a means to highlight the circulations (*sanguinities*) and blockages (*coagulations*) inherent in achieving mobility in the Anthropocene. This article bridges mobilities, materialism and infrastructure studies with logistics, disaster management and critical care, offering new understandings of the materials and movements upon which we rely.

Vulnerability is intrinsic to the complex global social-technical assemblages that constitute mobility.[6] I explore this vulnerability in the context of blood as a vital material that requires external transport infrastructure in order to enable internal bodily circulation. Two contemporary trends – the rise of climate change and the societal pervasiveness of mobility – are intertwined. The more society relies upon on fossil-fueled transport, the more it is vulnerable to disruptions in transport due to severe weather events. Further, issues arise with reliance upon static road infrastructure and wheeled transport modes that define automobility. For example, there were harrowing scenes during the 2015 Alberta, Canada wildfires as residents evacuated via one smoke- and heat- choked road.[7]

Road systems and electricity grids are ageing and subject to failure, as well as struggling to cope with new pressures. Climate change, for example, exacerbates these challenges posing "direct risks to people's health and systemic threats to hospitals and health services."[8] Newer communication infrastructures are also vulnerable to disruption. The 2017 ransomware attack, for example, impacted the United Kingdom's National Health Service, resulting in inaccessible patient records, diverted ambulances and cancelled operations.[9]

There is a pressing need to understand the impacts of major disruptions on health care and emergency service. Especially significant are impacts on essential medical travel and the acquisition of emergency medical supplies, including blood, during extreme weather events is also an issue. To complicate matters, blood supply chains are continuously shifting. Dynamics include an ongoing push to centralize Canadian Blood Services;[10] international travel resulting in increased exposure to blood borne diseases[11] and the use of drones to transport blood products and tests.[12]

My objectives are two-fold. One, to highlight the complex mobilities embedded in the movement of vital yet overlooked materials. Two, to reflect upon how such systems are vulnerable to disruption, focusing on the example of severe weather. This works privileges the material dimensions of geographies of embodiment.[13] First, I introduce the concepts of vital materialities, including hemovigilance, and crisis mobilities. Second, through nine vignettes, I convey the material and infrastructural complexity of transporting blood from vein to vein, that is, from donor to recipient focusing on one blood donation in Vancouver, British Columbia. Third, I reflect on the strengths and weaknesses of the Canadian blood system in relation to extreme weather. Fourth, I revisit the theoretical potential of vital materialities and crisis mobilities.

Vital materialities

Blood is a critical but under examined vital material. Blood is a "liquid tissue pumped through the body by the heart through thousands of kilometres of blood vessels. It delivers oxygen, minerals, hormones, nutrients and other important material to the organs, and helps clear the body of waste."[14] When describing a medical procedure, Mol observes "the colors on the screen represent the blood's velocity. … The apparatus is also capable of making this information - velocity – audible. Pshew, Pshew. … And it can be represented on a graph."[15] There is also significant external mobility that is more difficult to observe and track:

> Blood products are critical to the success of both routine healthcare delivery and emergency response efforts. Ensuring the safety and availability of blood products presents nations with considerable collection, screening, and distribution challenges that are often exacerbated by public health crises, particularly mass-casualty events involving traumatic injuries.[16]

Through the process of donation, blood can travel thousands more kilometres outside the body (see below, *Moving blood: From donor to recipient*). Blood is moved via, and constitutes, an interscalar infrastructure network. I explore the movement of blood, a vital material, to highlight the necessity of certain mobilities and the interface of this mobility with one source of disturbance, a changing climate.

Just as human bodies are metabolic, cities with "dense water, sewerage, food and waste distribution systems continually link human bodies and their metabolisms to the broader metabolic processes through which attempts are made to maintain public health."[17] Building on a tradition of following the material in science and technology studies, I attempt to trace the material and infrastructural circulations of blood from donor to recipient. This involves transversing multiple scales: bodily, street, urban, national and international.[18] I forward a pragmatic focus on the mobilities of vital materialities. I explore the complex and precarious assemblages – human, material, technological, ecological – that are mobilized in the achievement of imperative and time sensitive tasks.

The vital materiality of blood is constituted by blood itself in combination with transport, information and electricity infrastructure.[19] These infrastructures have their own materiality. For example, Sheller juxtaposes the infrastructures of mobility enabled by aluminum and, in turn, the transnational regimes of immobility resulting from the mining and energy-intensive production of aluminum.[20] Blood infrastructure is socio-material and includes institutions that (re)produce both blood donors and recipients. These dynamic infrastructures are inextricable from the production and maintenance of a national blood transfusion system.[21] Infrastructure enables the blood system and the blood system is a critical, yet overlooked, component of health and well-being.

The vital materialities of concrete and water provide useful juxtapositions. Harvey uses a materialist analysis to examine the relational dynamics of concrete in Peruvian state-building.[22] Concrete is a mundane vital material due to its ubiquitous role in infrastructure construction.[23] Harvey reveals how the promise of concrete as a "generic, homogeneous, and above all predictable material is constantly challenged by the instability and heterogeneity of the terrains to which it is applied."[24] Therefore, the image of concrete as a powerful bulwark of progress is contingent upon context.

Usher's analysis of the circulation of water in Singapore also offers insights. Leveraging Foucault's interest in the "naturalization of the urban," that is, circulations of people, resources and waste, Usher traces a shift from the disciplining of water through canalization projects to a focus on water security. That is, working with, rather than fighting against, ecological dynamics.[25] Discipline is characterized by efforts to "concentrate, contain and control" nature, while security "adapts to the reality of natural processes, respects their autonomy and seeks to identify, optimize and work through nature's discernable laws rather than stifle them."[26] Such observations are echoed more broadly in the literature, including Freudenberg et al.'s analysis of how canal development exacerbated the impact of Hurricane Katrina[27] and Vink et al.'s examination of the Room for The River project, an initiative to accommodate rather than suppress flooding in the Netherlands.[28]

If the power of concrete is mutable and the power of water is irrepressible, where does blood fit in? Blood unlike concrete continuously circulates, and far more than water, these circulations require a complex and disciplined transfusion network. Blood is human-produced, requires specific storage conditions and is perishable. It is a high maintenance vital material that is in demand in everyday and crisis contexts (though in exceptional circumstances supply can exceed demand, as experienced following the 2017 Manchester Arena bombing).[29]

Within the body, blood circulates autonomously. Outside the body, it is conducted at every stage. Though, even this framing is too definite. For some internal circulations are hindered, as evidenced by Mol's ethnography of atherosclerosis, a medical condition that obstructs arteries. And external materials can circulate autonomously.[30] Yusoff describes how bacteria and fungi were used as "living pigments" in prehistoric Australian rock art and continue to "colonize the paint pigments and refresh themselves over millennia to generate a living artwork."[31] In an era of post-human automation, circulating blood involves human guidance to a notable degree. For example, between the point of donation and point of receipt the blood type is checked and re-checked numerous times.

Using a materialist lens, I foreground blood in the study of its external, societal circulation. This echoes a materialist emphasis on the tools and infrastructures that both enable and shape human activity. De Laet and Mol use the example of a Zimbabwean water pump to illustrate how the 'fluidity' or flexibility of its design renders it a particularly 'appropriate' technology.[32] Focusing on water infrastructure in Mexico, Meehan advocates for moving beyond the perspective that tools are "handy implements used by humans to exercise dominion," toward the idea that the tools exert power.[33] In contrast to state infrastructure projects, Meehan illustrates how common household water tools -- barrels, cisterns, buckets -- intersect with state infrastructures. Such a "hydrosocial cycle"[34] raises the possibility for describing a '*hemo*social supply chain.'

Hemovigilance

Blood transfusion was pioneered in the context of armed conflict. A Canadian surgeon, Dr. Norman Bethune, made advances during the Spanish Civil War . Bethune made two major innovations. The first was the organization of blood banks, that is, an infrastructure for donating, transporting and transfusing blood: "each donor gave 500ml. .… The blood was put in a bottle labelled with the name of the donor and the date of the extraction, after which the bottle would be placed in a refrigerator at 1°C. … five cars transported the blood to transfusion sites."[35] The second innovation was "taking the blood to the wounded and not the wounded to the blood," yielding more successful patient outcomes.[36] Bethune's innovations were not without side effects, including the transmission of disease. During WWII hepatitis rates of blood donor recipients were high due to a lack of screening.[37]

The AIDS crisis brought risks of blood borne disease and, by extension, the risk associated with blood transfusion, to the fore. In a paper that aims to shed light on the complex inner life of individuals in relation to infrastructure, Irving recounts the daunting walk of one man -- Alberto Valsaco -- to a New York clinic in the 1980s to learn his HIV test results.[38] Irving explains:

> An HIV test in quite simple. Blood is drawn and tested for antibodies indicating the presence of HIV, and although nowadays results can take just 15 minutes, until recently it could take 14 days for results to be ready. … the time between the *test* and getting the *results* was often a period of radical uncertainty whereby a person dwelt in the world as someone who may or may not have a terminal

> illness and often found themselves imagining two possible futures, one of life and one of death.[39]

Valsaco recalls leaving the clinic and "All of a sudden … I was a person with AIDS."[40] The paper offers insights into the differential lived experience produced by, and experienced in, urban and health infrastructures.

In Canada, the Tainted Blood Scandal refers to the transfusion of HIV- and hepatitis-infected blood within the Canadian health care system. Approximately 32,000 Canadians were infected.[41] The Royal Commission of Inquiry on the Blood System in Canada, known as the Krever Inquiry, was convened in 1993 and found that cost considerations, (i.e. cutting corners), resulted in systemic failings. In 1997 the Commission recommended a total overhaul of the blood collection and transfusion infrastructure.[42] The creation of the Canadian Blood Services (CBS) was the result:

> Canadian Blood Services is a national, not-for-profit charitable organization that manages the blood supply in all provinces and territories outside of Québec.[43] We operate 41 permanent collection sites and more than 19,000 donor clinics annually to collect over 900,000 whole blood donations and deliver products to more than 700 hospital customers.[44]

The CBS is guided by a hemovigilance paradigm.

Hemovigilance is a form of biosecurity or biosurveillance, and refers to a high-level of accountability for the quality and care of blood components.[45] Biosecurity entails a "sensitivity to the cultural, biological and technological ways that infections move."[46] The goal is to "sort 'good' from 'bad' circulations, often framing a pure interior as under threat by a contaminated exterior."[47] One expression of this is the severe stance CBS takes towards donations from gay men: donations from men who have had sex with other men within the past year are prohibited.[48]

Barker advocates for a more complex relationship to biosecurity, recognizing the "empirical connections between circulating bodies, microbes, knowledges, electronic signals, seeds, capital, food and anxiety."[49] Likewise, Hinchliffe and Lavau offer a liminal reading.[50] Focusing on the case of the UK's wild bird survey as a means to secure against avian influenza, they argue against tighter integration (i.e. regulation) of human and animal life in favour of looser, more diverse relationships as a means to achieving security. In this paper, I focus on hemovigilance through the lens of infrastructure and supply chain disruption and resilience following severe weather events. Might attentiveness to blood supply chain security prevent profound disruption on par with the Tainted Blood Scandal?[51]

Crisis mobilities

I offer the term 'crisis mobilities' to refer to the movements, practices and experiences activated and hindered by emergencies and disasters ranging in scale from individual medical emergencies to mass casualty events. How do we get blood, and other vital materials, to people in need? What do we do when the infrastructure upon which we usually rely is missing in action? I forward two dimensions of crisis mobilities: extreme events and supply chains.

Extreme events

Potential causes of infrastructure disruption are numerous: "technical malfunctions, interruptions in supplies of resource, wars, terrorist attacks, public health crises, labor strikes, sabotage, network theft, extreme weather, and other events usually assumed to be "natural" (floods, earthquakes, tsunamis, etc.)."[52] Adey examines the relationship between mobilities, emergencies and governance, identifying a number of themes useful in conceptualizing their relationship, including anticipation, coordination and differences.[53] Scarry reflects on the political use of crises to forego reflective, democratic responses to emergencies, particularly the use of torture (as in the aftermath of 9/11). She espouses an emergency politics based on the spirit of mutual aid, ranging from the embodied performance of CPR to constitutional reformation illustrating that reflection and rapid response are not mutually exclusive.[54]

In their agenda-setting editorial, Hannam, Sheller and Urry reference global warming, hurricanes and oil wars as potential research trajectories.[55] However, while events such as Hurricane Katrina are research lightening rods, overall the link between mobility, disaster and climate change is undertheorized. Schwanen et al. call for greater engagement of the social sciences with the mobilities literature, including the non-linear and catastrophic dimensions of climate change.[56] Adey addresses the role on the inhuman, -- "irregular interruptions of the earth, weather patterns, fire, cyclones and tsunamis, an exorbitant nature" – acknowledging that in some cases "emergency mobilities may exceed attempts at governing them."[57] Rather than an exorbitant nature, I explore a nature exacerbated by Anthropogenic climate change.

Writing at the juncture of oil, climate change and mobility, Urry develops hypothetical future scenarios. These include transitioning to a low-carbon-society, virtual societies mediated by digital technology, reliance on technological solutions (e.g. 3-D printing, Skype, space travel) and regional warlordism resulting from resource conflicts.[58] What might be the implications of carbon constraint (e.g. fuel and/or mobility rationing) and resource scarcity on the circulation of blood, which is a surprisingly geographically expansive and, by extension, carbon intensive process? Will unevenness of network capital in terms of blood circulation be more apparent in future, with potential dystopic prescience from organ trafficking? Might technological innovations like artificial blood create greater flexibility? While this paper focuses on the logistics of contemporary blood supply chains, such transformative questions related to crisis mobilities are close to the surface.

The 2010 Icelandic volcano eruption is one example of crisis mobilities. A special issue of *Mobilities* journal was dedicated to exploring the its impacts. The eruption forced the closure of European airspace, resulting in “the cancellation of 108,000 flights, disrupted travel plans of 10.5 million passengers, and cost to the airline industry in excess of $1.7 billion in lost revenue.”[59] The article titles tellingly include reference chaos, disruption, uncertainty and stillness.[60] In the case of Iceland, the extensive socio-technical assemblages that permit global travel were vulnerable to environmental risk and slow to adapt and recover.

Moving from ash clouds to earthquakes, Sheller examines how humanitarian response to the 2010 Haitian earthquake exacerbated uneven mobility access.[61] “Natural disasters,” she writes, “bring to the fore the astounding interdependence and fragility of the complex mobility systems and infrastructural moorings that make up contemporary transnational geographies.”[62] Sheller finds that issues of mobility justice, already problematic in Haiti, were exacerbated with a militarized American aid response. The result was an islanding effect whereby both physical and political barriers further isolated citizens.

Supply chains

The military was an incubator for innovations in both blood transfusion and supply chain logistics. Cowen sheds light on the “radically undervalorized role of movement and circulation in everyday life,” examining how military practices influence corporate practices.[63] Trends towards lean supply chains and just-in-time delivery mean that disruptions often translates into shortages. This dynamic is in tension with “efforts to protect supply chains[, investing] logistical systems with biological imperatives to flow and prescribe “resilience” as a means of sustaining not only human life but the system itself.”[64] Supply chain circulation takes on the import of blood circulation, symbolic of economic vitality (for a contrasting example, see Reiffenstein and Selig on mortuary supply chains).[65]

Methods

Drawing together social science, medicine and logistics, I create an interdisciplinary, multi-sited ethnography of blood from ‘vein to vein,’ following circulations of blood from the point of donation to the point of care to describe this vital. multi-sited supply chain.[66] Informed by interviews, site observation and document analysis I create nine linked narrative vignettes that ‘follows the material,’ tracing the vital materialities of one blood donation.

How does one follow blood given that it is a health care good subject to quarantine and donor/patient privacy, as well as a complex, multi-faceted product that is transported via multiple modes and surprising distances? Redman examines the supply chain behind the quintessentially frivolous material of Mardi Gras beads, exchanged for sexual favours during the annual New Orleans festival.[67] The harsh working conditions in the Chinese factories where the beads are produced and the overwhelming waste that results from the brief exchange of beads, taints the bodily pleasures associated with Mardi Gras. Mol’s ethnography of atherosclerosis also centres on the body. She develops two parallel narratives, one describing her fieldwork on the multiplicity of medical practice and a sub-text engaging with the literature.[68]

I also drew on fiction to inform my approach. *Anatomy of a Soldier* tells the story of a British captain injured in Afghanistan.[69] Parker adds a twist: forty-five objects narrate the story, including a bag of blood:

> I was empty; my plastic walls had collapsed together and red showed only around my seals. The rest of the blood I'd carried since a young man donated it after a lecture, joking with a mate in the queue, was now in you.[70]

It is this overlooked journey from donor to recipient that anchors this paper. Though potentially dozens of humans facilitate this journey, I place the materiality of blood in centre stage.

I focus on the case of blood circulation in Vancouver, British Columbia. Located on Canada's West Coast, Greater Vancouver has a population of 2.5 million. Issues of disaster preparedness, whether due to climate change or an earthquake, are of increasing concern. A report issued by British Columbia's Auditor General states that the province is at "significant risk" should a catastrophic earthquake occur. This report lends energy to ongoing and new disaster preparedness efforts.[71] One such initiative is the Maritime Transport Disruption research project, which examines the resilience of health care supply chains in the face of disruptive emergencies.[72] The study focuses on coastal British Columbia where many communities are served by ferries and float planes.[73] Yet, blood was excluded from this study to date in part due to its complexity. Therefore, this paper contributes to understanding blood supply chain resiliency in Canada and other countries with national blood transfusion systems.

From vein to vein

Caveats

The process of donating, collecting and transfusing blood is technically, socially and politically complex, but beyond the scope of this article.[74] Rather, I focus on the materialities, mobilities and infrastructures activated between the point of donation and the point of care, that is receipt by a patient. This account is fictionalized for narrative purposes, but provides an accurate sketch of the mobilities of blood as a vital material in one Canadian city, Vancouver. The infrastructures enacted in any given donation will vary widely depending on geographic location, local conditions (e.g. weather, hazards), accessibility and availability of donors and patients, testing and treatment facilities, and available transport infrastructures.[75] Further, different blood types vary widely in terms of their mobility. The universal donor, O negative is in high demand and widely circulated, while other blood types are in lower demand.

Vignette 1: Donating

"All done," says the phlebotomist as she pulls the needle from my arm. It is a rainy March afternoon in Vancouver. I heave a sigh of relief and cautiously open one eye and then the other. I feel my whole body relax into the oversized chair. As I firmly hold two fingers on a cotton ball lodged in the crook of my arm, I watch the phlebotomist efficiently and discretely collect four test tubes and a translucent bag of penetratingly red blood. All told a little less than half a litre of blood is collected, with four and half litres left circulating in my veins.[76] The test tubes and bag are fastidiously labeled and I feel a puff of pride as I read my blood type: *O neg*. A universal donor, I have the one blood type that can be transfused to anyone else regardless of their blood type. A band-aid is placed over the cotton and I am directed to a quiet common area where I contentedly munch on cookies and sip apple juice. I plan the rest of my day and after resting for a few minutes, head out the door.

Vignette 2: Processing
The test tubes are placed in one box, the bag in another. About 80 people will donate at this mobile clinic today, with approximately 400 donations collected on average per day in Vancouver. There is 30-minute limit between when blood is donated and when it must be cooled in order to "maintain cell viability and limit bacterial growth."[77] At the end of the day, the cooled test tubes and bags are transported 20 minutes by van to the regional CBS office on Oak Street and unloaded at a humble docking bay. The bags are stored in a spacious walk-in refrigerator. The test tubes are taken to a lab where they are processed by a technician wearing a white lab coat. Three of my test tubes are packaged for transport to a centralized screening facility and the fourth is kept on site. My test tube samples along with those of the other donors from all over British Columbia and the Yukon (an area of 1.4 million km²) – 1,200 test tubes in total – are couriered by van to the Vancouver International Airport in the middle of the night. At 4am they are loaded onto an Air Canada flight and travel approximately 700 kilometres east to Calgary, Alberta, one of two centralized blood-testing facilities in Canada. The other is in Toronto, 3,400 kilometres from Vancouver. Testing confirms blood group and identifies antibodies and infectious diseases.[78]

Vignette 3: Manufacturing
Meanwhile, at the regional Vancouver CBS facility, the bag containing my blood is placed in a centrifuge that looks like a large washing machine. In 20 minutes my blood is separated into four main components. Each component serves different functions, and once outside the cozy confines of my body, each prefers different temperatures and each has differing expiration dates. Each bag of blood components has a bar code and is tracked via computer system. The donations are held on site, in quarantine, until the test results from Calgary are available.[79] Within 48 hours the Vancouver facility receives a report on the screening status of all the test tubes. With a green light, the blood components can be distributed to hospitals. My red blood cells are couriered by van to Vancouver General Hospital as part of a standing order (two kilometres north), my plasma is flown to Prince George (750 kilometres north) and my platelets remain in the blood bank for a couple of days until they are ferried to Victoria (110 kilometres west). At any given time, CBS has a five-day supply in their blood bank.

Vignette 4: Blood 101
Straw-coloured plasma accounts for the bulk of blood volume (55 per cent). All plasma is frozen and stays frozen throughout the supply chain. Once thawed it must be used within five days. Plasma replaces proteins and is used in patients undergoing extensive surgery

or suffering traumatic injuries. Red blood cells account for 40 to 45 per cent of volume and have a shelf life of 42 days when stored in cool conditions (1-6°C). Like plasma, red blood cells are used during surgery and in emergencies, as well as for cancer patients. Platelets account for less than one per cent of volume and have a shelf life of five days when stored at room temperature (20-24°C) and kept moving (*agitated*). Platelets are given to patients with bleeding disorders and undergoing cancer treatment. White blood account for less than one per cent of volume and are extracted as waste (*leukoreduction*), as these cells might be immuno-suppressive.[80] Some blood products are irradiated, washed or deglycerolized as determined by patient needs.[81] Once manufactured, a portion of donated plasma may be sent to the United States or Europe for further manufacturing into more specific blood products (*fractionation*). The blood products are then returned to Canada, adding thousands of kilometres to the supply chain journey.

I am all over the place.

Vignette 6: Road trip

There is snow and speed and the Red Hot Chilli Peppers. She is smiling, leaning forward in anticipation of her ski trip as she zips up the scenic Sea-to-Sky Highway to Whistler-Blackcomb Mountain. The front left tire hits black ice. Sliding turns to spinning. The car comes to a crashing halt at the base of highway signpost. The front end of the vehicle crumples. The rhythmic swish of windshield wipers is the only sound.

Vignette 7: Inventory

At the Transfusion Medicine Laboratory at Vancouver General Hospital, a registered nurse reviews the hospital inventory. He fills out a CBS order form, identifying the type, number and urgency of blood products needed. He loses count when the phone rings. Another car crash. He takes two bags of *O neg* red blood cells (one of them mine) out of the fridge. O negative, the universal donor, is used in emergencies when there is no time to determine a patient's blood type.[82] He packs the bags in a small beige travel cooler and they are transported via ground ambulance to the Vancouver International Airport airbase. Though the CBS blood bank is closer to the airbase than the hospital, CBS is only permitted to supply blood to hospitals. Therefore, the hospital must transport blood to the air base.

Vignette 8: Elevation

The air ambulance crew is assembling, two pilots and two paramedics (so there is always back-up), ready for deployment. As the site of the car crash is less than 100 kilometres away and on a highway with limited landing space, they take a helicopter rather than a fixed wing plane. While the pilots calculate the necessary fuel (gauging distance, weight, etc.), the paramedics await the arrival of blood by truck from the Vancouver General Hospital 12 minutes away. The blood arrives and is loaded and the crew of four lifts off.

Vignette 9: Extraction

The helicopter hovers near the scene but the police have not yet secured a staging area. The helicopter circles as the police halt traffic in both directions. When it lands, the sound is deafening. The fire crews are in the process of extricating the driver using the jaws-of-life. When finally pulled free, an hour after the crash, she is in hemorrhagic shock caused by extensive blood loss. Once in the air ambulance, the paramedic starts a line of *O neg* red blood cells as the helicopter takes flight.

Sanguinities and coagulations

Blood travels thousands of kilometres within the human body. Upon entering the blood donation system it may travel thousands kilometres more as it is screened, manufactured and transported. Blood has a societal sanguinity. A single blood donation is manufactured into at least three different components that are distributed to three different locations and are eventually transfused into three different patients. Upon a closer look the blood system relies upon and constitutes a "vast and unimaginably complex" material infrastructure circuit.[83] The local act of donating blood activates geographically expansive nodes. The relationship between not only bodies, but life, and infrastructures is enmeshed.[84] The intricacy is impressive and, as is often the case with functioning infrastructure systems, overlooked and taken-for-granted unless there is disruption (coagulation).

There are numerous potential metrics of complexity entailed in the mobility of vital materials, including the number of workers that handle one donation, number of transport modes used, number of kilometres travelled, number of borders crossed and the rate of wasted product (e.g. expired or spoiled product) (Figure 1). There is also expense. According to one practitioner, the estimated cost of one bag of red blood cells from donor to recipient, including donor time, transport, manufacturing, distribution, nursing and administration, is CDN$1,000 (GBP £600). Further, one transfusion is equated with the expectation (and cost) of two extra days in hospital. Given such complexity, the risks for disruption, or, coagulation of sanguinous flows, are numerous. Perrow observes that tightly coupled systems such as transport networks and blood donation networks "predictably fail … in unpredictable ways."[85] Cascading infrastructure failures can result.[86] Mobility infrastructures disruptions highlight how immobility is implicit in mobility.[87] Vulnerability results from reliance on any one system, though the scale varies depending on a range of technical and social factors.[88] There is an entangled relationship between mobilities and moorings.[89]

Figure 1. Simplified representation of transport modes activated by movement of blood from donor to recipient (fictionalized scenario)

donor :

van > courier > commercial airliner > van > van > surface ambulance > air ambulance

: recipient

There are two main supply chain considerations. First, ensuring there is enough donated blood in the system. Second, ensuring that the blood, once in the system, reaches patients. Severe weather, of the type projected under climate change, is a consideration in both processes. Further, it sheds light on the dynamics at play for other potential sources of infrastructure disruption (e.g. ransomware) and for other vital materials (e.g. pharmaceuticals).

Ensuring donation

A central component of resilience within CBS is the National Blood Inventory whereby shortages in one part of the province and/or country can be compensated for by supplies in other parts of the country. Within British Columbia there is a robust redistribution network that maximizes use of donated blood products with less than a one per cent wastage rate. There are six health care regions, each of which has at least one hub that (re)distributes blood to other regions. If stores of red blood cells are still on the shelf within 14 days of their expiry date, they are redistributed to a higher demand facility such as Vancouver General Hospital. Diverse transport modes, organized by CBS as well as hospitals, are continuously circulating standing orders, special orders and emergency deliveries between sites to optimize the distribution. One practitioner observes: "it is a living process."

Recent experiences with Zika and Ebola have spurred calls for international blood product sharing agreements.[90] Zika, in particular, is spread by mosquitoes, which thrive in a warming climate.[91] At the same time, increased travel hinders blood collection. It is common for Canadians to escape cold winters by travelling to warmer destinations. Potential exposure to disease, including the Zika virus, results in a window of exclusion from donation (e.g. 28 days). Further, harsh Canadian winters result in traditionally lower donor turnouts. A hard 2017 winter prevented blood donations in the eastern province of Nova Scotia. As a result, blood drive efforts were increased 6,000 kilometres away in British Columbia. These two inter-related trends could contribute to a downward trend in donation levels.

The reevaluation of optimal blood product storage times may bolster the National Blood Inventory. Health Canada is in the process of approving the storage of platelets from five to seven days.[92] Likewise, research into red blood cell viability has found that older blood, stored for up to 42 days, yields therapeutic benefits on par with fresher blood.[93] However, in counterbalance these measures, in 2016 CBS extended the permitted period between donations due to concerns of iron depletion in donors (contrasting with practices of pharmaceutical companies developing blood products[94]).[95] In the face of numerous changing dynamics from increased international travel to innovations in blood product best practices, the overall goal is to optimize the availability of blood as a vital material, as too few blood products impacts patient care and too many results in wasted blood donations.

Ensuring receipt

In terms of the mobility of blood once in the CBS system, there are multiple options. In British Columbia, blood products are transported by commercial airliner, floatplane, air ambulance, surface ambulance, ferry, barge, courier, truck and/or van. Critically, the CBS fleet is limited to surface transport (e.g. vans, trucks). It relies on commercial providers for all other modes of transport. The focus is on facilitating the continuous and seamless societal circulation of blood (and the products needed in its manufacture).[96] Improvisations, guided by power and knowledge of "baroque material regimes" are essential to navigating supply chain disruptions.[97]

Such spontaneous reconfigurations are not always possible. While delays are not uncommon, due to a plethora of factors from severe weather to construction closures, failure to deliver is rare. One such incident occurred in British Columbia in February 2017. A winter storm caused the closure of all three highways connecting the city of Kelowna (pop. 127,000) in the province's interior to Vancouver. Blood being transported by truck from Kelowna to Vancouver (390 kilometres) for manufacturing and then on to Calgary for screening, was stuck en route when snow and ice conditions led to road closures. While the blood was maintained at the correct temperature, it was unable to be manufactured within the permitted window. In total, 90 bags of blood were discarded. Hospital blood bank shelves were depleted as a result.

One practitioner recalled that this was the first such experience she had of no viable transport. However, with climate change, British Columbia is experiencing more intense precipitation events and such disruptions may be more common.[98] Further, if an event occurred, for example, on par with the Icelandic ash cloud event, it could ground the two commercial airlines that service Vancouver within Canada (i.e. Air Canada, WestJet), leading to a blood screening backlog and potentially wastage. Freeze-thaw events are also more common with climate change, and could exacerbate rock slides such as have been experienced on the Sea-to-Sky Highway.[99]

At a systemic level, due to cost considerations, CBS consolidated blood screening and manufacturing facilities. Blood screening was consolidated to two sites: Calgary and Toronto. Blood manufacturing was consolidated. For example, rather than each Maritime province (Nova Scotia, New Brunswick and Prince Edward Island) having its own production facility CBS experimented with one centralized facility in New Brunswick. Upon evaluating "700 bus shipments, 400 air shipments, and 500 courier deliveries" CBS opted for centralization.[100] It was concluded that winter weather will "always impact the blood transport network. … [but with] careful inventory, contingency, and operational planning, these impacts can be minimized."[101]

A related issue is transport of blood supplies during wide spread crises. This includes the transport of mass blood products, along with other supplies, into the Lower Mainland region in the case of a mass casualty disaster. It also includes overcoming last mile logistics, that is navigating the delivery of goods from a transport or supply hub to their final destination, which often poses costs and complexities greater than transporting good long distances.[102] Drones may offer interesting possibilities in such circumstances.[103]

Concluding Discussion

This paper describes the complex mobilities embedded in the movement of vital (and yet often taken for granted) materials and highlights how such systems are vulnerable to disruption. The transport infrastructure upon which CBS relies, and the blood system itself, as a networked infrastructure, is as complex, expansive and integrated as other critical infrastructures, such as electricity grids. Based on the potential for severe weather events to disrupt flows of blood into CBS via donations, and flows of blood from donors to recipients once in the system, there is a need to expand hemovigilance to supply chain security. Describing a *hemo*social supply chain through the use of narrative vignettes, including areas of flow (sanguinitiy) and blockage (coagulation), contributes to proactive planning capacity.

Graham observes that the “degree to which infrastructures are resilient to all manner of disruption is both socially constructed and politically contested.”[104] This raises important questions of distributional justice and the politicized nature of infrastructure networks.[105] Who is served by critical infrastructures and, by extension, blood systems? Who is in need of greater access? And how does this map onto the blood product infrastructure? How do these play out in a vast country with a socialized health system? How does infrastructure disruption, whether due to severe events, as explored here, or from other sources intersect with a lean supply chain and just-in-time delivery paradigm?

In short, how do we move things when it really matters? The concepts of vital materialities and crisis mobilities are valuable in exploring this question bridging both scalar and temporal dynamics. The receipt of vital materials, such as blood, can directly impact one’s life chances. Mol details the obstructed circulation of blood within the bodies of patients with atherosclerosis and the resultant care. At a larger scale, Graham observes urban infrastructure metabolisms (e.g. water, waste) and links with public health. Blood as a vital material circulates at both scales, from internal bodily circulations to geographically diffuse journeys: *I am all over the place*. It has a unique specificity, differentiating it from other ubiquitous materials such as Harvey’s mutable concrete and Usher’s irrepressible water. Blood circulates continuously, and far more than water, these circulations require a disciplined transfusion network. As a hemosocial supply chain it has power and force that brings to mind de Laet and Mol’s Zimbabwean bush pump, both shaping and enabling human activity.

Integral to vital materiality is its mobility. Blood needs to be transported to a person or community in need. Crisis mobilities refer to the movements, practices and experiences activated, but also hindered by, emergencies and disasters. Extreme events – from earthquakes to ash cloud to the 2017 British Columbian winter storm – reveal vulnerabilities inherent in complex social-technical assemblages. Severe weather events, as an expression of climate change, are a particular form of disruption anticipated to increase in frequency and intensity. Urry builds scenarios of carbon constrained futures, while Adey delineates the present interface of mobility, emergency and governance. Crisis mobilities straddles these two temporal frames, both needing to respond to ever-changing contemporary dynamics, from increases in mosquito borne illnesses to the use of drones, while also being attuned to uncertain future trends. In both cases, Cowen emphasizes that the preservation of consumer supply chains is paramount, protected and infused with “biological imperatives to flow” on par with the urgency accorded to the necessity of blood circulation within the human body, attention that needs to be turned to blood itself.

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