WHAT FACTORS ARE ASSOCIATED WITH THE USE OF TELETRAUMA IN NORTHERN BRITISH COLUMBIA?

by

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Abstract

Despite the existence of universal health care for Canadians, health inequalities persist. Those residing in rural regions of Canada may be at a disadvantage for accessing appropriate services. To enhance access, a teletrauma program was implemented in the Robson Valley, connecting rural clinicians during emergency cases. This study was undertaken to better understand the experiences of teletrauma users and why teletrauma is utilized. Data were gathered from 14 interviews with clinicians, health administrators, a researcher, and a health executive. Guided by interpretive description methodology, four major themes emerged, including: teletrauma affects the entire system of care; teletrauma enables a network of care built on interprofessional relationships; reasons clinicians use teletrauma are multifaceted and interrelated; and, interconnectedness of the healthcare system. Information from this study provides insight into the role and function of teletrauma in northern British Columbia and how it may better serve the needs of rural clinicians.

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Definitions

Client site. "The site of the client or local provider(s) receiving support from consulting clinicians" (Provincial Health Services Authority, 2014, p. 4)

Consulting site. "The site the consulting provider broadcasts from" (Provincial Health Services Authority, 2014, p. 4)

Level 1 Trauma Center. "[A] Level I Trauma Center is a comprehensive regional resource that is a tertiary care facility central to the trauma system. A Level I Trauma Center is capable of providing total care for every aspect of injury" (American Trauma Society, n.d., para. 5)

Level 2 Trauma Center. "A Level 2 Trauma Center is able to initiate definitive care for all injured patients (American Trauma Society, n.d., para. 7)

Level 3 Trauma Center. "A Level III Trauma Center has demonstrated an ability to provide prompt assessment, resuscitation, surgery, intensive care and stabilization of injured patients and emergency operations" (American Trauma Society, n.d., para. 9)

Level 4 Trauma Center. "A Level IV Trauma Center has demonstrated an ability to provide advanced trauma life support prior to transfer of patients to a higher level trauma center. It provides evaluation, stabilization, and diagnostic capabilities for injured patients" (American Trauma Society, n.d., para. 11)

Northern Health Authority. The health care organization that is responsible for delivering care to the Northern Health Authority region in British Columbia

Rural. Rural and small town areas are census subdivisions outside of a central metropolitan area (urban core population >50,000) or a census agglomeration (urban core population >10,000) (Statistics Canada, 2015)

Telehealth. “The use of telecommunications and virtual technology to deliver health care outside of traditional health-care facilities” (World Health Organization, 2019, para. 1)

Teletrauma. A telehealth service that is designed to meet the needs of those delivering and managing the care of traumatically injured patients requiring immediate clinical management

Trauma. Acute injuries requiring immediate medical management

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1.0 Background

1.1 Health care accessibility

Despite the existence of universal health care for Canadians meant to ensure access to medically necessary care, rural and remote communities have proportionately fewer health services and providers available (Pong et al., 2011). Many services have become centralized to more urban areas requiring rural patients to travel longer distances for care. Compared to urban patients, those residing in rural areas are least likely to access specialist services (Sibley and Weiner, 2011); critical care or obstetrics are especially challenging for rural patients to access (Ministry of Health, 2015). A lack of availability of health services for rural patients can result in higher all-cause mortality rates (Kulig & Williams, 2012), higher rates of avoidable deaths (Canadian Institute for Health Information, 2017c), and a three-fold increase in risk of death in the emergency department (Gomez et al., 2010). Inequitable health care access exists in northern British Columbia (BC), the region in which this research is located, and is characterized by variable human, technological, and informational resources.

Despite attempts to enhance access to health care services, including visiting specialists, the issue of care delivery and service inaccessibility for geographically isolated communities has long been a problem facing many Canadians (Romanow, 2002). Several reasons have been attributed to the challenge of rural health care delivery, including geographic dispersion and low population densities (Hanlon & Halseth, 2005), lack of local human and financial resources (Ministry of Health, 2015), and the distinct health needs of those living in rural and remote areas (Pong et al., 2011). The inequalities faced by Canadians who live in rural locations directly contradict Canada's legislated mandate to provide universal access to necessary medical care.

The *Canada Health Act* (1985) explicitly mentions 'accessibility' as one of its five main principles, requiring that health care and human resources be available regardless of region. Provincial governments receive federal funding based on the expectation that each province abides by these principles and, according to the *Canada Health Act* (1985), insurance plans must provide services that do not impede reasonable access to care. However, the term 'reasonable access' was only defined in terms of economic accessibility; that is, insured individuals could receive medically necessary hospital and physician services whether or not they had the ability to pay (Canada Health Act, 1985). This definition did not take into account the inability of many Canadians to access care due to geographic barriers. As a result, Health Canada (2000) made a distinction between economic and physical accessibility to health care services. Thus, while ambiguity surrounding the term 'reasonable access' exists to give provinces the flexibility to decide which additional services to provide as needed, it has also contributed to access inequities for rural patients, as evidenced by increasing centralization of services in more urban areas. Although legislation exists to protect and uphold the principles of universal health care for Canadians, there remains a stark contrast between what access looks like for many rural patients in comparison to their urban counterparts.

1.2 Distribution of health resources

Health care and human resources are unequally distributed throughout BC (Pong et al., 2011), creating a divide between rural and urban patients in terms of health care service accessibility. Rural patients also access care in ways that are distinct from those in urban centers, reflective of a lack of local resources (Pong et al., 2011). For those health resources that do exist in rural settings, services are often organized and delivered differently as

compared to urban regions (Pong et al., 2011). More specifically, there is marked differential access to human health resources for rural versus urban patients (Sibley and Weiner, 2011). For instance, only 2% of the specialists in BC worked in rural areas in 2017 (Canadian Institute for Health Information, 2017b) despite 7.4% of BC's population living in rural regions (Statistics Canada, 2017). Even when services are available in rural BC, traditional in-person consultations are typically inaccessible (Copley, Kitson, & Pawlovich, 2017). This gap in human resource coverage may result in rural patients having to travel long distances to receive care, putting them at an increased risk for adverse outcomes.

Fragility of health delivery systems also exists for rural communities due to chronic human health resource shortages, including small numbers of physicians and ageing physicians with imminent retirements (Ministry of Health, 2015). This problem is not unique to Canada; other countries with similarly low population densities face like circumstances. Australia, for example, has long encountered recruitment and retention issues for rural areas. Reasons attributed to these difficulties have included professional isolation (Lannin & Longland, 2003) and a lack of local resources (Curran, Fleet, & Kirby, 2006) leading to health inequities similar to those found in Canada. To attain a more balanced geographical distribution of clinicians across northern BC, the Northern Health Authority began providing financial incentives for those willing to work and live in underserved communities. While some health care providers accept these incentives and work in remote areas for a short time, this method has been demonstrated to have only limited success for long-term retention (Barer & Stoddart, 1999). A more recent study noted that recruiting and retaining of nurses in rural Canada remains a challenge despite the existence of financial incentives (Kulig, Kilpatrick, Moffitt, & Zimmer, 2015). Considering that only 8% of

physicians live in rural areas compared to 19% of Canadians (Canadian Medical Association, n.d.), inequitable distribution of human resources remains problematic for rural health care delivery. Failed recruitment and retention strategies for rural clinicians coupled with barriers to accessing appropriate care may be contributing to the existing health disparities in northern BC.

1.3 Geographic context of rural health care delivery

The total population of BC is nearly 5,000,000 individuals spread across greater than 900,000 square kilometers (Statistics Canada, 2017). The Northern Health Authority is the largest geographic health region in BC and is comprised primarily of rural and remoted communities (Figure 1). The Northern Health Authority region covers nearly two-thirds of BC's

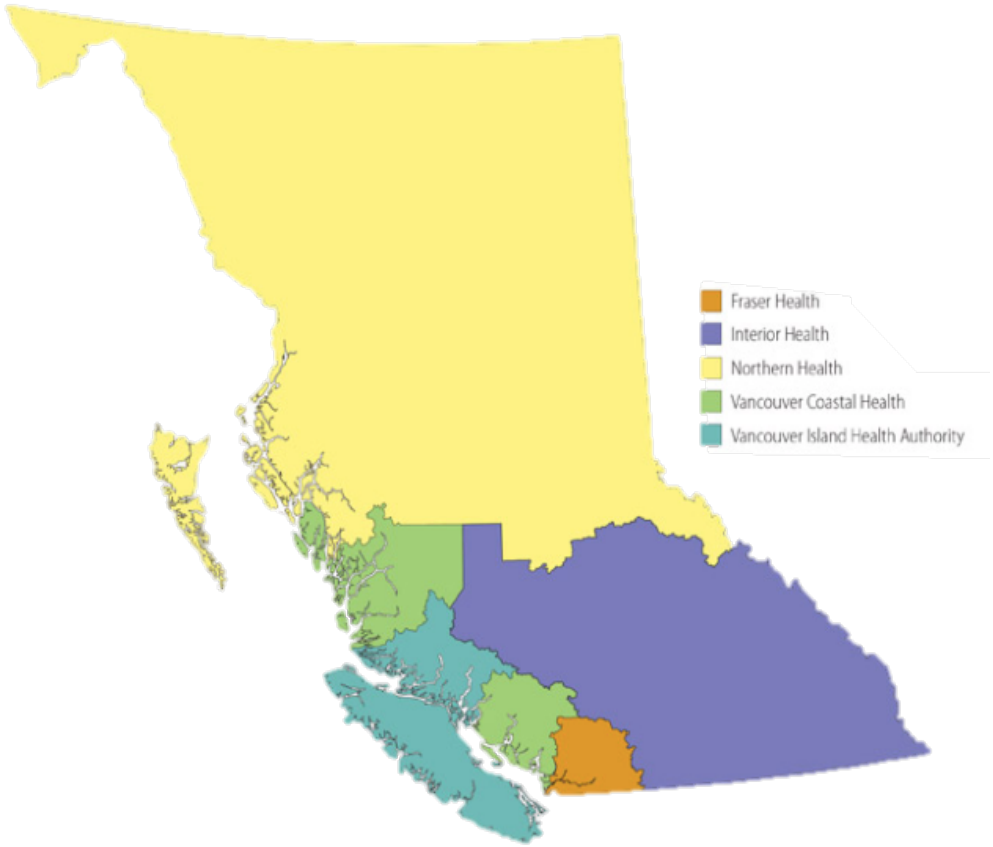

Figure 1: Geography of British Columbia by Health Authority (Government of BC, n.d.)

total landmass (BC Stats, 2012) and services approximately 280,000 residents (BC Stats, 2018). The vast geography, combined with low population densities (0.4 persons per square kilometer) (BC Stats, 2012), creates health delivery challenges unique to the region (Figure 2). These problems are further compounded by the large distances between health facilities, making travel difficult and often dangerous during inclement weather. Strategies have been adopted by the Northern Health Authority to combat issues associated with a highly geographically dispersed patient population. Aligned with the Ministry of Health's (2015) direction for health

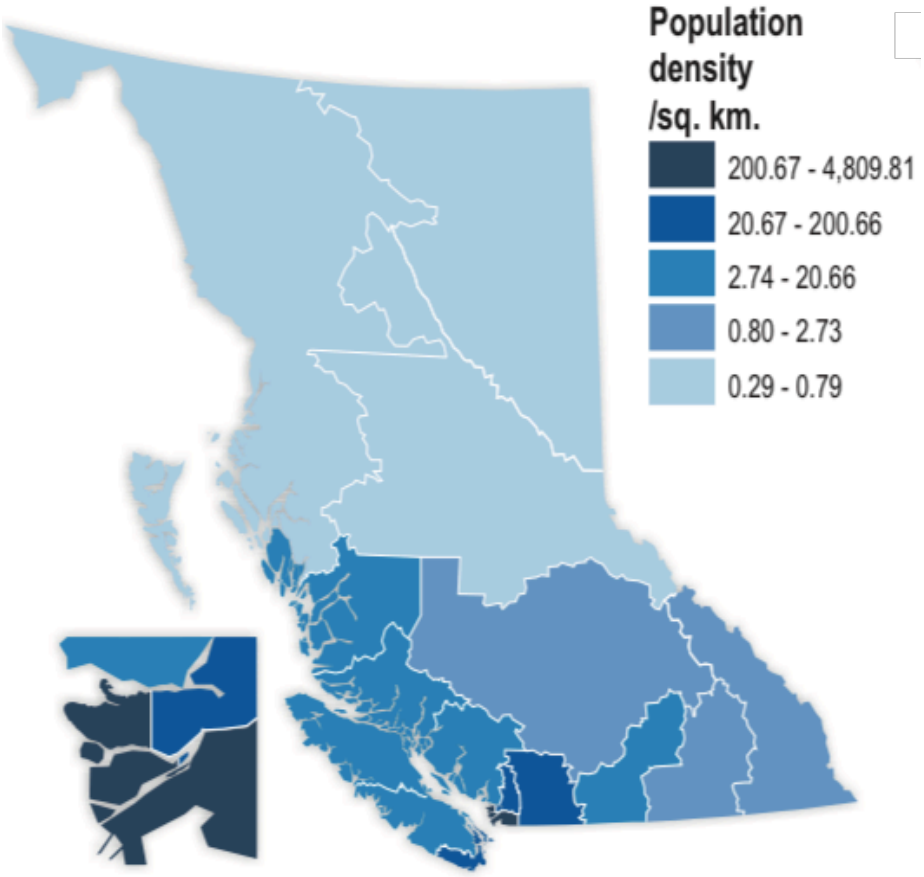

Figure 2: Geography of British Columbia by Population Density (BC Stats, 2010, as cited in Foster, Keller, McKee, & Ostry, 2011)

services, an objective of the Northern Health Authority's (2018) Service Plan for 2018/19 – 2020/21 is to optimize access and patient flow to "improve appropriateness, access and timeliness of specialty and facility-based care" (p. 19) by means of "innovative service delivery approaches… in a variety of areas across the system" (p. 20). One strategy that aligns with the Northern Health Authority's (2018) objectives is telehealth, a service modality that may be fitting for northern BC's remote geography.

1.4.0 Telehealth in rural Canada

1.4.1 Benefits and opportunities. Telehealth is a solution that may be used to overcome the distinct challenges faced by rural communities and has well-recognized positive effects including improved patient outcomes, enhanced access to care, and cost savings for both patients and providers (Desai, Williams, & Smith, 2013; Herrington, Zardins, & Hamilton, 2013; Saurman et al., 2011; Stingley & Schultz, 2014). As a modality of care, telehealth enables the provision of health management, health promotion, clinician support, education, and consultation at a distance. The World Health Organization (2019) defines telehealth as "the use of telecommunications and virtual technology to deliver health care outside of traditional health-care facilities" (para. 1). Telehealth reduces inequitable access faced by those who are geographically isolated by capitalizing on the availability of existing telecommunication infrastructure such as broadband networks (Jong, Mendez, & Jong, 2019). For rural patients, this may decrease the need to travel long distances for care thereby reducing patient costs and removing the dangers often associated with highway travel. In some cases, the implementation of telehealth was able to reduce transfer rates to trauma centers by up to 90%, leading to significant cost savings without any changes in mortality (Duchesne et al., 2008). As such, the

use of telehealth enables patients to access appropriate care from within their own communities by bringing care directly to the patient. Considering the appropriateness and benefits of telehealth for rural areas, the Ministry of Health (2015) explicitly mentions telehealth services for remote regions of BC as being a key strategy moving forward. Thus, telehealth is a recognized solution with notable positive outcomes that is suitable for northern BC's unique geography.

Health service access disparities in rural settings may also be overcome by the use of telehealth. In northern BC, it has been suggested that the high rates of telehealth utilization may be due to limited access to health services and a lack of health care providers (Terekhova, Tabassi, Gabriel, & Jafari, 2017). Because services tend to be concentrated in urban settings, rural clinicians rely on information and communication technologies to supplement the care they give. As a means of connecting clinicians, use of telehealth enables professional development and collegiality, which may in turn improve recruitment and retention in rural areas (Moffatt & Eley, 2010; Wielandt and Taylor, 2010). Although many rural providers already deliver excellent emergency care in communities with limited resources, physicians want to access timely specialist support to ensure the highest quality of care for their patients (University of British Columbia, 2018). Telehealth may be a solution that addresses the gap in care that exists for rural patients by offering virtual real-time support to clinicians and may encourage decentralization of human health resources. Use of telehealth allows patients to access appropriate care where and when they need it despite being geographical isolated. Thus, telehealth represents an opportunity to address some of the issues related to a highly distributed and fragile workforce in rural areas.

1.4.2 Telehealth for acute care and beyond. Telehealth may be particularly useful in the acute care setting. For acutely-ill patients in rural locations, specialist access and timely treatment are important to support the delivery of quality emergency care. A lack of high-level expertise in rural and remote areas has been suggested as justification for the implementation of a tele-emergency service (Al-Kadi et al., 2009; Dyer et al., 2008; Galli, Keith, McKenzie, Hall, & Henderson, 2008; Hernandez et al., 2016; Latifi et al., 2009; Mohr et al., 2018; Saffle, Edelman, Theurer, Morris, & Cochran, 2009). Despite a lack of local resources, use of telehealth to access specialist knowledge and care has had notable positive effects. For example, use of telehealth is reportedly cost-saving (Demaerschalk et al., 2013; Duchesne et al., 2008; Natafgi et al., 2018; Wibbenmeyer et al., 2016; Yang et al., 2015b), reducing costs for both the consulting and client sites. Total hospital costs for a trauma center were $7.6 million prior to telehealth implementation compared to $1.1 million after service adoption; an 85% reduction in cost (Duchesne et al., 2008). One reason cited for the substantial decrease in costs is the reduction in the number of transfers of stable trauma patients allowing hospitals to share the burden of cost for trauma cases (Duchesne et al., 2008). Similarly, a base-case cost-effectiveness analysis of medical expenditures demonstrated an annual cost savings of $46,620 per emergency department when treating 10 acutely-ill and injured children via telehealth as compared to conventional treatment (Yang et al., 2015b).

Although telehealth for acute care is intuitively understood as being physically present within the emergency department, other applications have extended these boundaries to pre-hospital care. Several studies have examined the use of telehealth for stroke evaluation prior to patient arriving at the emergency department (Barrett et al., 2017; Bergrath et al., 2012; Geisler

et al., 2019; Wu et al., 2014). Other pre-hospital applications have included continuous ambulance telemetry for coronary heart disease patients (Woollard, Pitt, Hayward, & Taylor, 2005) and a remotely-supported pre-hospital ultrasound system (Eadie et al., 2018). Telehealth has also been discussed in the context of military application in austere operational environments to aid in the management and evacuation of combat casualties (Nettesheim et al., 2018; Waterman, Laughlin, Belmont, Schoenfeld, & Pallis, 2014) and for disaster medicine (Case, Morrison, & Vuylsteke, 2012).

The potential for telehealth to enhance access to care and to improve treatment can also extend to urban locations where specialists are present but may not be able to access the patient case in a timely manner. To facilitate rapid access and enhance communication, mobile phones have been used to send and receive pictures between plastic surgeons thereby improving care (Farber, Haik Liran, Weissman, & Winkler, 2011). That is, use of telehealth enabled earlier involvement of senior staff in the care process, improved communication between clinicians, and increased the ability of clinicians to independently manage similar cases in the future (Farber et al., 2011). In rural areas, both physical separation and temporal delays to appropriate health services often exist, resulting in reduced access to proper care. Considering the wide-ranging scope of applicability and benefits of telehealth for patients and clinicians, telehealth services are fitting for rural geographies from both physical and temporal perspectives.

1.4.3 Telehealth system components. Telehealth uses a wide variety of methods to deliver remote care, including store-and-forward technology, videoconferencing, and secure messaging systems. For telehealth during emergency care, for example, there is variability in

technology used depending on the particular application of the service. This has included a low-bandwidth store-and-forward transmission of echocardiograms to the computer of a remote cardiologist (Barbier, Vecchia, Mirra, Di Marco, & Cavoretto, 2012) and mobile BlackBerry Messenger to transmit chest radiographs over a cellular network (Scheuermeyer et al., 2016). In areas containing less communication infrastructure, such as the province of Alto Amazonas in Peru, Very High Frequency (VHF) radios and email have been used for voice and data communication (Martinez, Vollarroel, Seoane, & del Pozo, 2004). In general, the clinical demands of acute care medicine and environmental factors (such as infrastructure) determine the system components that are used. Thus, telehealth system design depends on the clinical situation for which it is intended and the local resources available to service providers.

1.4.4 Telehealth uptake in Canada. Popularity of telehealth in Canada continues to grow due to the versatility and wide scope of applicability. According to a report produced by Canada's Health Informatics Association [COACH] (2015), the number of clinical telehealth sessions across Canada grew 120% between 2010 and 2014. In terms of number of patients served, this has equated to nearly half a million Canadians who used telehealth (COACH, 2015). Another study examining telehealth for primary care in BC found that usage doubled between 2013 and 2015, with the highest rates of use in Northern BC (Terekhova et al., 2017). The growing interest expressed by rural clinicians (Northern Health Authority, 2018) and increased service utilization (COACH, 2015) highlights a demand for telehealth services in Canada. As popularity and demand continue to increase, feasibility of telehealth may also increase.

1.5.0 Telehealth services in northern British Columbia

In rural BC, there is increased demand and uptake of telehealth. Specifically, the Northern Health Authority has created several telehealth services that can provide timely access to appropriate care, including Tele-Infectious Disease and TeleNephrology. In the wider BC area, other services offered include TeleMental Health, TeleThoracic, TeleStroke, and Home Health Monitoring. The breadth of telehealth programs across BC aligns with the Ministry of Health's (2015) strategies for service delivery and provides benefits for both local clinicians and patients. Although telehealth has undeniable benefits for rural and remote regions, limitations exist. For example, there is little information on telehealth programs in northern BC. Despite substantial expansion of technology-based health care delivery (COACH, 2015), there is a lack of knowledge regarding use of telehealth and characteristics of users in BC (Terekhova et al., 2017). Another drawback is the potential for differential care, including antibiotic prescribing rates and the uptake of diagnostic testing. For example, it has been noted that clinicians using telehealth are less likely to order diagnostic tests (3% versus 50%, $p<0.01$) and have poorer performance on appropriate antibiotic prescribing (16.7% versus 27.9%, $p<0.01$) compared to clinicians who do not use telehealth (Uscher-Pines et al., 2016). Notwithstanding, use of telehealth has continued to demonstrate positive outcomes and benefits for patients and providers in rural areas (Marcin, Shaikh, & Steinhorn, 2016). Considering the uptake and growth of telehealth services in BC, telehealth adoption may be expected to increase as the technology becomes normalized within the health care system.

1.5.1 Teletrauma in the Robson Valley. To support the delivery of high quality emergency care in rural BC, the Northern Health Authority implemented a virtual medicine

project for remote family physicians who would like on-demand support (University of British Columbia, 2018). An aim of the project was to facilitate rural clinicians' access to timely and useful support from other health professionals during emergency care situations (University of British Columbia, 2018). Over an 18-month period beginning in 2016, real-time virtual care consultations were conducted through videoconferencing and secure text-messaging between clinicians in the Robson Valley and emergency physicians in Prince George, approximately 200 kilometers away (Figure 3). The Robson Valley consists of two small communities, Valemount

Figure 3: Map of McBride, Valemount, and Prince George within the Northern Health Authority (Comprised of Three Health Service Delivery Areas) (Northern Health Authority, n.d.)

and McBride. After hours, McBride and Valemount hospital are staffed by only one physician and one nurse despite the communities being 90 kilometers apart. The communities are situated on a highway that is frequented by large numbers of tourists travelling between BC and the neighboring province, Alberta, particularly in the summer months (May to October). During the winter months (November to February), many winter sport enthusiasts travel to the Robson Valley for snowmobiling, skiing, and mountaineering. As a result, these small communities commonly face demands for more advanced trauma emergency services. The geographic isolation of these communities, poor cellphone coverage, and wildlife make travel along the highway dangerous. As a result, clinicians in the Robson Valley may be exposed to traumatic injury and emergency cases stemming primarily from motor vehicle accidents and winter sport activities. In particular, motor vehicle accidents often account for the disproportionately high injury rates in rural areas (Gonzalez, Cummings, Mulekar, & Rodning, 2006; Peek-Asa et al., 2004). Considering the physical location, seasonality, and exposure to tourism, the Robson Valley presented an opportunity to capitalize on the benefits of teletrauma. By engaging digital technologies to provide on-demand support during trauma and emergency management, there was the opportunity to reduce gaps in care and provide increased support for physicians within the communities.

1.6 Injury and trauma in a northern context

Traumas and injuries disproportionately affect rural areas, being commonly more frequent and having a higher mortality rate (Peek-Asa et al., 2004; Simons et al., 2010). Canadian Institute for Health Information (2017a) reports that for the most remote regions of Canada, such as the North West Territories and the Yukon, injury hospitalization rates in 2016

were more than double the national rate. Patients in rural areas also experience a larger number of deaths. It has been noted that the mortality rate for rural patients is 30% higher compared to urban patients of the same age (DesMeules et al., 2006). For rural BC, the Canadian Institute for Health Information (2017c) reports a rate of 280 avoidable deaths per 100,000 people for those residing in the Northern Health Authority region, as compared to 185 for BC and 198 for Canada. The degree of distance from an urban center also appears to influence the risk of death. That is, the highest death rates are for those patients who live in the most remote regions (Jong, 2010). Several reasons have been attributed to the large number of trauma-related deaths, including increased severity of motor vehicle accidents (Muelleman & Mueller, 1996) and longer time from injury discovery to in-hospital care (Esposito et al., 1995). Although the reasons may not be fully explicated or understood, rural patients have distinct health profiles requiring health delivery methods that are appropriate, contextually relevant, and timely.

Resources may also be inadequate in rural areas and clinicians may be less well-equipped for high acuity patients who require comprehensive services. For rural patients, greater distance from a Level 1 or Level 2 trauma center equates to longer time to definitive trauma care. Because trauma care is time sensitive, the proximity of the patient to a facility with appropriate services is a key factor determining patient outcomes. This is known as the Golden Hour concept which posits that the risk of death is reduced with prompt care (Sampalis et al., 1999). It has been identified that over 7 million Canadians remain outside a 1-hour driving distance to definitive care, and of these, all reside in rural and remote areas (Hameed, Schuurman, Razek, & Simons, 2010). For those patients who live further than one hour away

from a trauma center, the risk of dying in the emergency room was 3.5 (95% CI 2.5 - 4.9) times, or 350% greater as compared to those with immediate access (Gomez et al., 2010). The designation of the treating facility also influences outcomes for trauma patients. For example, patients receiving care at a Level 1 trauma facility have a 25% reduction in mortality as compared to patients managed at a non-trauma center (MacKenzie et al., 2006). Similarly, the risk of dying in a tertiary trauma center was 75% lower than in primary centers (Sampalis et al., 1999). Because there are often barriers to accessing definitive care in rural regions, including lower-designated facilities and physical isolation, trauma patients may not be receiving appropriate or timely care. Specifically, prolonged time to coordinated care as a result of geographic separation and resource availability may therefore contribute to the higher mortality rates observed in rural populations (Gomez et al., 2010).

For northern BC, a lack of local resources (Ministry of Health, 2015) and substantial geographical distance to high-level trauma care (Hameed et al., 2010) are known barriers to accessing definitive care. In regards to these issues, the Ministry of Health (2015) has identified access to trauma services as being a critical consideration for rural communities in BC. However, BC has been commended for its successful adaptations to enhance access, despite geographic isolation and climate, by encouraging local hospitals to become involved early on in the trauma care process (Hameed et al., 2010). By supporting the role of rural sites in managing trauma, rural patients and the regional trauma care system may both benefit from the use of telehealth, and in particular, teletrauma services.

1.7 Teletrauma for rural patients

Telehealth is frequently used for emergency and trauma care in community and rural hospitals. While telehealth for trauma may be broadly described as emergency telehealth, or 'tele-emergency,' terminology in the literature is inconsistent and not specific to trauma. Galli et al. (2008), Henderson (2006), and Sterling et al. (2017) use the term 'telemergency,' while others use 'tele-emergency' (Mueller, Potter, MacKinney, & Ward 2014; Natafgi et al., 2018; Ward et al., 2016). Labels such as 'emergency telemedicine' (Ellis, Mayrose, & Phelan, 2006), or those with similar phrasing, have also been used. Examples of telehealth applications with a narrower clinical focus include telesonography (Al-Kadi et al., 2009), teleradiology (Ashkenazi et al., 2007) and tele-airway management (Cho, Chung, Choa, Yoo, & Kim, 2011) despite the fact that they are all used for emergency situations. The term 'telehealth' has also been combined with particular medical conditions such as stroke, mental illness, and ophthalmology to include services such as telestroke (Khan et al., 2010), telemental health (Southard, Neufeld, & Laws, 2014), and teleophthamology (Woodward et al., 2016).

Within the emergency care category, telehealth has been adopted specifically for use in trauma settings. These have included burn evaluation and management (Saffle et al., 2009), pediatric emergency care support (Yang et al., 2015a), dental trauma diagnosis (Lienert, Zitzmann, Filippi, Weiger, & Krastl, 2010), and traumatic orthopedic injury evaluation (Jacobs, Jacobs, van Sonderen, van der Molen, & Sanderman, 2015). Language regarding teletrauma is equally diverse. Terminology used to describe telehealth services during trauma cases has included tele-ultrasound (Al-Kadi et al., 2009), virtual critical care (Westbrook et al., 2008), and teleradiology (Franken et al., 1997). While existing terminology may reflect specific clinical

function or technological focus, telehealth for trauma situations may be generalized as 'teletrauma.' Thus, teletrauma is the use of telehealth services designed to meet the needs of those delivering and managing the care of traumatically injured patients. For the purpose of this thesis, 'teletrauma' will refer to any telehealth service used in the context of trauma.

The appropriate management of a trauma patient requires timely and coordinated care, a large amount of resources, and immediately available expertise. Trauma centers typically include a surgical subspecialty, such as a trauma surgeon, available 24-hours in urban zones. Rural and remote communities, on the other hand, may not be equipped with the resources or clinical experience to effectively manage complex trauma patients (Latifi et al., 2007). For example, it has been noted that a lack of clinician capacity to manage critically ill patients may compromise care in rural settings (Jong, 2010). This has created large discrepancies in trauma care between rural and urban centers, which may result in reduced quality of care, poorer patient outcomes, and a high rate of patient transfers. For many rural and remote health care facilities, the majority of trauma cases encountered are immediately transferred to the nearest center to deliver definitive care (Ashkenazi et al., 2007; Duchesne et al., 2008). However, this may present a missed opportunity for rural sites to actively participate as key players in a regional trauma system; teletrauma may facilitate the accurate triage and effective transfer of the traumatically injured patient. For example, it has been found that the implementation of telehealth has led to a reduction in unnecessary transfers by identifying only those patients most in need of transfer, while stable patients are evaluated and eventually discharged locally (Duchesne et al., 2008). Within the Northern Health Authority, teletrauma has permitted physicians to conduct procedures and manage patients within the rural community thereby

reducing the number of transfers to an urban center (University of British Columbia, 2018). It also allows some patients to remain in their own community for treatment, thus reducing travel cost and risk for the patient and the patient's family. This approach shares the burden of trauma cases and decentralizes trauma care by engaging a regionalized approach that emphasizes the important role of rural facilities.

The Golden Hour concept dictates that trauma patients receive definitive in-hospital care within 60 minutes (Sampalis et al., 1999). Considering the geographic vastness of northern BC, it is not feasible to construct trauma-capable facilities as a means of extending the 1-hour catchment area to all rural patients. However, the Northern Health Authority has a regionalized trauma system whereupon Level 3 and Level 4 centers, often situated in rural and remote areas of BC, participate in the care process. Teletrauma has been recognized as a possible solution for extending the geographical reach of regionalized trauma systems (Hameed et al., 2010) and has been consistently adopted in rural areas (Duchesne et al., 2008; Franken, Harkens, & Berbaum, 1997; Mohr et al., 2018; Roccia, Spada, Milani, & Berrone, 2005; Saffle et al., 2009). Capitalizing on the existing regional trauma system in northern BC, teletrauma may improve access to the definitive care provided by larger centers. As a result, the trauma system becomes integrated at the regional level by relying on rural sites to provide triage and early management of trauma patients. Additionally, rural clinicians can perform otherwise unfamiliar procedures and develop professional skills, despite residing in areas with low user densities and less trauma exposure. Clinician confidence may also be enhanced, having less anxiety regarding unfamiliar cases while reducing feelings of professional isolation (Lambrecht, 1997). Thus by extending expertise and clinical support to BC's periphery via teletrauma, rural sites play a key role in the accurate triage

and early care of trauma patients conferring benefits to patients, clinicians, and the trauma system.

1.8 Research question

Practicing clinicians in McBride and Valemount are vital to the excellent health care that is delivered to this unique region in northern BC. It is important to engage the perspectives of rural clinicians to better understand how the Robson Valley functions as a part of the regional trauma system. Clinicians in these communities have insight into the complexities of rural trauma care within the context of geographic and professional isolation, resource access limitations, and the distinct health profiles of rural BC trauma patients. By adopting strategically designed teletrauma services, clinicians may maximize the function of the Robson Valley as a rural trauma site and advance the trauma system as a whole. Because teletrauma serves as the conceptual and physical link between the Robson Valley and an integrated system of trauma care, clinicians perspectives are essential to understanding teletrauma in a northern context. Rural clinicians may thus represent the primary drivers, and key knowledge holders, of an effective regionalized trauma system that relies on teletrauma.

To understand this further, this research will address the research question: What factors are associated with the use of teletrauma in northern British Columbia? Understanding the experiences of physicians using teletrauma and the perspectives of key stakeholders will contribute knowledge on how these services can complement and extend high quality patient care within the Robson Valley region of northern BC. This research will address gaps in knowledge and may further catalyze strategic implementation of future teletrauma services in

the region and have the potential for large-scale positive effects across all aspects of BC's health delivery system.

2.0 Literature Review

A systematic search of the literature was conducted to provide an overview of the empirical knowledge on teletrauma research. Arksey and O'Malley's (2005) framework for scoping reviews was used to guide the search methodology. Knowledge gained from this literature review provides an understanding of the current state of teletrauma research and identifies gaps and potential directions for future teletrauma research.

2.1 Search methodology

This systematic literature search was guided by Arksey and O'Malley's (2005) scoping review methodology. Stages included 1) identification of the research question; 2) identification of all relevant studies; 3) study selection; 4) charting the relevant data; and 5) collating, summarizing and reporting the results (Arksey & O'Malley, 2005). This method was selected to identify, describe, and summarize the knowledge base of relevant literature on teletrauma. The scoping review methodology allows researchers to draw conclusions about the current landscape of research on a topic, while remaining methodologically rigorous and allowing the inclusion of diverse forms of literature (Arksey & O'Malley, 2005). The method is appropriate given the early state of teletrauma research and its ability to provide a comprehensive review of the breadth of the literature.

2.2 Study selection and analysis

To examine teletrauma literature, a systematic search of electronic databases was conducted including Cumulative Index to Nursing and Allied Health Literature (CINAHL) Complete, Biomedical Reference Collection: Comprehensive, PsycINFO, EconLit, and PubMed. Keywords included terminology related to any telehealth service, trauma, and a rural setting,

while relevant subject headings were used according to the database searched (Appendix A). The search was reviewed by a health librarian. No date or age limiters were used, since limited research was available. The search was restricted to peer reviewed articles available in English and human subjects. Inclusion criteria consisted of care provided in clinic, hospital, or emergency department and articles having a telehealth component to retain a focus on telehealth services provided within rural institutions. Articles were excluded if there was no acute or emergency care situation, or if there was no real-life clinical component. A matrix was created with clearly defined rules for the screening process to ensure reliability of the review. The number of excluded articles were recorded at each step. After an initial screening of titles and abstracts, full text articles were reviewed according to the eligibility criteria and then selected for inclusion (Figure 4). Information from articles was extracted using a data extraction framework to organize and ensure consistency of data collection (Appendix B). Framework headings included the year, study location, study type, objectives, patient group, sample size, telehealth technology, associated factors, evaluation aim, communication network, and findings. Headings were created according to the research questions and to provide a descriptive overview of the current literature.

The Quadruple Aim framework (Bodenheimer & Sinsky, 2014), adapted from Berwick, Nolan, and Whittington's (2008) original Triple Aim framework for health care system optimization, was used to help categorize articles according to evaluation aim. Aims include a) provider experience, b) patient experience, c) population health, and d) cost optimization. Although the Triple Aim has been used by health care organizations across the world to guide the delivery of high quality care (Sikka, Morath, & Leape, 2015), it has been revised to include

an integral part of the health care system: the provider experience. The provider experience has been cited as a necessary prerequisite to achieving the Triple Aim and ensuring a more balanced view of health system performance (Bodenheimer & Sinsky, 2014). Use of the Quadruple Aim framework for this literature review permits identification of which aspects of the health care system are being examined and highlights gaps in teletrauma evaluation research.

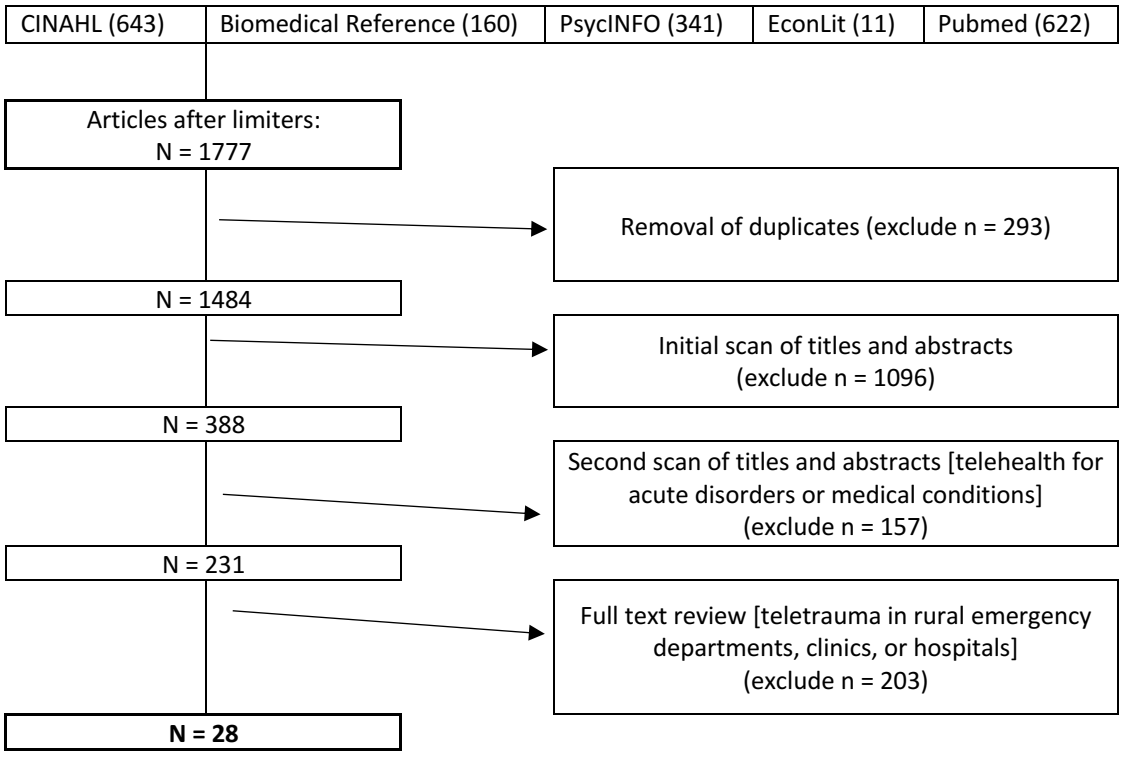

Figure 4: Article Selection Flowchart

2.3.0 Findings

From the original 1777 articles identified after the initial search, 28 articles met the inclusion criteria and were included in the analysis (Appendix B). Of the studies identified, 16 mentioned patient populations classified as trauma cases. The remaining 12 articles examined cases meeting the definition of traumatic injury (acute injuries requiring immediate medical

management) and were thus included, but did not specifically classify patients as being trauma patients.

2.3.1 Study characteristics. A large proportion of articles were published within the last 10 years (n=12) although teletrauma research has appeared as early as 1997 (Franken et al., 1997; Lambrecht, 1997; Rottger, Irving, Broerr, & Tranmer, 1997). Three studies utilized observational cohort study designs (Mohr et al., 2016; Mohr et al., 2017; Mohr et al., 2018), six were classified as descriptive analyses (Al-Kadi et al., 2009; Ashkenazi et al., 2007; Dyer et al., 2008; Ehrlich, Kobrinsky, Petlakh, Rozinov, & Shabanov, 2007; Lambrecht, 1997; Roccia et al., 2005), three were identified as comparative or before-and-after studies (Jacobs et al., 2015; Saffle et al., 2009; Westbrook et al., 2008), while the most frequently used design was a retrospective analysis (n=11). Studies were conducted in 11 different countries, the most common being the USA (n=15) and Canada (n=3). In total, 16 articles included patient cases that were specifically considered trauma cases.

Of the 28 studies, 61% (n=17) included a non-teletrauma comparison group in analysis (i.e. trauma with no telehealth component or phone consultation only). The largest teletrauma sample sizes examined were n=1,322 telehealth consultations regarding an injury (Brebner et al., 2004), n=672 reports of dental trauma following accidents (Lienert et al., 2010), and n=519 patients receiving radiology examinations (Franken et al., 1997). Studies with the smallest teletrauma sample sizes were n=14 clinician surveys evaluating telehealth for ultrasonography (Al-Kadi et al., 2009), n=2 case reports of telehealth to treat children with severe burns (Syed-Abdul et al., 2012), and n=1 case report of a traumatically injured child who received remote clinical management prior to transfer (Rottger et al., 1997). Articles with a study population

that included patients of all ages comprised 61% (n=17) of the total, followed by adults over 18 years (n=4), and pediatric patients under the age of 18 years (n=7).

The communication network for teletrauma programs varied in size: one article studied telehealth consultations for acute injuries from 14 community hospitals consulting a larger hospital (Brebner et al., 2004), another examined a telehealth service between nine rural hospitals consulting a Level 1 trauma center to evaluate and manage burn patients (Wibbenmeyer et al., 2016), and two articles studied a teletrauma service between eight rural emergency departments and a consulting academic children's hospital to examine the appropriateness of transfers of patients using teletrauma and hospital costs (Yang et al., 2015a; Yang et al., 2015b). The largest network included maxillofacial trauma cases from 35 rural hospitals consulting a specialized center (Roccia et al., 2005). Typically, articles described teletrauma services between a single rural community hospital or emergency department and a center with a higher level of care (n=13).

2.3.2 Terminology in the literature. The term 'teletrauma' is associated with the use of telehealth technologies for trauma care and management. Few articles (Latifi et al., 2009; Ricci et al., 2003) used the term 'teletrauma' to describe a telehealth system designed for use during trauma care. Instead, several studies labelled their telehealth service based on the specific technology used. These included tele-ultrasound (Al-Kadi et al., 2009), teleradiology (Ashkenazi et al., 2007), and telesonography (Dyer et al., 2008). Although the functions of the individual systems are similar, the services were labelled based on their diagnostic or technological focus. This adds to the confusion surrounding terminology of telehealth for trauma care by introducing a large number of terms used to describe the same general concept. Despite the

lack of a formal definition, all telehealth technologies which are used at any point during the management of traumatic injury may be generalized as 'teletrauma' regardless of a focus on a particular aspect of care (i.e. sonography, basic consultation, or airway management). The majority of language used combines 'telehealth' or 'telemedicine' with phrases such as 'for use during trauma situations' or with phrases containing similar wording.

2.3.3 Rurality. The definition of rural varied between articles. Some articles stated that the client site was rural or remote but did not elaborate on how this was defined (Al-Kadi et al., 2009; Ehrlich et al., 2007; Elkaim et al., 2010; Lienert et al., 2010; Wibbenmeyer et al., 2016). Others used officially recognized rural zones, whether provided by a government body or health care organization, to classify sites as rural (Dharmar et al., 2013; Mohr et al., 2016; Mohr et al., 2018; Yang et al., 2015a). However, several articles expanded on the meaning of rural by describing the remote facility characteristics and surrounding geography in relation to a larger center. For example, Ashkenazi et al. (2007) describe their facility as a "410 bed general hospital designated as a Level 2 trauma center… located in a rural area and is the only trauma center available for immediate transfer of injured patients within a 90 km diameter... [and] lacks a neurosurgical service" (p. 550). Despite a facility designation that is higher than most hospitals in rural areas, Ashkenazi et al.'s (2007) description of the lack of appropriate services in conjunction with geographical isolation depicts the challenges faced in rural care delivery. Thus, rurality was described in distinct ways across the literature.

Several aspects or rurality were identified including geographic separation (Brebner et al., 2004; Duchesne et al., 2008), lack of appropriate resources (Ashkenazi et al., 2007; Dyer et al., 2008), temporal barriers to care (Roccia et al., 2005; Saffle et al., 2009; Westbrook et al.,

2008), or some combination of these. Moving forward, it may be of use for future studies to define rurality in terms of these characteristics in addition to the accessibility of surrounding higher-level services. This will aid in understanding the local context of health service delivery and how telehealth operates within that context. By identifying the various aspects of the health system and environment, rural telehealth services may be evaluated more accurately.

2.3.4 Essential system components. Despite the varied language used, the essential components required for telehealth emergency services in rural areas were consistent throughout the literature. For trauma care, this typically included a real-time bidirectional audio-visual videoconferencing system with a dedicated network line (Duchesne et al., 2008; Dyer et al., 2008; Latifi et al., 2009; Ricci et al., 2003). It was common for teletrauma systems to have mounted cameras with remote control capabilities (Duchesne et al., 2008; Ricci et al., 2003; Rogers et al., 2001; Yang et al., 2015a; Yang et al., 2015b), however, most articles described the system only as having cameras with pan/tilt/zoom functions. One study described their teleradiology system as an "online consultation process" (Ashkenazi et al., 2007, p. 551) to view and discuss pathological head computed tomographic findings without further explanation of what the technology entails. Another used fax, conventional telephone, and a cellphone to provide remote care from a neurosurgeon to a traumatically injured child (Rottger et al., 1997). Although different technologies and techniques have been used to establish a teletrauma system, more than half of the articles (n=15) used some form of videoconferencing. This has included a two-way audio-visual connection (Marcin et al., 2004; Mohr et al., 2016; Mohr et al., 2017; Mohr et al., 2018), audiovisual communication system (Ricci et al., 2001; Rogers et al., 2001; Westbrook et al., 2008; Yang et al., 2015a; Yang et al., 2015b), transmission of audio,

visual, and vital signs (Latifi et al., 2009), and the explicit mention of a videoconference system (Al-Kadi et al., 2009; Brebner et al., 2004; Dharmar et al., 2013; Duchesne et al., 2008; Dyer et al., 2008; Ehrlich et al., 2007; Lambrecht, 1997; Syed-Abdul et al., 2012). As an example, Dharmar et al. (2013) describe their system as "a pole-mounted telemedicine system with a turnkey videoconferencing unit… a flat-screen high-resolution monitor, and an uninterrupted power supply. The videoconferencing unit provided bidirectional video using a high-definition camera capable of pan, tilt, and zoom functions" (p. 2389). For teletrauma systems deployed in rural areas, there were similarities in the types of technology used and the technological capabilities.

The design, specific elements, and capabilities of the telehealth system were driven by the needs of the clinical situation in which it was employed, provided appropriate local infrastructure was in place to facilitate the technological requirements. The technological components supported assessment of the patient by multiple parties at a distance in real time without requiring staff at the client site to position cameras (Duchesne et al., 2008; Ricci et al., 2003); a virtual presence is established at the client site with minimal interference to on-site staff. The similarities in technological components for rural teletrauma identified across the literature supports the future development of teletrauma systems designed to meet the needs of patients and providers. Further knowledge syntheses in this area may be used to contribute towards the creation of technological guidelines for rural sites wishing to adopt teletrauma services.

2.3.5 Service evaluation aim. Examination of service evaluation aim permits insight into how the health care system is being affected by teletrauma services and identifies gaps in

research. The majority of articles were classified as having only examined one aspect of Bodenheimer and Sinsky's (2014) Quadruple Aim. The most frequently evaluated aim was population health (n=26). Population health evaluation, in the context of teletrauma, included analysis of the safe medical management of patients (Ashkenazi et al., 2007), transfer rates (Duchesne et al., 2008), and clinical outcomes for patients (Syed-Abdul et al., 2012). Provider and patient experience was typically evaluated using quality of care measures (Dharmar et al., 2013; Latifi et al., 2009) or satisfaction surveys (Al-Kadi et al., 2009; Brebner et al., 2004; Dyer et al., 2008; Lambrecht, 1997). Evaluation aims studied the least were patient experience (Dharmar et al., 2013; Marcin et al., 2004; Saffle et al., 2009) and cost optimization (Duchesne et al., 2008; Latifi et al., 2009; Saffle et al., 2009; Yang et al., 2015b). Articles categorized under the cost optimization aim included those evaluating transfer costs for teletrauma patients (Latifi et al., 2009; Saffle et al., 2009), assessment of total hospital charges (Duchesne et al., 2008), and a formal economic analysis (Yang et al., 2015b). Teletrauma service evaluations covering three or more aims were less common (Dharmar et al., 2013; Latifi et al., 2009; Marcin et al., 2004; Saffle et al., 2009) and usually included an examination of patient and provider experience as well as population health. Articles with combined evaluation aims typically included written surveys distributed to patients or providers and either a cost assessment or examination of clinical outcomes; one identified changes in diagnosis or therapeutic management of patients (Dharmar et al., 2013) whereas another evaluated patient transport costs (Latifi et al., 2009; Saffle et al., 2009).

While articles covering multiple evaluation aims could be considered more comprehensive, each individual aim appeared to be less robustly studied compared to those

articles focusing on only one aim. For example, Saffle et al., (2009) distributed a Likert scale containing only four questions to patients and providers to assess their experience using teletrauma. Similarly, Marcin et al. (2004) simply asked about level of satisfaction and importance of the service. Ricci et al. (2003), on the other hand, used a more robust method to assess patient and provider experience which included interviews, in-person observations, and questionnaires. This provided a more in-depth analysis of the teletrauma-user experience through examination of attitudes, perceptions, and behaviors of patients and providers. A similar finding was discovered for the cost optimization aim; many studies postulate that teletrauma was (or could be) cost-saving, whereas Yang et al. (2015b) provided more formal analysis of associated costs. Although it is useful for research to include all aspects of the Quadruple Aim (Bodenheimer & Sinsky, 2014) to fully understand the effects of a service across the entire health system, it may be advantageous to capitalize on the robustness of single or double-aim studies by synthesizing knowledge from multiple articles. Knowledge synthesis in this area contributes towards a more comprehensive understanding of how teletrauma affects health systems while relying on robust studies that focus on only one or two aims.

2.3.6 Acceptability. The user experience is frequently evaluated in studies examining teletrauma services (Al-Kadi et al., 2009; Dharmar et al., 2013; Dyer et al., 2008; Lambrecht, 1997; Mueller et al., 2014; Ricci et al., 2003; Rogers et al., 2001; Saffle et al., 2009; Westbrook et al., 2008). Teletrauma users include a variety of individuals involved with the encounter, including health care professionals (nurses, doctors, specialists) from both the client site and consulting site, patients, and family members of the patient. One article in particular, examining the impact of teletrauma for critically injured children, evaluated parent as well as provider

satisfaction using validated surveys (Dharmar et al., 2013). The authors measured various aspects of acceptability, assessing quality of care, changes in care, and satisfaction for teletrauma or telephone consultations. Ninety-five clinicians and 75 parents were surveyed. Although inter-rater reliability of the care quality tool is limited, the instrument was applied by two independent pediatric emergency physicians, raising confidence in the accuracy of findings. The instrument also covered the entire care continuum from information gathering and diagnosis to discharge planning. In addition, the parent satisfaction survey referred to several potential sources of satisfaction, including the overall experience, knowledge and skill of the staff, and whether or not they felt informed. Results were then combined with quantitative analysis of the teletrauma and telephone consultations, providing a methodological rigorous examination of user experiences in the context of pediatric trauma care.

Studies involving patient (or family) and provider perceptions of teletrauma have produced positive results although 'acceptability' is measured in different ways across articles identified; clinicians have judged the system to be easy to use (Ricci et al. 2003), collegiality between the client and consulting sites was improved (Al-Kadi et al., 2009; Dyer et al., 2008; Westbrook et al., 2008), and up to 92% of providers were satisfied or very satisfied with a teletrauma interaction (Al-Kadi et al., 2009). Teletrauma services for rural environments are also reportedly life-saving (Ricci et al., 2003; Rogers et al., 2001; Rottger et al., 1997). In two cases, a rural clinician was guided through an unfamiliar emergency procedure by an expert consultant, saving the life of the patient: Rogers et al. (2001) described a successful emergency cricothyroidotomy by a community hospital surgeon who had not performed the procedure in more than 20 years; Rottger et al. (1997) mentioned that a craniotomy, a procedure that

normally would have been conducted by a neurosurgeon, was successfully performed by a rural physician not trained on the procedure. In both cases, teletrauma adequately facilitated safe and appropriate management. Thus, 'acceptability' of teletrauma services can be considered an umbrella term that includes satisfaction, usability, and perceived value. Of these concepts, satisfaction was frequently used to capture patient or provider perspectives of teletrauma systems (n=7) reflecting acceptability of the service. However, while satisfaction with teletrauma services was generally positive, the full scope of benefits can be difficult to measure (Latifi et al., 2009) and thus the concept of acceptability should not be limited only to satisfaction as a proxy measure.

2.3.7 Feasibility. Across literature identified, teletrauma was noted as being feasible; five articles explicitly mention the service as being feasible (Dyer et al., 2008; Ehrlich et al., 2007; Marcin et al., 2004; Ricci et al., 2003; Wibbenmeyer et al., 2016). However, the concept of feasibility was measured in distinct ways across the various studies. Some examples of teletrauma feasibility include: effective and reliable clinical ultrasound exam performance (Dyer et al., 2008); reliable use of satellite communication to support remote doctors (Ehrlich et al., 2007); accurate burn size estimation (Wibbenmeyer et al., 2016); decreased overall hospital costs (Duchesne et al., 2008), and; lesser costs for videoconferencing as compared to telephone when considering transfer decisions (Yang et al., 2015a). Therefore, 'feasibility' can be further categorized into clinical feasibility (i.e. accurate diagnosis), economic feasibility (i.e. cost saving), and technical feasibility (i.e. reliable technology). Clinical feasibility was most commonly described in terms of therapeutic management or quality of care received (n=17). For example, Dharmar et al. (2013) reported more changes in diagnosis and therapeutic

interventions for patients who had teletrauma as compared to those with telephone consultations, resulting in a higher quality of care for teletrauma patients (5.60 [95% CI, 5.42-5.79] vs. 5.20 [95% CI, 5.07-5.34], $p<0.05$, as measured on a 7-point scale). The authors attributed the changes in diagnostic and therapeutic interventions to the specialists' ability to visualize the patient, family, and bedside equipment. The frequency of changes may also reflect the specialists level of involvement in the care process. However, the authors noted that further study is needed to delineate how the number of changes in care affects clinical outcomes. Teletrauma also facilitates the rapid identification and transfer of more severely injured rural patients, improving care (Duchesne et al., 2008). In both cases, the teletrauma systems were judged as being feasible. However, it may be useful for future research to adopt a common definition of feasibility in the context of teletrauma to facilitate program evaluation and comparison.

Considering the large number of clinically feasible telehealth services identified in the literature, feasibility can be expected to increase further. In particular, improvements in teletrauma feasibility may first take place in the form of technological feasibility as technology continues to advance. Clinical and economic feasibility may then increase as the medical system integrates teletrauma into existing health delivery services.

2.3.8.0 Factors associated with teletrauma use. Associated factors can be categorized as being either antecedent (identifiable prior to the telehealth event) or as outcomes (identifiable after the telehealth event). These can be further subdivided into clinical or organizational factors (Figure 5). This classification system supports a targeted approach to teletrauma utilization where the system is activated only for those patients who may benefit

most, identified and selected based on certain clinical and organizational criteria. Whereas some articles examined factors antecedent to individual teletrauma encounters and may therefore be used to screen patients, other studies cited reasons for adopting the teletrauma service as a whole.

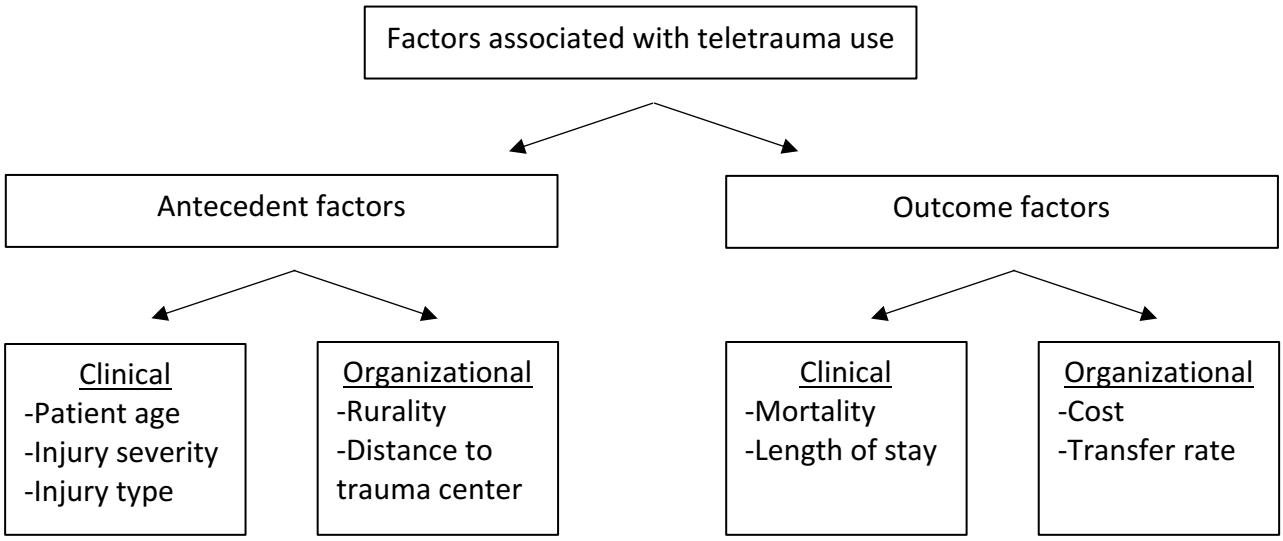

Figure 5: Classification of Factors Associated with Teletrauma Use with Examples

2.3.8.1 Antecedent factors. Antecedent clinical factors included injury or trauma severity scales (Duchesne et al., 2008; Marcin et al., 2004; Mohr et al., 2017; Ricci et al., 2003; Rogers et al., 2001; Yang et al., 2015a), limb injury location (Brebner et al., 2004; Elkaim et al., 2012; Lambrecht, 1997), mechanism of injury (Duchesne et al., 2008; Latifi et al., 2009; Mohr et al., 2017), and patient age (Dharmar et al., 2013; Franken et al., 1997; Marcin et al., 2004; Yang et al., 2015a; Yang et al., 2015b).

Several clinical factors were found to be significantly associated with use of a teletrauma service. Scales were frequently used to evaluate the severity of injuries in trauma patients, including the Injury Severity Score (Baker, O'Neill, Haddon, & Long, 1974) or Revised Trauma

Score (Champion et al., 1989). The Injury Severity Score assesses injuries from multiple body regions and sums them to generate a composite anatomically-based severity score (Baker et al., 1974). The scores range from 3-75, with higher scores correlating with increased mortality and morbidity. The Revised Trauma Score, on the other hand, uses a physiologic scoring system that relies on three physiologic measures (Glasgow Coma Scale, systolic blood pressure, and respiratory rate) to describe severity of injury. The scores range from 0-12, with lower scores indicating increased severity. The scales were used in several studies to quantify injury severity and examine association with teletrauma use. It has been found that severely injured patients were more likely to receive a teletrauma consultation. Duchesne et al. (2008), for example, compared a cohort of patients who did not have teletrauma (n=351) to a group of patients that received teletrauma (n=51) to evaluate outcomes for rural patients. The authors found that teletrauma patients had an Injury Severity Score of 18 compared to 10 for those patients who did not receive teletrauma ($p < 0.001$). The authors also mentioned that they were able to select more severely injured patients, resulting in more aggressive treatment early on in the care management process. Similarly, Mohr et al. (2017) found that, as compared to patients with minor injuries, those with severe injuries were 70% more likely to receive a teletrauma consultation (unadjusted OR 1.70, 95% CI 1.13 – 2.56). This finding is echoed by several other studies reporting on injury severity or physiological illness (Duchesne et al., 2008; Marcin et al., 2004; Ricci et al., 2003; Rogers et al., 2001; Yang et al., 2015a). Specific symptoms and mechanisms of injury have also been examined. Mohr et al. (2017) found that patients presenting with hypotension, penetrating injury, tachycardia, and burns were more likely to receive teletrauma, while Duchesne et al. (2008) identified hypotension, penetrating injury,

higher initial base deficit, and the need for more blood transfusions as being associated with teletrauma use. Although one study (Latifi et al., 2009) found that more patients with blunt as opposed to penetrating injury used teletrauma (91% versus 9% respectively), the small sample size and lack of a more in-depth statistical analysis reduces confidence in this unique finding. Younger patient age was also found to be significantly associated with teletrauma use in a number of studies (Dharmar et al., 2013; Franken et al., 1997; Marcin et al., 2004; Yang et al., 2015a; Yang et al., 2015b); Marcin et al. (2004) reported a mean age of 5.5 years for teletrauma patients versus 13.3 years for non-teletrauma patients ($p < 0.01$). Similar results in an adult population were demonstrated by Mohr et al. (2018) who found that, as compared to younger patients, adults aged 65 years and older were 4.7 times less likely to receive teletrauma (risk difference -4.7, 95% CI -8.6 – -0.8).

Antecedent organizational and hospital-level factors were also examined in 14 of the captured literature (Al-Kadi et al., 2009; Ashkenazi et al., 2007; Dharmar et al., 2013; Duchesne et al., 2008; Dyer et al., 2008; Ehrlich et al., 2007; Jacobs et al., 2015; Mohr et al., 2016; Roccia et al., 2005; Rottget et al., 1997; Saffle et al., 2009; Syed-Abdul et al., 2012; Westbrook et al., 2008; Wibbenmeyer et al., 2016). Antecedent organizational factors included access to specialist knowledge or services (Ashkenazi et al., 2007; Duchesne et al., 2008; Dyer et al., 2008; Ehrlich et al., 2007; Roccia et al., 2005; Saffle et al., 2009; Syed-Abdul et al., 2012; Westbrook et al., 2008), number of unnecessary transfers (Ashkenazi et al., 2007; Jacobs et al., 2015), clinical experience of local health professionals (Dharmar et al., 2013; Al-Kadi et al., 2009; Rottger et al., 1997; Wibbenmeyer et al., 2016), and hospital-level factors included rurality, number of trauma cases, and distance to a facility with a higher level of care (Mohr et al., 2016).

Mohr et al. (2016) found that geographic factors such as rurality and distance to a facility with a higher level of care did not significantly explain variability in teletrauma use. However, the authors mentioned that the rural facilities all had similar capabilities resulting in a lack of variation of usage after teletrauma was adopted. Access to specialist knowledge or services was a commonly cited reason to adopt and use teletrauma (n=7). Saffle et al. (2009) mentioned that untimely subspecialist involvement was a challenge overcome through the deployment of a teletrauma system. Physician confidence with therapeutic management and clinical experience were also factors identified in the literature; a lack of physician experience or familiarity with certain clinical situations have been noted as justification to adopt a teletrauma system (Al-Kadi et al., 2009; Wibbenmeyer et al., 2016). Similarly, physicians were reportedly more likely to initiate a teletrauma consultation if they were uncertain of the diagnosis or clinical management of a patient (Dharmar et al., 2013).

2.3.8.2. Outcome factors. Clinical outcome factors associated with teletrauma use were frequently reported by studies (n=14), including mortality (Duchesne et al., 2008), length of stay (Mohr et al., 2018; Westbrook et al., 2008), and perceived quality of care received (Dharmar et al., 2013; Ehrlich et al., 2007; Latifi et al., 2009; Marcin et al., 2004). For example, Duchesne et al. (2008) noted that despite teletrauma being used for more severely injured patients, mortality did not change (17 [4.8%] pre-teletrauma vs. 4 [7.8%] post-teletrauma, $p>0.05$). On the other hand, the authors noted that the length of stay in the emergency department increased. The availability of teletrauma was associated with an increase in length of stay for transferred patients (12.6 minutes, 95% CI 0.6–24.6) and non-transferred patients (15.6 minutes, 95% CI 9.7–21.4).

Organizational outcome factors were also studied, and included transfer rate or status (Brebner et al, 2004; Ehrlich et al., 2007; Jacobs et al., 2015; Lambrecht, 1997; Latifi et al., 2009; Mohr et al., 2017; Mohr et al., 2018; Roccia et al., 2005; Westbrook et al., 2008; Yang et al., 2015a; Yang et al., 2015b) and cost (Duchesne et al., 2008; Latifi et al., 2009; Saffle et al., 2009; Yang et al., 2015b). Roccia et al. (2005), for example, noted a 50% reduction in the number of transfers to a specialist center as a result of teletrauma use. Cost reduction was also often associated with reduced transfers; Latifi et al. (2009) noted that 29% (n=17) of transfers were prevented, saving an estimated $104,852 in transfer costs. Lesser costs as a result of implementing teletrauma was consistently mentioned in the literature (Duchesne et al., 2008; Latifi et al., 2009; Saffle et al., 2009; Yang et al., 2015b).

2.4 Discussion

The 28 articles included in this review provide insight into how teletrauma functions within rural geographies and the effects of teletrauma on population health, patients, providers, and the health care system. Outcomes were frequently reported in the literature and the benefits were well-recognized; numerous articles explicitly mentioned the utility of teletrauma for rural areas (Al-Kadi et al., 2009; Duchesne et al., 2008; Dyer et al., 2008; Ricci et al., 2003; Rogers et al., 2001; Rottger et al., 1997; Syed-Abdul et al., 2012). As well, several antecedent factors associated with teletrauma utilization were delineated. These factors were categorized as being either clinical (i.e. demographics, signs and symptoms, medical interventions) or organizational (i.e. staff clinical experience, hospital rurality). Classifying these factors aided in understanding how various aspects of the care system can be used to target patients for teletrauma consultation. Although several elements, such as lack of access to

timely specialist involvement and lack of physician familiarity with or confidence during major trauma, can be used to identify and select sites that may benefit from teletrauma, this falls outside the scope of this thesis. Other elements, however, can be used develop a selective strategy for individual teletrauma encounters. Mohr et al. (2018) explicitly call for a targeted approach to teletrauma utilization. Uncovering the factors significantly associated with teletrauma use may lead to more judicious use of teletrauma resources in rural areas by identifying and selecting those patients who may benefit most.

Studies included in this review investigated and reported on a variety of factors associated with use of a teletrauma system. Few articles (Duchesne et al., 2008; Mohr et al., 2017) examined signs and symptoms of patients, in addition to other clinical and demographic information. Although specific physiological signs (base deficit, tachycardia) may be used to select patients for future teletrauma use, further study is needed before this information can be clinically useful. For example, Brebner et al. (2004) noted that of the 1,322 injuries evaluated through a teletrauma consultation, 94% were of the upper and lower limbs, 80% of which were fractures or suspected fractures. Because of the high prevalence of limb injuries in trauma cases, use of 'upper or lower limb injury' as a selection criterion for teletrauma may be too broad to be immediately useful without further study. On the other hand, several articles reported on clinical factors, identifiable prior to a teletrauma encounter, that are generalizable to and useful for future trauma cases. Across the literature, it was consistently found that younger patient age (Dharmar et al., 2013; Franken et al., 1997; Marcin et al., 2004; Mohr et al., 2017; Mohr et al., 2018; Yang et al., 2015a; Yang et al., 2015b) penetrating injury (Duchesne et al., 2008; Mohr et al., 2017), and high severity of illness or injury (Duchense et al., 2008; Marcin

et al., 2004; Ricci et al., 2003; Rogers et al., 2001) were significantly associated with teletrauma use. These findings can be used to support the development of criteria to select patients for targeted teletrauma use. Other factors mentioned but not yet studied by other research included the need for more blood transfusions, radiograph consultation, higher initial base deficit, fractures of upper or lower limbs, injuries in primary dentition, injuries after hours (Monday to Friday, 1800h – 0800h), burns, tachycardia, ambulance transport, and endotracheal intubation; future research investigating these factors may support the continued development of teletrauma selection criteria.

For use within this thesis, findings provide guidance on the selection of individual factors and variables to be explored. However, none of the studies have specifically explored the experiences of physicians using teletrauma, and other stakeholders engaged in the planning and delivery of healthcare services. Understanding these perspectives are much needed and essential to developing a comprehensive understanding of teletrauma services within a rural setting. As well as contributing to the current study, this review identifies gaps in current teletrauma research and highlights areas for further clinical and health services research.

3.0 Methods

Teletrauma represents an important service option for rural care. Teletrauma connects clinicians to the necessary resources to enable timely and appropriate care for rural patients. Thus, various components of the health care system may be affected along the care continuum. This section will provide an overview of the theoretical orientation and methods for the current study. In addition, this section will begin with an overview of the research question and objectives.

3.1 Objectives

The objectives of the proposed study are to a) describe the Robson Valley teletrauma program, b) identify factors associated with teletrauma service utilization, and c) explore the perspectives of physicians who have used teletrauma or who have practiced rurally. To address these objectives, this study will examine the question: What factors are associated with the use of teletrauma in northern British Columbia?

First, the current Robson Valley teletrauma program in northern BC will be described in detail. This will enable a thorough understanding of its current functioning, utility, and outcomes, and provides the general context for the following two objectives. Second, factors associated with teletrauma service utilization will then be identified through interviews with physicians who have used teletrauma. This includes physicians who have used a teletrauma system or who have practiced rurally and may have had exposure to trauma. Identification of associated factors will provide information as to which aspects of the health care system (patient type, physician characteristics, environmental factors, etc.) are associated with teletrauma service use. Third, perspectives of teletrauma users will be explored to better

understand the use of teletrauma in a rural context and how it functions as a part of the trauma system. The knowledge gained by this study may provide insight into the establishment of teletrauma as an integral component to a high functioning regionalized trauma system.

3.2 Theoretical orientation

The interrelations between rurality, illness-related factors, and general population characteristics are complex (Hartley, 2004). For the rural population in Canada, the effects of physical environment on health service delivery cannot be simply described in terms of spatial isolation from larger centers. The design and evaluation of rural health systems requires consideration of associated economic factors, societal norms and cultural beliefs, demographic factors, and local resources, among others. The individual must be viewed as an integrated component of their unique environment existing and actively functioning within in a health care system. To examine and evaluate health care delivery systems, it is necessary to engage a theoretical perspective that appreciates the dynamic relationships between place, individual, and society. To facilitate understanding between these components within the context of teletrauma service deployment and utilization, Andersen and Newman's (1973) theoretical Health Service Utilization framework was used (Figure 6). The framework provides insight into how the use of teletrauma is influenced by, for example, geographical distribution of resources, individuals within a community, and technology. Use of the framework may also uncover mutable factors to be leveraged to enhance equitable access to appropriate care while accounting for potential effects across the whole health system.

Three main components are specified including a) societal determinants, b) health services system, and c) individual determinants (Andersen & Newman, 1973). Each of the three main

components consist of dimensions, or sub-components, as outlined in Figure 6. The sub-components provide a means of operationalizing the major factors to make assumptions about how changes in one area may affect health service utilization. For example, Andersen and Newman (1973) postulate that accessibility (falling under the organization of health services system category) is assumed to increase as government health expenditures increase and waiting times for medical care decrease, thus altering service utilization. The authors also describe how the unit of analysis for health services utilization can shift the relative importance of major determinants. For example, when examining the volume of services delivered as

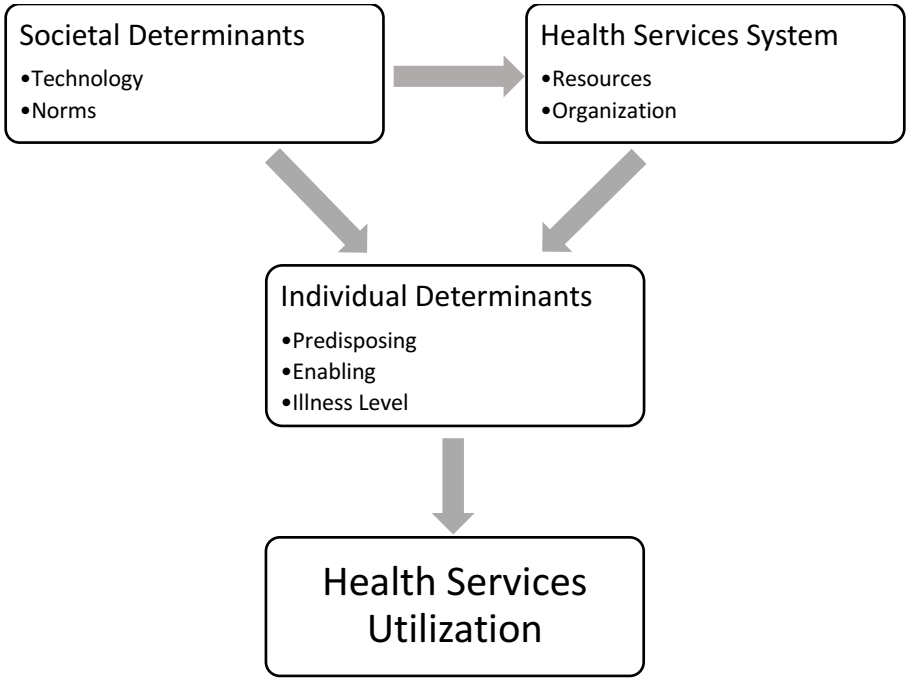

Figure 6: Health Service Utilization Framework (Andersen & Newman, 1973)

opposed to studying initial provider contact, physician characteristics may be more important than individual determinants (Andersen & Newman, 1973).

Thus, the model can be used to gain a better understanding of trends and patterns in service utilization while remaining sensitive to the local context and unit of analysis. For rural

teletrauma, the health service utilization model helps to delineate the interrelations between major determinants of health and provide a deeper understanding of how the various components influence use. More specifically, the model can explain unwanted variation in teletrauma utilization and may uncover which variables are most responsible and susceptible to change. To guide targeted teletrauma program uptake, for example, the model can enhance understanding of the relative value and impact of the various health system components within a rural context; the adoption of teletrauma programs according to patient characteristics (individual determinants) or clinician characteristics (health system services), and whether technology plays a role (societal determinants), could play a role in determining which communities may benefit the most from teletrauma. Therefore, it is possible to influence service use outcomes by leveraging context-specific determinants based on identified mutability and relative importance. The model adequately captures the modern perspective of health care as being complex and holistic with dynamic context-dependent relationships between variables. Andersen and Newman's (1973) model thus provides theoretical guidance, and was used to inform the collection and analysis of data, provide a lens through which to understand the research findings, and contextualize implications of the study within a dynamic, comprehensive view of the health care system.

Although Andersen and Newman's (1973) model was used to provide an overarching perspective of how determinants are linked and operate within the context of rural teletrauma use, the components of the model served as sensitizing concepts to guide the analysis of the study data. The notion of a sensitizing concept was first delineated by Blumer (1954) and has evolved to become an important interpretive device in social research which may "deepen

perception [and] provide starting points for building analysis" (Charmaz, 2003, p. 259). Sensitizing concepts act as a jumping-off point for the development of themes and patterns while remaining grounded in the data and flexible to new directions in analysis. Sensitizing concepts support an inductive process and guides the creation of concepts throughout analysis whether or not they are included in the final work (Bowen, 2006). This is in contrast to definitive concepts which may prescribe themes or patterns prior to data collection and analysis; "sensitizing concepts merely suggest directions along which to look" (Blumer, 1954, p. 7). Concepts may be indicated by the data, revealing new and insightful directions in analysis and allowing for flexibility as themes and patterns emerge. This conceptual framework was embedded within an overall inductive process to discover and generate findings.

In addition to the Andersen and Newman's (1973) model, this research also incorporated an interpretive approach. Rooted in the naturalistic paradigm, the interpretive approach utilizes inductive analysis to generate knowledge that is grounded in the data. As opposed to deductive methodology, whereupon a theory is constructed a priori and tested through observation, inductive approaches build theory grounded in instances of empirical observation. As put by Patton (1980), "inductive analysis means that the patterns, themes, and categories of analysis come from the data; they emerge out of the data rather than being imposed on them prior to data collection and analysis" (p.306). Thus, sensitizing concepts and the inductive approach are complementary and fitting for this study; findings remained grounded in the data and free from prescriptive analysis, suiting the exploration of teletrauma user experiences within an appropriate theoretical perspective.

3.3 Research Design

Data was gathered from key stakeholder interviews on teletrauma while following the principles of Thorne et al.'s (1997) interpretive description methodology. This research approach originated with the purpose to develop knowledge surrounding complex phenomena in the applied sciences (Thorne et al., 1997) and intends to reveal "the kind of knowledge that sits somewhere between fact and conjecture" (Thorne, 2008, p. 15). Use of interpretive description provides insight into and generates knowledge about the health experience with methodological and theoretical integrity (Thorne et al., 1997).

From an epistemological and ontological standpoint, interpretive description is underpinned by a constructivist lens, through which there is the belief that human experience is socially constructed and that multiple realities exist (Thorne, 2016). When considering the nature of the applied sciences, this method is conceptually fitting; health care also spans both scientific objectivity and the subjectivity of patient care. Although interpretive description originated with the intent to address clinical questions in the nursing field, it has expanded to include other applied disciplines. A primary component of the method is that knowledge generated should have practical implications and have the potential to contribute towards applied or disciplinary knowledge (Thorne, Kirkham, & O'Flynn-Magee, 2004). Thus, many health professions have used interpretive description as a way to explore complex phenomena and develop knowledge that is clinically useful. This has an included:

- An examination of patient preferences for physician behaviors during end-of-life communication (Abdul-Razzak, You, Sherifali, Simon, & Brazil, 2014);

- Understanding the challenges of rural occupational therapists and physiotherapists in northern British Columbia (Roots, Brown, Bainbridge, & Li, 2014); and,
- An exploration of physician perspectives towards cancer survivors' work integration issues (Morrison, Thomas, & Guitard, 2015).

Interpretive description capitalizes on the flexibility of data sources, data collection methods, and analytical methods to produce findings that are driven by the interpretive dynamic between data and researcher. Although interviews are a common way to generate data, interpretive description also allows for diverse sources of data including theoretical explorations, narratives, and case studies. The inductive approach advocated by interpretive description relies on the researcher's interpretation of data to yield truths built out of the data. These truths are constructed from within the research design presenting a logically coherent, conceptual description (Thorne et al., 2004). As a logic-based method, interpretive description accurately captures the individuality of the lived experience with methodological integrity by making explicit the decisions made throughout the research design. By doing so, the audience has access to the logic behind each decision made by the researcher, permitting outside evaluation of the credibility of findings.

When developing this research, other more traditional qualitative methods were considered including phenomenology and qualitative description. While several different school of phenomenology exist, each with distinct theoretical and philosophical foundations (Dowling, 2007), phenomenology is generally considered to be both a philosophy and methodology that attempts to uncover the essential meaning of a phenomenon (van Manen, 1990). To reveal the deeper meaning of human experience, the phenomenologist must suspend all preconceived

notions, worldviews, and prior knowledge of the experience ('bracketing') (Kleiman, 2004). Doing so permits a naïve, pure description of the phenomenon as lived and experienced by the individual. Interpretive description, on the other hand, is not so tightly bound by rigid philosophical tenets and theory, but is instead highly focused on logic to inform and produce findings that are clinically relevant and practical (Thorne et al., 2004). The flexibility afforded by interpretive description is more fitting of the purposes of this study. Additionally, the methodological complexity and philosophical proficiency required for phenomenological research would significantly add to the duration of this study.

Qualitative description was also considered as an approach to inquiry. Qualitative description is a naturalistic form of inquiry (Sandelowski, 2000) that is often used in health care research. This approach is less theoretically-bound than phenomenology and does not require bracketing of preconceptions (Gearing, 2004). While qualitative description is closely linked to interpretive description, qualitative description aims to ensure descriptive validity; one goal of the qualitative descriptive method is that it produces a valid summary of events that remain close to the words of the participants, rather than findings which are highly interpretive in nature (Sandelowski, 2000). This is attained in part through transparency of researcher presuppositions and positionality. Because the emphasis remains on presenting a valid account of the lived experience in the subjects' own words, qualitative description is less fitting for this study; interpretive description aims to move beyond a descriptive account as "investigators are rarely satisfied with description alone and are always exploring meanings and explanations that may yield application implications" (Thorne et al., 2004, p. 3). Interpretive description still recognizes the reciprocal-interpretive relationship between researcher and subject but instead

emphasizes logic and transparency as a means of dealing with researcher presuppositions, positionality, and biases. Additionally, interpretive description aims to produce findings that are relevant to disciplinary knowledge and directly applicable to practice. As such, interpretive description was selected as the most appropriate method for this study. The approach is fitting given the complex, experiential phenomenon of teletrauma use while adhering to rigorous methods needed for the creation and application in the clinical setting.

3.4.0 Sample and recruitment

3.4.1 Study setting. The Robson Valley geography and health care delivery was briefly described in chapter one. Physicians in the Robson Valley have identified a lack of access to timely care and lack of access to necessary resources as being challenges of health care delivery in the area (University of British Columbia, 2018). To overcome these challenges, a virtual care program was implemented. The system consisted of synchronous and asynchronous service delivery, including an on-demand, real-time videoconferencing service and a secure text-messaging service. The system was comprised of several user endpoints. These included a mobile teletrauma cart in the emergency room of the Valemount hospital, a desktop computer in the home of a physician, a videoconference system in a separate room of the hospital, and a fixed-unit screen and camera in the trauma bay at the University Hospital of Northern British Columbia in Prince George, BC Canada.

When a physician was not present in one of the communities, the teletrauma program enabled a virtual connection to be established between McBride and Valemount. This permitted remote evaluation and consultation between the communities. Physicians were able to contact the University Hospital of Northern British Columbia in Prince George when

consulting on a case or preparing a transfer. When physicians wanted to initiate a call with the University Hospital of Northern British Columbia in Prince George, the rural physician in the Robson Valley had to log in to the system, select the site they wished to call, and then wait for the consulting clinician to answer the call. A similar process was in place for consultations within the Robson Valley. The system was also capable of connecting with a larger center (i.e. Vancouver General Hospital).

The teletrauma service was used by nurses, physicians, and specialists. In the Robson Valley, it was typically a nurse contacting a physician, or a physician contacting a physician. Between the Robson Valley and Prince George, a rural physician would often consult another physician or a specialist. For the purpose of this thesis, 'teletrauma user' refers to nurses, physicians, or specialists who used the system to consult with other health care professionals, including nurses, physicians, or specialists. While it was suggested that several different specialists have been consulted using the system, the term 'specialist' most often refers to emergency room physicians.

3.4.2 Sampling approach. Purposive sampling was initially used to identify participants. This process includes a purposive selection of participants, based on the judgement of the researcher, as a means of gaining access to knowledge or experiences (Cresswell & Plano Clark, 2011). As noted by Patton (2002), cases are selected for the purpose of being information-rich. That is, the technique allows for the identification of those who would provide data most relevant to the investigation (Morse, 1995; Thorne et al., 1997). In addition, this also permits efficient use of resources while remaining focused on the phenomenon of interest. In contrast to quantitative techniques which emphasize generalizability and aim to broaden understanding,

purposive sampling intends to facilitate an in-depth and comprehensive understanding of an experience or phenomenon (Patton, 2002). Thus, a sample is generated with the intention of accessing knowledge that only a particular group of individuals hold. Given the context and purpose of this study, purposive sampling is fitting. Following this approach, snowball sampling was then used as a means of gaining further access to this difficult-to-reach population. The use of snowball sampling can help to enrich the sample and access new participants through social networks (Noy, 2008). By asking participants to identify other individuals whom they may consider to have valuable knowledge or insight, the sample size can be increased while remaining focused on the topic under study. Considering the established relationships between rural practicing clinicians, this sampling technique was an effective way of accessing more teletrauma knowledge-holders despite the population being small and difficult to access.

3.4.3 Participant recruitment. Capitalizing on existing relationships, the researcher (TW) worked with stakeholders to identify and recruit participants. As the Northern Health Authority is engaged in the development of the Robson Valley teletrauma program, and telehealth programs more broadly, the use of existing relationships was an effective means of accessing this population and purposively sampling the participants. As described in the background section, the Northern Health Authority region is predominantly rural and remote, and the number of health care providers is limited. Thus, it was necessary to utilize social networks and intraorganizational communication networks to recruit relevant knowledge-holders. This included social networks between physicians, and existing relationships with the Northern Health Authority stakeholders and individuals at the Rural Coordination Center of British Columbia.

It was estimated a potential sample size of 5-8 participants would be needed for this study. This was based upon consideration of the small pool of potential participants from which to select and the desire to achieve theoretical saturation. Saturation, according to Sandelowski (1995), is a theoretical point whereupon no new information emerges from the data. That is, the researcher continues to sample until no new substantive information is identified from participants; no new patterns or themes in data analysis arise. Based on findings from interviews conducted with teletrauma users previously, saturation was assumed to be reached at six participants. Although this theoretical saturation limit was identified previously and this was used to guide sample size selection, it was not a requirement to cease sampling and exclude potential participants; each participant is expected to bring information that is new and valuable. In this study, saturation was reached at five participants.

3.5 Data collection

Primary data were generated from six semi-structured interviews with physicians who have used a teletrauma service or who have experience practicing in rural areas. The semi-structured nature of the interviews allows openness and spontaneity in conversation, while keeping the interview focused on the central concepts. Several variables thought to be associated with teletrauma use were selected and were integrated into the interview questions. The interview schedule was also reviewed and tested with clinical experts, including an emergency department physician with expertise in pre-hospital medicine and trauma (Appendix C). To link the data collection to the theoretical framework, a model was created adopted from Andersen and Newman's (1973) original framework (Figure 7). The example includes several variables selected from and adopted into the 'individual determinants'

component of health service utilization. Additional factors at the health service level included number of uses of telehealth, duration of use, and transfer status. The framework was used to guide the selection of variables to be discussed during the interviews and aided in the visualization of how variables are interrelated. However, participants were open to speak freely.

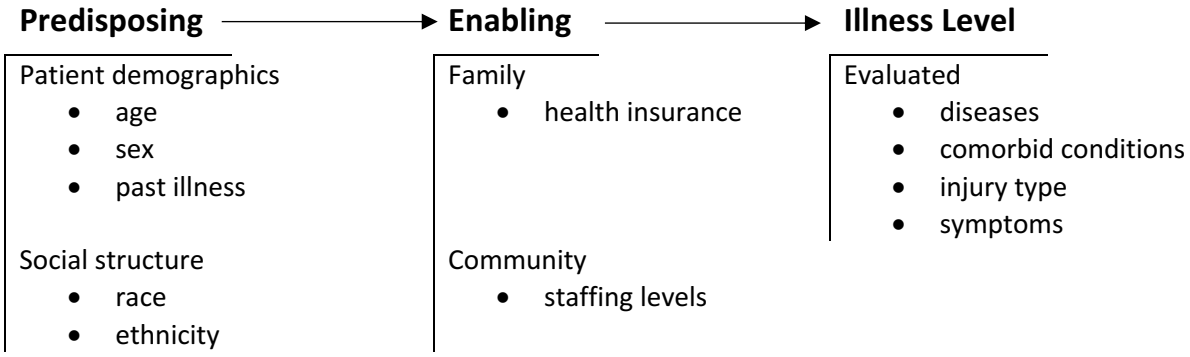

Figure 7: Individual Determinants of Health Adopted from Andersen and Newman (1973)

Participants were provided with a comprehensive information sheet and consent form and were able to contact the researcher to obtain further information or express their willingness to participate while maintaining confidentiality. Snowball sampling was then used to recruit additional participants; interviewees were asked to identify and contact other potential participants who may be interested and were asked to distribute the study documents and contact information of the researcher. After written or verbal consent was obtained, telephone or in-person interviews were conducted using open-ended questions. These were digitally recorded and transcribed verbatim, allowing the researcher (TW) to repeatedly return to the primary data source as a means of immersion in data to facilitate and enhance analysis.

Interview questions were created and developed iteratively over time. As interviews progressed, questions were revised and adapted to best uncover the experiences and insights of participants. Questions were developed as to not be leading or to include slang or other medical jargon (Rubin & Rubin, 2011). Interview questions were initially reviewed by the committee and it was agreed that questions would evolve with ongoing data collection to focus on emerging themes and areas of interest. The interviews were designed based on Spradely's (1979) approach to asking descriptive questions. Grand tour questions involve asking participants about a general sequence of events or locale and typically illicit rich descriptions, whereas mini tour questions inquire about specific events or examples (Spradley, 1979). Grand tour questions and mini tour questions were used at different points throughout the interview to ensure richness and depth of responses. Probes were used to gain further insight if answers were short or superficial, and to help guide participants if they were unsure how to answer. Interviews began with open conversation and general questions to allow the researcher to learn about the participant and their context of practice, and to build rapport. The end of the interviews also included open conversation as a way of debriefing participants.

Eight interviews with key stakeholders were conducted previously which included physicians, administrators, and Northern Health Authority executives involved with teletrauma. These were part of a larger internal quality initiative for telehealth within the Northern Health Authority. Since these included other relevant stakeholders, a secondary analysis of these interviews was undertaken for the purpose of understanding teletrauma use from a variety of perspectives within the health system. Interview data from the previous study helped to uncover deeper meaning of teletrauma in this context of the present study and provided

additional insight from unique perspectives. In total, 14 interviews were analyzed; six interviews were conducted to generate primary data and transcriptions from eight previously conducted interviews were re-analyzed for use within this project.

3.6 Data analysis

Data analysis followed the principles of the interpretive descriptive method which takes a constructivist approach to knowledge creation (Thorne, 2008). That is, knowledge produced are not facts but truths; the end product is a conceptual description that is meaningful and relevant to practice (Thorne et al., 2004). As data are transformed into knowledge through analysis, the researcher must engage an approach that emphasizes logic, transparency, and flexibility (Thorne et al., 2004). Instead of providing rigid steps for analysis, Thorne et al. (2004) advocates for creativity within a setting of transparency. The responsibility to ensure that the reader is able to follow the cognitive analytic process lies entirely with the researcher. By doing so, the interpretations can be said to have analytic logic producing truths that are viable and inform disciplinary knowledge.

To produce such knowledge, analysis occurred concurrently with data collection. By creating meaning from the data and postulating relationships and themes, the researcher makes a commitment to the interpretations and has the responsibility to make explicit this process (Thorne et al., 2004). As such, the reader has access to the interior logic behind analytical decisions and can make credibility judgements about posited interpretations. Several strategies were used to ensure a transparent and logical knowledge creation process. One technique involved becoming immersed in the data. This immersion facilitates what Thorne (2008) considers to be the most difficult aspect of an interpretive descriptive study: to create

knowledge out of data through interpretation. This begins with close reading of the transcripts. As the researcher becomes engaged with and organizes data, themes and patterns emerge driven by personal interpretation. This sorting and immersion in the data enhances critical thinking and supports the researcher's ability to reflect on patterns and themes, creating new avenues for knowledge creation. Immersion in the data was attained by listening to digital recordings for transcription accuracy, and then reading and re-reading transcripts several times. Close reading of transcripts occurred during and following completion of the data collection phase.

To manage the data, NVIVO software was used. Using a software package permits the "effective archiving, management and storage of the vast quantities of raw data generated through the qualitative research process" (Banner & Albarran, 2009, p. 25). The software facilitates data organization and theory-building by providing a visual framework on which to hang concepts and themes. For the purposes of this study, NVIVO was used to generate initial codes, while manual mapping techniques were used to visually explore the linkages in the data and eventual themes.

Once data were organized and mapped, the researcher (TW) examined the data for key words, ideas, or quotes. These were flagged with concepts thought to be applicable and relevant. Codes are ideas or labels that provide insight into and are reflective of the phenomenon of interest (Graneheim & Lundman, 2004). These codes were then compared to other transcripts and evolved over time to reveal threads across interview data. Codes were then systematical organized and arranged into broad categories which were used to support the identification of themes. The process of applying codes and concept development was

based on Bowen's (2006) sensitizing concepts. The sensitizing concepts approach supports the inductive analytic process and is in alignment with the flexibility of interpretive description; codes were not assigned a priori, but were instead used to guide knowledge development whether or not they were to be included in the findings (Bowen, 2006).

In line with Thorne's (2004) techniques for analysis, emphasis was put on intellectual inquiry and transparency of the cognitive processes to guide interpretations. As such, fields notes were taken during and after interviews, and a reflexive journal was kept throughout the entire process. Reflective journaling aided critical thinking, cultivated the interpretive dynamic relationship between the researcher and data, and provided a means for identifying and exploring new insights as data were encountered. Field notes supplemented understanding of the data and helped to contextualize data in terms of individual interviews and as a cluster of interviews. These techniques also present the reasoning process behind analytic decisions which aligns with Thorne's (2004) commitment to a transparent, logical process of knowledge creation. Transparency during analysis allows the reader to follow the cognitive processes and use of reasoning to create knowledge. This makes explicit the reasoning behind decisions made and aids in the accruement of credibility and trustworthiness of study findings (Carcary, 2009). To further enhance the inductive analytic process, a constant comparative method was used. Analysis occurred while other interviews were being conducted and the researcher alternated between new data and prior interviews, analyzing themes and ideas as they became apparent. This permitted a view of the interview data as being linked and aided in the identification of patterns and commonalities. Visually mapping the data became a useful tool during this process. Overall, this method supported an organic exploration of key themes and patterns as

data emerged, permitting flexibility in researcher interpretation while remaining focused on the phenomenon of interest.

Additionally, a main focus of analysis remained on producing findings that could support disciplinary knowledge. Put by Thorne et al. (2004), the study should "[generate] an interpretive description capable of informing clinical understanding" (p. 3). As a means of maximizing logical coherence and establishing credibility of the findings, data analysis was an iterative, transparent process with an "explicit awareness of the investigator as interpreter" (Thorne et al., 2004, p. 6). Thus, the research remained cognizant of positionality, gender, power complexes, biases, judgments, and social constructs subscribed to, as they all inevitably influence how data is perceived. This awareness of self was maintained through reflexive journaling, a concept discussed in the following section.

3.7 Rigor

Lincoln and Guba (1985) proposed a quality framework to judge the authenticity and quality of a research product that is generally accepted by the research community (Thorne, 2008). To evaluate the credibility of findings and establish qualitative work as being trustworthy, several criteria were posited by Lincoln and Guba (1985) including: credibility, transferability, dependability, and confirmability. Conceptually, the philosophical underpinnings of Lincoln and Guba's (1985) naturalistic inquiry are in alignment with interpretive description: there are multiple realities which are contextual and subjective; the researcher and object of study influence one another; and, no truths developed a priori can account for or predict the realities to be encountered (Lincoln & Guba, 1985). Thorne's (1997) methodology appreciates the subjectivity of the lived experience and allows for the possibility of shared realities by

acknowledging the researcher as a key component of the constructed truths. Given the philosophical alignment with interpretive description, Lincoln and Guba's (1985) framework will be used to assess quality and authenticity of findings.

Credibility refers to the degree of agreeableness or 'fit' between the subjects' truths and the researcher's representation of those truths (Schwandt, 2001). In essence, it is the link between the researcher's findings and reality, demonstrating the internal validity of the study. To build and demonstrate credibility of findings, several techniques were used. These included prolonged engagement and constant comparison of the data. As data and findings became available, feedback was sought from the researcher's committee members to ensure that findings were accurate, logical, and validly represented participants' descriptions. This process of peer review aids novice researchers to "synthesize and see patterns in their data… and assists with the development of internal validity" (Morse, 2015, p. 1215). It is noted that validity should not depend on consensus (Morse, 1998); it is something earned and demonstrated through analytic integrity. As a means of producing findings that are closely linked to reality and participants' description of a phenomenon, a lot of time was spent with participants during the data collection phase. The development of trust and intimacy between the researcher and the participant helps to enable a clear, valid account of the phenomenon through thick, rich description (Morse, 2015). Thick description of the data facilitates credibility by providing sufficient data to demonstrate themes and patterns (Morse, 1995). The constant comparison method (Glaser, 1965) was another strategy used; secondary analysis of stakeholder data provided diverse perspectives. The process included systematically analyzing and comparing data to previously collected and analyzed data. This method facilitates analysis of new

perspectives through examination of the similarities and differences between perceptions (Glaser, 1965). Thus, a deeper understanding of teletrauma is jointly constructed through a diverse group of stakeholders, exhausting all viewpoints of a phenomenon.

Transferability refers to the potential for findings to be used in different contexts; that is, the researcher "[provides] the data base that makes transferability judgements possible on the part of potential appliers" (Lincoln & Guba, 1985, p. 315). For study results to be applicable to other situations, thick description was used. This included a detailed description of the context in which interviews occurred. Whether interviews were conducted while participants were at work, over the phone or in person, whether or not they were rushed, and the surrounding social or cultural environment helps readers to judge the transferability of findings. A detailed, rich description derived from field notes and an audit trail aided in the establishment transferability. This technique is necessary for outside readers to be able to transfer the findings to different contexts or individuals (Guba & Lincoln, 1989).

Dependability establishes findings as being repeatable and consistent over time. As one important means of ensuring trustworthiness, dependability helps to confirm that findings are accurate and supported by the data (Morse, 2015). Similar methods of triangulation were used to help establish dependability; the researcher's committee examined codes applied to help ensure consistency and accuracy throughout the development of study results. Committee oversight regarding the conduct of the study, decisions made throughout study design, and analytic logic helped to develop dependability. Use of an audit trail also helps to ensure findings are dependable; accurate, comprehensive documentation ensures to readers that the research process is logical and traceable (Schwandt, 2001).

Confirmability helps to assess the accuracy of findings. The use of an audit trail and reflexivity are important techniques to demonstrate confirmability (Morse, 2015; Tobin & Begley, 2004). This concept provides the reader with confidence that findings were derived from the data and participant narratives rather than researcher biases or preconceived ideas. A reflexive journal was kept to remain cognizant of how personal influences can alter interpretations of the data, to permit insight and self-reflection, and to keep track of the rationale behind analytical decisions made. Reflexivity as an attitude supports the interpretive-reciprocal relationship between researcher and data, and recognizes the influence of the researcher on every aspect of the study design. Providing a transparent, self-critical account of the research design and analysis makes explicit the 'how' and 'why' of decisions made to readers, aiding in the accruement of trustworthiness of findings. For this study, examination of how personal positionality, interests, and values affected every aspect of the research process was central to authenticating credibility.

3.8 Ethical considerations

This study complies with the requirements for ethical research involving humans as set out by the Tri-Council Policy Statement – 2 (TCPS-2). Ethical approval for minimal-risk clinical study was granted by the University of Northern British Columbia Research Ethics Board in a harmonized review process involving the Northern Health Authority (REB H19-02054). Ethics approval to analyze secondary data was granted by the Research Ethics Board of University of Northern British Columbia for use within this thesis (Ethics Application E2017.1204.084.00H).

Potential participants were provided with an information sheet and consent form after expressing interest in the study. Individuals were then given the opportunity to ask questions

about the study. Verbal or written consent was obtained from each participant prior to the start of the interviews and participants were made aware that they were free to stop the interview, decline to answer any question, or withdraw consent at any time. Although anonymity cannot be guaranteed due to the small study population, participants were assured that every effort would be made to keep their information confidential. Participants also agreed to digital recording of interviews to facilitate analysis at a later date. While no risks were expected from study involvement, participants were aware that discussing clinical events or professional practice could be distressing. To minimize the potential for discomfort during interviews, questions were asked in a sensitive manner and the concluding questions were designed to debrief participants. Data is stored on a password protected computer on a secured network with anonymized participant names; only the researcher (TW) has access to the computer. Data will be stored for five years in accordance with the University of British Columbia data storage policies and will then be destroyed. Participants are aware they are able to have a copy of the findings emailed to them upon conclusion of the study.

3.9 Knowledge translation

Generating applied and relevant knowledge was a key aim from the outset of this study. The target audiences include participants, the public, health system professionals, and academics. As such, upon completion of the thesis, the researcher (TW) will share findings in the following ways: participants who expressed interest in study findings will receive a summary of the research; a presentation will be created and delivered at the Brown Bag Lunch series (a joint initiative between the Northern Health Authority and University of Northern British Columbia to promote health research in the north); a one-page executive summary will

be created and shared with the Northern Health Authority and the University of Northern British Columbia to be distributed online; chapters of the thesis will be published in academic journals; and, findings will be taken to relevant conferences.

4.0 Findings

4.1.0 Introduction

This study explored factors associated with the use of teletrauma in a rural setting. Andersen and Newman's (1973) framework was used to guided inquiry and sensitized the researcher to look for individual, health system, clinician, and geographic factors. Three overarching objectives directed the study:

1. Describe and understand the Robson Valley virtual care program
2. Identify factors associated with teletrauma service utilization
3. Explore the perspectives of clinicians who use or have been exposed to teletrauma

In total, fourteen interviews with participants familiar with or playing a key role in teletrauma use or development were analyzed. Primary analysis included six interviews with physicians involved in rural practice or teletrauma, conducted between December 2019 and February 2020. Eight interviews were conducted previously, between July 2018 and August 2018, with physicians, administrators, and executives. These interviews underwent secondary analysis, whereupon transcripts were coded and reanalyzed for use within this study. The interview questions with physicians (n=6) were designed to explore perspectives on teletrauma for rural contexts, the functioning of a teletrauma program, and how certain patient, clinician, organizational, and geographic factors influence use of teletrauma.

Following analysis of the study data, as guided by the interpretive description (Thorne et al., 1997) approach, four themes emerged as shared their experiences, feelings, and insights into teletrauma for northern rural settings. These included: teletrauma in a northern rural context; factors associated with teletrauma use; teletrauma as a tool to foster team-based care;

and, interconnectedness of the health care system. The following section will provide an overview of the key demographic characteristics of the study participants, followed by an overview of the findings.

4.1.1 Participants. All six physician participants newly interviewed specifically for this thesis have practiced in rural settings in the past or present. Years of experience practicing in rural areas ranged from two years to more than 20 years. Five physicians were family practitioners, while one was an emergency physician. Three physicians worked in the Robson Valley at the time of writing this thesis. The remaining three worked in urban centers but still spent a portion of their time practicing in rural environments, although not in the Robson Valley specifically. Other rural sites included Fort Saint James, Burns Lake, and Fort Saint John (Figure 3). Physicians were familiar with teletrauma systems, or have had to use telehealth for an acute care situation, whereas three physicians had extensive direct experience with the teletrauma program in the Robson Valley.

Of the previous interviewees (n=8), two were physicians in the Robson Valley, one an administrator involved in the set up and deployment of the Robson Valley teletrauma program, one a regional trauma lead, one a health services administrator, one a regional director, one a researcher that evaluated the Robson Valley teletrauma program, and one a Northern Health Authority executive. This group of interviewees had varying levels of familiarity and involvement with the Robson Valley teletrauma program. However, all of the participants (n=8) worked within the Northern Health Authority region and had knowledge of the local context. A list of the roles and locations of focus for primary and secondary participants is shown in Table 1.

Primary Participants (n=6)	Role	Location of Focus
P1	Family physician	Client site
P2	Family physician	Consulting site
P3	Emergency physician and trauma team leader	Client and consulting sites
P4	Family physician	Client site
P5	Family physician	Client site
P6	Family and emergency physician	Client and consulting sites
Secondary Participants (n=8)	**Role**	**Location of Focus**
S1	Trauma and Emergency Lead	Northern Health Authority region
S2	Family physician	Client site
S3	Family physician	Client site
S4	Project Manager	Northern Health Authority region
S5	Health Services Administrator	Client sites
S6	Regional Director	Northern Health Authority region
S7	Researcher	Northern Health Authority region
S8	Health Executive	Northern Health Authority region

Table 1: Roles and Locations of Focus for Primary and Secondary Participants (N=14)

4.1.2 Interviews. Individual in-depth interviews (n=6) were conducted with physicians over the phone with the exception of one which was conducted in person. All interviews took place during the day or early in the evening. Interviews lasted between 26 and 60 minutes and averaged 29 minutes. All interviews followed the protocol as described in section 5. Interviews

were often deep and rich, supported by the personal experiences and feelings of physicians. The narratives provided by participants provided insight into the underlying attitudes and perceptions of teletrauma, rural practice, and telehealth in general. However, several participants noted that they had work-related time-constraints, or had just worked a long shift. Fluidity of the conversation fostered genuine interaction between the researcher and participant, and allowed for spontaneity and intimacy when sharing experiences. This was evidenced by the sharing of many personal stories and feelings. To protect the identities of participants and to make a distinction between primary (n=6) and secondary (n=8) interview data, a labeling system of P1 (Primary 1) through P6 and S1 (Secondary 1) through S8 is used.

4.1.3 Structure of findings. The findings from this study are presented under four themes to answer the research question and present new ideas that emerged. Throughout the interviews, participants (n=6) were asked specific and broad questions regarding the function of teletrauma, factors associated with system activation, and their personal experiences of practicing in rural settings. For example, participants were asked to describe their experiences using teletrauma, and to identify specific situations when they found teletrauma most beneficial. The questions elicited rich accounts of rural teletrauma utilization, revealed the nuances of rural practice, and provided insight into the role of telehealth for rural sites in the context of trauma. Data collection and analysis occurred iteratively, each informing the other, to aid in the development of an integrated, deep understanding of physician perspectives. These findings were compared and contrasted with pervious interviews (n=8) to enhance understanding from unique perspectives and different levels within the same health system.

Four major themes emerged throughout the analytic process. The first describes how teletrauma is used in a northern context in addition to barriers and facilitators to use, and factors associated with increased teletrauma utilization. The second is factors associated with teletrauma use. The third is that teletrauma is a tool to foster team-based care built on strong interprofessional relationships; teletrauma is more than just the technology being deployed. The fourth is the concept of interconnectedness as the unifying concept that binds rural clinicians, teletrauma, and team-based care, and how clinicians are vital to successful teletrauma models. That is, technological solutions to rural health care delivery should be clinically-driven and clinician-led to best reflect the nature of rural health care delivery. The themes are discussed below to provide insight into physician perspectives, the role of teletrauma in a northern rural context, and telehealth more generally.

4.2.0 Teletrauma in a northern rural context

4.2.1 The Robson Valley teletrauma program. Teletrauma in the Robson Valley was initially implemented for emergency room use. Telehealth carts were placed in the remote emergency room and had to be plugged into a wall outlet. Clinicians would have to log in to the system, phone the consulting site to ensure their system was powered on, place a call, and then have the call accepted by the consulting site. Once activated, the cart would be connected directly to a fixed wall unit in the trauma bay at Prince George's hospital. Physicians in the Robson Valley also had access to the system from their homes. When connecting directly with specialists in Prince George, only physicians would use the service. When used locally between McBride and Valemount, nurses, medical students, and physicians would use the service to communicate with one another.

The system was used during several trauma and emergency cases since it was deployed. As mentioned by one participant,

> We had a severe major trauma patient that presented [to the Robson Valley] and we were able to help McBride run that case to provide I guess resuscitation and had that patient go in the back of the ambulance with the physician and make it to Prince George and continue on the care, so it worked fantastic. (S1)

Another participant (P5) described a scenario in which the system was successfully used to perform a cardioversion with the help of a remote specialist. While teletrauma may be used to accurately triage and rapidly transfer patients, there were several instances where the service was used to provide local early management of a trauma case prior to transfer. This participant also reported their use of teletrauma to stabilize a trauma patient by performing a thoracentesis and inserting a chest tube on the advice of a remote specialist. Thus, triaging, patient stabilization for transfer, and early clinical management of trauma patients have been notable uses of teletrauma in the Robson Valley as identified by participants.

4.2.2 Facilitators to teletrauma use. The facilitators that were helpful to use teletrauma, were typically identified in the context of how teletrauma had evolved in the Robson Valley, as the system was adapted to facilitate use. Facilitators of teletrauma use included the specific characteristics of the technology and the relationships between the clinicians using the service. The seamlessness of the technology was a factor mentioned by three participants, a characteristic not attributed to the older teletrauma carts. That is, the process of activation and functionality during a call was simple and effortless. One participant stated,

> Your applications and the way that you call people, it needs to be simple, simple, simple… and, you know we've changed that whole process… so you don't have to do a phone call anymore to get somebody in. You just now click a name on the screen and it goes through to that doctor immediately. So it's as simple as that. (P5)

This is in contrast to older inefficient systems that would require the user to "log in and enter a billion passwords and set up a meeting" (P1). Or, for fixed-unit systems, the cart may become unplugged, moved, or powered off, hindering timely activation. The efficiency and simplicity of the activation and consultation process were key aspects facilitating teletrauma use. Participants often used the analogy of a telephone to exemplify simplicity of a teletrauma system: "[teletrauma has] got to be as reliable, easy, and simple as the phone… and the closer we can get to those with that video enhanced option, I think then we'll start to get adoption in a more meaningful way" (P1). Another, comparing teletrauma to the ease of use and familiarity of telephone, mentioned "the reason smartphones work so well is because people use them hundreds of times a day… so in our case, [teletrauma is] very normalized so that nurses activate it, you know, in a very methodical way" (P2). Thus, when the technology is familiar, it is easier to use thereby facilitating effective system utilization. Comparing teletrauma carts to iPads, one rural physician stated, "the issue [with teletrauma carts] was that it was not user friendly at all… so with iPads, everybody is kind of well aware of the technology, you know, and it's simple, easy to use" (P5). These technological developments have facilitated teletrauma use by making the consultation process seamless and effortless.

Flexibility of the technology to receive clinical input was also important. These included mobility of the system, multi-caller capabilities, and resource accessibility. One participant used

an example of holding the camera to view diagnostic results or images: “if they want to see an ECG, we again just move the iPad to see the ECG… and then if we do, like, an ultrasound… we just move the iPad so they can see the screen of the ultrasound” (P5). Camera mobility is particularly useful during trauma cases, enhancing accurate assessment and effective management. As noted by a consulting site emergency physician, “a better usage of this teletrauma would be, you know, visualize. Somebody having a camera and going around and saying, ‘okay, here's the monitor, here's what the patient looks like, here's the wound’” (P3). The ability to access necessary resources in a timely manner was also mentioned. One participant stated the reason they chose one app over another was for its ability to easily select and involve multiple individuals on one call (P4). Another made a distinction between telehealth carts and iPads emphasizing the ability of iPads to effortlessly involve multiple callers (P5). Because trauma cases often require teams of clinicians and specialists to adequately manage the patient, multi-caller ability is an important characteristic of teletrauma technology.

Another major concept identified by participants that facilitated use of teletrauma was interprofessional relationships. Participants frequently mentioned the importance of relationships, trust, and mutual understanding of site capabilities as being vital to teletrauma utilization. Rural physicians have expressed their hesitation calling a consulting clinician “because you don’t want to waste their time” (S2). But, when rural physicians “know [the consulting clinicians] by name, you know their faces and you know that they’re fine accepting your calls whenever, then it makes it so much easier to push that button” (S2). The ability to simply visualize the patient, rural and consulting clinician, was noted as being a determining factor for a positive teletrauma encounter; “it is more likely that you're going to get a negative

encounter when someone's got less riding on it; they don't see your face, they don't see the patient's face, they don't see what you're dealing with" (P6). That is, apprehension to call a consulting clinician was reduced when teletrauma users were familiar with one another and have an established interprofessional relationship. The visual component to teletrauma also helps to develop a mutual understanding of site resources and capabilities. Put by one rural physician, "they don't always realize what we're dealing with here… but if I can go, 'let's livestream with the patient and I will show you what I'm seeing,' I feel like it will be often more receptive" (P6). Another reported that "understanding of context" and "having the expertise [rural physicians] need" (S3) were desirable qualities of the consulting site clinicians. Locally, relationships between clinicians were noted as being key to delivering care remotely; "I need to know the person that's on the other end of the phone. If I don't know that person, if I haven't worked with them, if I haven't met them face to face, it's far more difficult" (P1). Three other participants echoed this finding. This mutual understanding of resources and capacity may help to share the responsibility of care between sites resulting in rural clinicians feeling more supported.

Participants identified several facilitators to teletrauma use including technological aspects and characteristics of teletrauma users. Most notably, participants mentioned the importance of seamlessness and simplicity of the consultation process, and flexibility of the technology to accomplish clinical means. It was also identified that strong interprofessional relationships between those using the service facilitate teletrauma use.

4.2.3 Barriers to teletrauma use. During the interviews, participants were asked to reflect upon the barriers of teletrauma use in their field of work. Reported barriers included

ease of use, familiarity with the technology, and workflow changes at the consulting site. Within the Robson Valley virtual care program, various aspects of the technology presented challenges to teletrauma users, particularly with the older teletrauma carts that were initially deployed. For those located in the Robson Valley, the arduousness of the teletrauma cart was identified as a key barrier to its use. One participant commented:

> [If] you needed to plug something else in and forgot to plug it back in… or [clinicians] needed the space to hang something else for whatever reason and so then the carts had to be moved and things took a little bit longer to set up, then it might not be their go-to, they might choose the phone for some things. (S4)

These issues were echoed by a rural practicing physician who stated "when we used those old carts, if we tried to do a video call, everybody ran away because they knew how difficult it was... [and] the cart was connected to a land port, so you couldn't move it around" (P5). Lack of simplicity of the system was frequently cited as a reason to abandon teletrauma during a real-time case; "I've been in situations where I fumbled with technology… [and] very quickly abandoned the video option… because of the fact that we needed timely connectivity and it wasn't happening with the with the technology" (P1). Thus, the lack of portability and simplicity of the system was a major barrier to teletrauma use and often resulted in participants using alternative modes of communication.

Workflow changes at the consulting site was an issue consistently reported by physicians, administrators, and others. A consulting site physician noted that "it's pretty tough for us on this end to commit ourselves to utilizing [teletrauma] while we have a really busy department with a three, four hour wait constantly" (P3). The physician then elaborated on the

potential burden that multiple peripheral sites using teletrauma could place on consulting physicians: “we only have one main hospital… and probably 8 peripheral hospitals, right? So if every department had [teletrauma] and they get to using it then that would put a lot of pressure on our department” (P3). A researcher described the potential workflow challenges as increasing “overcrowding virtually” (S7) of the consulting emergency department, whereupon virtual consults may increase the workload of consulting sites that are already overcrowded.

Lack of familiarity with the technology was another barrier to use. As stated by a rural practicing physician, “when you have other pieces of equipment that you don't utilize as much, you tend to have to re-familiarize yourself with it… it’s not intuitive… it’s not automatic” (P2). If the system is not regularly used, the activation process and use during a trauma case may become less timely, resulting in increased stress on the physician while they are attempting manage often life-threatening medical situations. One administrator noted the impracticality of having to read an instruction sheet during high-stress clinical situations when “you’re not used to using [the technology] and when you’re in a panic or your adrenaline is high” (S4). As a result, many rural physicians have dismissed the teletrauma system and reverted to the familiar, such as telephone. In summary, a variety of barriers were identified and these relate to the practicality, portability, and usability of the system within the context of real-time clinical trauma care.

4.2.4.0 Effects and outcomes of teletrauma. Several notable effects of teletrauma were identified, including the potential for organizational cost savings, increased local management of patients, improved health outcomes, and enhanced confidence for clinicians. These were categorized according to Bodenheimer and Sinsky’s (2014) Quadruple Aim: cost optimization,

patient experience, provider experience, and population health. A rural physician (P4) and a Northern Health Authority executive (S8) noted the importance of the Quadruple Aim (Bodenheimer & Sinsky, 2014) when examining the effects of teletrauma across the health system. Responses to the teletrauma survey administered to participants are also reported.

4.2.4.1 Teletrauma survey responses. As a part of the interviews, participants were asked to rate their experiences using teletrauma on a five-point Likert scale (Figure 8). Overall,

Statements	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)
I was able to communicate clearly and effectively using the teletrauma technology (n=4)	75%		25%		
Use of tele trauma has changed my clinical management plan (n=5)	40%	60%			
Use of tele trauma facilitated timely access to appropriate care (n=5)	80%	20%			
I believe teletrauma to be helpful in the provision of high quality trauma care (n=5)	80%	20%			
Teletrauma is beneficial for patients (n=5)	100%				
Teletrauma is beneficial for providers (n=5)	80%	20%			
When in-person evaluation is not available, teletrauma is an acceptable alternative (n=5)	60%	40%			
Overall, I am satisfied with the teletrauma service (n=4)	50%	25%	25%		

Figure 8: Participant Responses to Teletrauma Survey (N=5)

five of the six participants responded to the survey questions. One participant declined to answer any of the questions due to a perceived lack of experience using teletrauma. Some of

the participants refused to answer a particular question because of limited experience or relevance to their teletrauma encounters.

All respondents strongly agreed that teletrauma is beneficial for patients. Eighty percent (n=4) strongly agreed and 20% (n=1) agreed that teletrauma is beneficial for providers, helps in the provision of high quality care, and facilitates timely access to appropriate care. When asked about the acceptability of teletrauma when face-to-face is not available, 60% (n=3) strongly agreed and 40% (n=2) agreed. All respondents (n=5) strongly agreed or agreed that use of teletrauma changed their clinical management plan, however the proportion of those who strongly agreed (40%) was notably less than for other statements. The most dispersed set of responses were for the statement regarding satisfaction with teletrauma; 50% (n=3) of respondents strongly agreed, 25% (n=1) agreed, and one responded with 'neutral.' Seventy-five percent (n=3) strongly agreed that they were able to communicate effectively using teletrauma, with one neutral response.

4.2.4.2 Cost optimization. No participants reported actual instances of cost savings for the health system that had occurred as a result of using teletrauma. Four participants noted the potential cost savings of the teletrauma system. For example, one physician remarked on the lower prices of new technology as compared to the previous teletrauma equipment in the Robson Valley (S2). Another described how increased local management of patients could decrease costs by reducing the number of emergency room visits and cost of travel (P4). However, one participant said that cost savings should not be the objective of teletrauma:

> If it's just about saving money, there may or may not be a good outcome to the organization. So for instance, the cheapest outcome for a trauma is if the patient dies,

just to be fairly blunt. Because then they don't get into hospital, they don't get to ICU or whatever, so that's cheap, that's a good [return on investment]. (S3)

On the other hand, one administrator highlighted the importance of examining redundancies during care management as a result of using teletrauma (S6). That is, if the consulting clinician directed the rural physician to perform diagnostic tests during the teletrauma consult, would these tests then be repeated again at the larger facility after the patient arrives thereby increasing organizational cost.

4.2.4.3 Patient experience. Teletrauma had many notable effects on the patient experience, including increased satisfaction and decreased costs associated with travel. Teletrauma may enable patients to remain in the community for treatment thereby saving travel costs and resulting in satisfaction with the health event. A health administrator gave an example of a case where transfer was avoided through the use of teletrauma and the patient was able to be discharged locally (S1). The participant went on to characterize this situation as "[bringing] the care to the patient" (S1). A physician corroborated this finding, describing the situation as "a real win-win" when they could manage patients locally and prevent transfer (P2). Participants also identified that patients using the teletrauma system saved money that otherwise would have been spent on travel. However, it was mentioned that the family or support system would typically have to absorb the cost of travel; "in a trauma situation, it's not just the cost to the patient, it's the cost to all the family and support providers… people have to stay in hotels and they have to catch airplanes… it's a huge burden" (S5). The cost savings also extended to non-trauma patients. As one physician explained,

> There are also huge cost savings involved… typically if you are to get an appointment for cardiology, it would take about three months to get an appointment. And, you know, then the patient needs to travel down to Kelowna, which is a 500 kilometer drive, and then spend a night or two in a hotel, and then they see the doctor for 10 minutes, you know, then they come back… So those kinds of cases are really helpful to just have access to somebody immediately. (P5)

A researcher had a similar response, giving an example of when telehealth is not available and a transferred patient has to miss work for an extended period of time, arrange childcare, and find a means of transportation back home (S7). As a result of remaining in the community, thereby saving money and reducing travel risk, patients were reportedly satisfied with their health events. One physician stated that patients have had very positive experiences with teletrauma (S2). Furthermore, satisfaction with the health service encounter extended to the family as well, particularly in trauma situations; "if you have a big case where we have to resuscitate… the family thinks you probably didn't do everything you could. But if there's a specialist in the room [virtually], they immediately feel much more comfortable… like everything was done" (P5). Thus in trauma settings, cost savings and satisfaction with health care were not isolated to the patient. It was consistently identified that the family or support unit benefited from teletrauma.

4.2.4.4 Population health. Participants frequently discussed effects of teletrauma related to the population health domain. It was identified that teletrauma improved care outcomes, enabled more appropriate transfers, and increased diagnostic accuracy. Three participants explicitly mentioned that teletrauma use saved lives and enhanced patient safety.

One physician stated, “I've heard stories across the province where a physician has told me that, you know, without [teletrauma], the patient would be dead” (P1). This was echoed by a rural practicing physician who stated, “hands-down, there's no way telehealth does not 100 percent improve patient care,” particularly for traumatically injured patients (P6). Multiple participants also provided examples where, as a result of teletrauma support, patients were able to be appropriately stabilized prior to transfer, reducing the risk of adverse outcomes during transport.

In addition to safe patient transfers, teletrauma also facilitated transfers that were more appropriate. One physician noted, “our biggest issue here in rural towns is to get patients out that need to go out” (S2). This was echoed by an administrator who stated, “ultimately a transfer may be needed, but it’s that being able to maximize when a transfer is appropriate and maximize the preparation for a transfer” (S7). For patients in the Robson Valley, teletrauma helped to identify those who needed to be transferred and reduced unnecessary transfer. One rural physician mentioned that this also applied locally:

> Now you can see the patient via video link and you can already decide ‘do I have to get this patient to travel this way or is it something that can be dealt with locally?’ And we had several cases where patients did not have to travel just because we had direct access and we could decide, make a better decision. (S2)

When discussing transfers, participants also referred to the appropriateness of the consulting site. One participant elaborated on appropriate transfers as “[diverting] to a better center based on earliest or earlier specialist involvement” (P1). Thus, patients who needed to be

transferred were identified more rapidly as a result of specialist involvement and unnecessary transfers were reduced.

Diagnostic accuracy was enhanced through the use of teletrauma. Particularly in situations when rural clinicians were uncomfortable, teletrauma facilitated accurate diagnosis and proper care. It has been noted that the use of teletrauma changed the clinical management of several patients. One physician in the Robson Valley recounted an emergency case whereupon early specialist involvement via teletrauma changed the clinical management of a pediatric case, preventing an adverse outcome (P4). The physician went on to describe that if the clinical management plan had not changed, the outcome "would have been not good" (P4). Another physician in the Robson Valley noted that as a result of the change in care, "we've had cases that I think had really good outcomes because of the fact that we had early intervention from specialists that guided us" (P5).

4.2.4.5 Provider experience. A notable impact of teletrauma was increased support for rural clinicians professionally and personally. The importance of this outcome was put into perspective by on rural physician:

> Obviously [teletrauma] helps patient care. It can help improve outcomes. It can save lives. It can reduce costs. Those are all kind of the typical ones. But I but I would say, as importantly or more importantly, it improves the quality of life of the nurse on the ground. So instead of them working in isolation and being super stressed, their stress goes down because they're well supported. (P2)

This finding was evident in nearly all interviews with participants. Physicians typically talked about the anxiety associated with rural practice particularly when faced with difficult or

unfamiliar situations. Rural physicians felt more supported, experienced less anxiety, and were more confident providing care when using teletrauma; “for the physician that needs to manage these cases, it decreases your level of anxiety significantly to just have somebody else there that can share decision making and responsibility” (P5). Another stated “we deal with very difficult situations sometimes that we don’t have daily experience with and it really decreases my levels of anxiety significantly if I know I have somebody that can back me up in a difficult situation” (S2).

Teletrauma also enabled professional development, making rural clinicians more confident when faced with similar patient presentations in the future. That is, clinicians were more confident independently providing care in cases they had previously managed using teletrauma; “what I found in my experience is you do a few difficult cases with a specialist on the other side and then you have enough confidence to do the next one on your own” (S2). One physician in the Robson Valley remarked that as a result of teletrauma use, “there's a lot of patients that we would have sent out previously that we're now comfortable dealing with locally” (P5). Thus, participating in the care of patients who otherwise would have been immediately transferred provides learning opportunities for rural clinicians and supports professional development.

Furthermore, teletrauma facilitated the mutual understanding of context between sites. For example, rural clinicians felt more supported when they knew that the consulting site understood their capabilities and resource limitations. One rural physician explained that as a result of using teletrauma, “[consulting clinicians] actually have a better understanding of what services we can do and can’t do in Valemount” (S3). An administrator reported a similar effect

of teletrauma: “I think too there will be an appreciation of what sites have and what sites don’t have and what maybe even regional sites can offer” (S1). This insight into rural practice afforded by teletrauma also affects emergency medicine more broadly. One researcher noted these far reaching effects:

> One of the things that I thought was notable was how [the development of mutual understanding] then informs people that may be teaching in teaching hospitals or through the Faculty of Medicine, through the emergency department, Department of Emergency Medicine, how that enriches the faculty members to be able to speak to emergency practice not just in urban or regional sites, but what that’s like across the province in rural and remote areas. (S7)

Through teletrauma, a clearer picture is uncovered of what emergency medicine looks like for northern BC, not being isolated from urban centers. Consulting sites may then be more aware of the needs of rural sites and more receptive to providing timely support.

As a result of increased clinician support and mutual understanding, teletrauma improved the quality and efficiency of care delivered by rural clinicians. One physician noted, “if I feel supported, I’m likely to give better care. Because if I’m not feeling frantic, I’m going to be calmer, make clearer decisions and be more confident about the decisions I make” (P6). More confident decision-making in the rural emergency room also allows for optimization of workflow. The same physician noted how the confident clinical management of a patient allowed her to move on to subsequent cases:

> If I know that, you know, that the splint is appropriate and that this is appropriate, it also gives me a certain amount of freedom to carry on to my next case. I can carry on

> with the next patient without having to panic running backwards and forwards to have to go check the ankle pulse or the tie. (P6)

The optimization of care processes also extended to patient transfers, enabling more timely transfers between facilities. One participant remarked on the optimization of transfers as a result of teletrauma; “now you can get a specialist on the line who can actually see the patient and see the situation that you’re in and we’ve definitely experienced that is easier to get those patients transferred out” (S2). The same participant elaborated that previously, a transfer would take two hours to arrange and then would often get declined. However, the use of teletrauma has optimized the transfer process, creating “a much easier situation” (S2).

4.3.0 Factors associated with teletrauma use

During the interviews, the participants identified numerous factors that were associated with teletrauma utilization, and telehealth more broadly, were identified. Upon analyzing the data, these were organized into individual determinants and health services system factors, guided by Andersen and Newman’s (1973) framework. Individual determinants are comprised of patient-specific and illness factors, whereas the health services system category includes organizational factors, clinician characteristics, and the physical environment.

4.3.1 Individual determinants. Across the interviews, specific signs and symptoms, injury types, or interventions were found to not drive teletrauma use. While several participants described clinical cases in which teletrauma was useful, participants did not associate patient demographics or specific physiological markers with increased likelihood of using the system. Put by a rural physician with more than 10 years of experience using telehealth for emergency situations,

> So whatever the emergency is, is what we use it for. So we've done cardioversions. We've done joint dislocation that need to be reduced. We've packed, you know, serious nosebleeds. We've treated pre-term labor. We've treated sepsis, sick kids, sick elders, broken bones. I mean, the list is endless. (P2)

When asked whether or not there were specific patient profiles within the trauma category for which they would activate the teletrauma system, participants responded with several examples. These included neurosurgical patients, motor vehicle accidents, and major trauma. However, considering the wide range of situations reported by participants in this regard, patient characteristics were not found to be associated with increased teletrauma use. One participant highlighted this finding: “I think [teletrauma use] depends on the cases, you know, so it depends on what comes in our emergency door. I don't think there's a specific patient that we deal with… so it varies considerably” (P5). Another had a similar response regarding teletrauma, stating that “telehealth is used for, you know, to treat emergencies. And so whatever the emergency is, is what we use it for” (P2). Particularly in small sites where clinicians are not exposed to a large number of trauma or emergency cases, patient characteristics were not identified as driving teletrauma use.

4.3.2 Health Services System. Clinician characteristics were the most commonly cited reasons for activating teletrauma, particularly when clinicians were unfamiliar or uncomfortable with clinical management. One mentioned that it is those cases which cause anxiety and fear when teletrauma is especially helpful and may be activated more often (P5). This finding was echoed by several other participants. A rural clinician in the Robson Valley stated, “I think we kind of use [teletrauma] when we think we're going to potentially run out of

ideas in our plans, then we just use it… if I feel incapable of managing this on my own, I phone these guys" (P5). Another physician, practicing outside of the Robson Valley, commented on clinicians' comfort level as being associated with teletrauma use:

> I think anything that makes nurses uncomfortable dealing with [acute patients] in isolation is what's most useful. So I wouldn't focus on the medical problem. I would focus on the challenges on the local care team on the ground. So making their life better, if they're super stressed out about- and obviously, the sicker the patient they have in front of them, the more stressed out they're going to be, because they work in isolation. That's where I see the most value. (P2)

This finding was also relevant at the local level. One physician described how it is the nurse's comfort level with a clinical situation that ultimately determines their willingness to use telehealth between McBride and Valemount (P1). The interdisciplinary aspect of the care team may also be a driving factor; speaking of the necessity of team-based care by including northern-trained nurses, P3 mentioned that "[health organizations] have to start utilizing and maximizing the cognitive potential of the other professionals that work with the situation." He went on to describe that many emergency rooms are "nurse-run departments" where "a lot of the procedures are done by the nurse [and] decision-making is shared." Another physician mentioned how often nurses reach out to physicians using telehealth: "I don't think there's a day that goes by when the nurse doesn't reach out to one of the docs on call" (P2).

The rural setting was another reason cited as contributing to clinician anxiety and subsequent activation of teletrauma. One consulting site specialist noted that the wide range of clinical situations that rural clinicians have to be prepared for contributes to anxiety when

practicing rurally (P3). Put by another, “what typically happens with the rural [physician] is we don’t deal with [trauma] cases often enough to get really good at it” (P5). Thus, clinician characteristics, shaped by the environment and clinical context in which they practice, influences the threshold to use teletrauma.

Three participants described how organizational factors may be associated with teletrauma utilization. These included local resources and volume of exposure to clinical cases. For those sites that see trauma infrequently, clinicians may be more likely to activate the system. As described by one physician, “if you have a very low volume site for trauma, a very low volume site, they are the sites that will likely use [teletrauma] more” (P3). That is, less trauma exposure contributes to a lack of familiarity with clinical management, decreasing clinician comfort which then lowers the threshold to use teletrauma. A physician in the Robson Valley also mentioned site resources as contributing to a higher likelihood of activating teletrauma, particularly for “those [patients] whose immediate medical needs are beyond the facility that’s dealing with them” (P1). One specified that the lack of immediate access to a neurosurgical specialist contributed to teletrauma utilization (P6), whereas another identified a lack of general surgeons (P3). Thus, site resources and case volumes play a role in the rural clinicians’ decision to use teletrauma, although these factors were less reported by participants.

Aspects of the environment also influenced teletrauma utilization, including weather and physical location. Poor weather, for example, often forces rural clinicians to treat the patient locally in the event that they are unable to be transferred. One rural physician explicitly mentioned the low threshold to use teletrauma during poor weather conditions (P4). During

time-sensitive situations, extended local management caused increased stress on clinicians. A case was highlighted by another physician from the Robson Valley:

> For instance, if we have somebody with a myocardial infarction, if the weather allows, those people can be out within an hour by plane. But if the weather does not allow, you know, and the roads are bad, those patients often end up staying our emergency room for up to seven, eight hours. And then, you know, the [physician] needs to deal with all the complications and stuff that might come. And it's been very helpful to have an intensivist that can again guide you through all these things. (P5)

For trauma patients, teletrauma utilization when patient transfer is delayed is vital to safe patient care and appropriate management. The same physician noted that during extensive trauma cases, the situation may be exacerbated due to the timeliness of care required; “you end up having to look after those patients for an extended period of time, you know, without the real training and the capability of doing that. So [teletrauma] is an awesome way of dealing with these cases” (P5). This finding was echoed by a consulting site physician who commented on the utility of teletrauma for stabilizing patients prior to transfer, so that patients have less risk of deteriorating when weather impedes timely transport (P6).

The location of the communities also plays a role in exposure to risks and the potential of needing to use teletrauma. Because the Robson Valley is located on long stretches of highway, there is a risk associated with travel. One participant from the Robson Valley gave an example of a patient who was referred for diagnostic imaging and died along the highway after being involved in a motor vehicle accident (P5). Another physician confirmed this finding: “we have had people travel on roads and communities for something that's minor and routine and

die because of being in a road accident... probably one person a year the last two or three years" (P4). Thus, geographical factors such as inclement weather and large distances between sites, particularly in the context of travel risk, affect rural clinicians' threshold to use teletrauma.

Across interviews with participants, organizational factors, clinician characteristics, and geographical factors were drivers of teletrauma utilization. These included poor weather and travel risk, lack of clinician confidence or comfort, lack of local resources and the need for a higher level of care, and decreased case volume. Specific patient factors were not reported by participants as being associated with teletrauma use.

4.4.0 Teletrauma as a tool to foster team-based care

Teletrauma was consistently discussed in terms of its reliance upon strong interprofessional relationships and suitability for the rural context. The technological component of teletrauma was noted as being important yet not a vital piece of program success. Although the technology is one aspect to consider, the impetus of teletrauma is its ability to connect clinicians and establish an effective team-based model of care. Thus, teletrauma moves beyond the technology it utilizes and instead is viewed as a tool by which to enhance communication and build relationships.

4.4.1 Teletrauma is more than the technology. Technology continues to play an important role in successful teletrauma deployment and utilization. Participants identified several technological aspects that were fitting for the rural trauma setting. These included a "camera that would either be wearable or… that you just hold" (S4), the ability to "get multiple people in [on the call]" (P4), and seamless activation; "it's not going to be something where you

need to log in and enter a billion passwords and set up a meeting" (P1). These characteristics suit the trauma context given the timeliness required for treatment, involvement of several parties simultaneously, and the need to examine injuries or diagnostics images up close and from different angles. However, technology alone is not key to successful teletrauma consultation. As noted by one participant, "the technology can make [teletrauma] better. Don't get me wrong. But, you know, the technology isn't the solution. It's just a part of the solution" (P1).

Across the interviews, it was consistently noted that the potential of teletrauma is being limited to the characteristics of the individuals using it. When talking about the ideal technological components, participants frequently mentioned caveats to successful teletrauma use including user attitudes, mutual understanding of site resources and capabilities, and rapport with the other user. That is, even if the teletrauma system had been designed with the ideal technology, poor attitudes and anonymous users may limit the capabilities of teletrauma. As put by one rural physician,

> If you can build those relationships with the doctors, you know them by name, you know their faces and you know that they're fine accepting your calls whenever then it makes it so much easier to push that button and say 'listen I just need a quick answer on this question, please help me.' (S2)

Another mentioned that "you want someone nice, when I say nice, someone who wants to be there, wants to be helpful, who understands the context" (S3). Thus, the effectiveness of teletrauma can be limited by the attitudes of the individuals who are using the service. While technology can support or detract from the effectiveness of teletrauma, participants identified

that it is not the major driving force of successful service utilization. One participant, speaking with regards to a successfully deployed teletrauma program, stated that “ninety-five percent of what made [the teletrauma program] fantastic was the attitude in the group of specialists supporting it. It was not the technology. The technology was five percent of it” (P1). This perspective was echoed by three additional participants. Another stated that “relationships are always the pivotal piece. The technology supports the relationships, but it doesn’t define them” (P2). He went on to describe how successful teletrauma programs need to be relationship-based; “if it's an anonymous program by, that is, anonymous people, anonymous technology, I think that that's less likely to be of value to the average rural physician and patient” (P2). Thus, while teletrauma can be supported through appropriate technology that aligns with clinicians’ needs, relationships are the main driver of successful teletrauma use. As put by one participant, “if I can leave one impression in your ear, it’s that I really do think technology is wonderful, but it’s really about the relationships and the people” (P1).

Beyond the technology, teletrauma is a tool through which to foster interprofessional relationships and support effective team-based care. One participant gave an example of acting as a secondary provider during high-acuity situations and the resultant effect on the psyche of the treating physician:

> So when I do anesthesia and I'm called into, for example, I'm called into a difficult airway, the primary provider is very nervous because they're there alone, right? And whereas I can be the secondary provider and I am not nervous because it's not primarily my case. Yet, I'm there to help. So the psychology of trauma is different if you're the

> secondary provider, right? So that is the biggest benefit to any communication, is that the secondary provider can have a different psychological point of view. (P3)

In situations when rural clinicians feel vulnerable or uncomfortable, teletrauma supports a team-based model of care by facilitating secondary provider involvement. The technology facilitates this interaction but does not define it. As a result, clinicians feel more supported particularly in high-stress situations; “and, I mean, it's a huge help… when I'm taking care of something that I'm having difficulty with but I know that my colleague just walked in… and often, my heart rate goes down if they just kind of walk in and say ‘hey [P3], can I help?’ It's like, ‘thank God you're here’” (P3). Successful teletrauma use therefore relies on existing relationships and simultaneously enables the development of these relationships to reach the goal of effective team-based care.

4.4.2 Teletrauma as a dynamic, fluid service. Teletrauma is dynamic and evolves from within the rural context and as driven by clinicians who use the service. That is, after a teletrauma program is established, the system can be used in different ways as clinicians discover situations in which it is useful. Additionally, technological components may be altered or adapted. Despite being deployed for use within a particular set of circumstances, teletrauma may be adapted by clinicians and based on clinician need and local context.

Over time, clinicians developed uses for the service outside the context of trauma and emergency care. One participant described using the service to manage a simple laceration: “I actually had a relatively simple laceration that I had a medical student sew up in Valemount when I was in McBride. So that was done over video” (P1). Another mentioned that the service had become a part of a weekly routine for clinicians in the Robson Valley to meet and discuss

cases (P4). Thus, while the initial focus of the program was emergency care support, the service had evolved into use for minor cases, group meetings, and ward rounds to suit the local context of care delivery. Put by a practicing rural physician, “the clinicians on the ground, how they see this tool being helpful to them and their patients changes over time the more they use it” (P2).

Teletrauma extended to the pre-hospital setting, used as proactive communication for high-risk situations and community events, streamlining access to emergency services. A participant described how nurses began using video calls during mountain bike races to remotely connect with physicians, “and if there’s an injury, they just call in on the same video system and they show us the injury and they say ‘we’re sending this patient down in the ambulance, get ready for this’” (P5). The service has also been used to remotely triage minor cases within the Robson Valley and decide whether or not an in-person consults was necessary by traveling between the two communities. As described by the individual who set up the program,

> So if the McBride doc was covering Valemount, he could stay in McBride and the nurses could run the system and he could call in from his house and do a quick consult to see whether he needed to go into the clinic or if they needed to send them through to Prince George or if they could return the next day in regular business hours. (S4)

A physician in the Robson Valley elaborated on this particular use of the service, stating that they could remotely view the case and decide whether or not to travel to the other community to see the patient in-person; “so sometimes it's something simple that can wait till the next day or, you know, a possible fracture. That's not going to change your management by waiting another day or so. So it's really helpful to sort those things out” (P5)

Duration of use varied by clinical context as well. Because complex cases were often managed with the help of specialists at the Prince George site, call duration was longer for more severe cases. Calls for patients managed locally were often shorter because the cases were minor. Reported length of use ranged from “maybe five, 10 minutes” for minor cases, to “maybe 20 minutes, 40 minutes” for more complex cases (P4). Another stated that for local cases, “that might be a 10-minute or a 15-minute call” and for “big emergency cases where we got specialists into those cases, it might be for an hour” (P5). Frequency of use also varied by intended use. Put by one participant, “we used it probably at least once a month, sometimes twice… that’s for specifically with a specialist in Prince George. But we used it much more often locally (P5). Another, referring to local use of the system, stated “we actually use it every Wednesday morning. I just call in and check in with the group. So every morning they do a morning huddle at 8:30 in the morning” (P1). Despite the intended purpose for the program when implemented, clinicians have adapted use of teletrauma resources to suit their local needs. Adaptability of the service, whether it was originally intended or not, has led to successful use in several unique circumstances that reflect the context of rural health care delivery.

Malleability of telehealth programs is important as clinicians and care context ultimately determine the technology; technology does not drive care. Even though programs may be deployed with a narrow clinical focus, as in teletrauma, clinicians and the local context shape the purpose, design, and use of the system. In the Robson Valley, for example, previous experience with teletrauma has driven technological adaptations and the procurement of new technology to best support the local context. Although the technological components of the

telehealth cart could not be modified, clinicians' experience using the system provided insight into which technologies would work best for future systems. After the Robson Valley virtual care program, clinicians began using simple, mobile technology with multi-caller capability and seamless activation. This included an iPad between emergency rooms and an online application to support videoconferencing on iPads. Drawing a distinction between the activation process of the older telehealth carts and newer technology, one participant stated,

> Simplicity of the system is so important. If it's easy, then it's easy for people to buy into that and to use the system. But if it's a long drawn out process to contact somebody then, in an emergency situation time is of the essence [and] you don't have time to go through those kind of procedures. (S2)

Another participant reflected on the importance of technological adaptions as being clinician-led and driven by the clinical interface; "so it's not what somebody thinks might be a good idea, who has no connection with the clinical service. But it's driven by people who are delivering the care which I think is really good" (S3). Use of teletrauma beyond the intended purpose of the system was also highlighted by a consulting site physician: "I think [teletrauma] could be used for anything critical care wise or really any clinical question that the peripheral site has. So it's role isn't really that understood. It's certainly underutilized, like grossly underutilized" (P3). Thus, technological development and 'off-label' uses of teletrauma are inevitable and are determined by the needs of rural clinicians.

4.4.3 Goals of teletrauma. Several goals of teletrauma for a northern rural context were identified. These included characteristics of the technological design and function of the service.

For service design, it was consistently noted that rural clinicians want a teletrauma service that is adaptable at the point of care. That is, clinicians want technology that adequately reflects the context in which they practice and has the ability to adapt to the situations they encounter. The underlying principles identified were versatility and usability of the service. Put by one participant,

> Once people gain experience with what [teletrauma] looks like, the technology, how they manage patients using it, they start to develop new ideas in their mind about, oh, I could actually use this for something else too, or that. So that kind of stretching of the opportunities for the technology in the context which that rural physician works is undoubtedly shaped by the experience they initially start with. And then you just go from there. So in other words, they have no idea where it's going to take them. The important part is to start and then they start to see all sorts of new opportunities that they can't see at the beginning. (P2)

Although teletrauma programs may be initially deployed for a particular set of clinical uses, participants highlighted the importance of clinical versatility. As mentioned by one rural clinician, “especially if you're a provider in a small community with a doctor, you're a provider of many things not just an 8 hour shift in [emergency]” (P3). To support a versatile service, it is vital that use of the technology is not restricted to accomplishing only a clinically-narrow set of tasks. Instead, it was found that the technology should be adaptable and driven by the care that rural clinicians deliver. One participant explained, “a lot of people think they have [teletrauma] all figured out at the beginning. Administrators and I.T. people… make this classic mistake because they don't deliver the care” (P2). He went on to describe how it is the care that rural

clinicians deliver and “how they see this tool being helpful to them” (P2) that should drive the technology. This finding was echoed by an administrator who stated “it really has to meet the needs of the individuals who are going to be using it. Because in the past we have brought in telehealth equipment in one of my sites and it was never used” (S5). Thus, the technology deployed should have the ability to accommodate the variety of clinical uses as led by clinicians, appropriately reflecting rural practice. This is reinforced by the flexible ways that communities used and adapted technology in their everyday practice, as stated in the previous section.

Regarding technological characteristics, several clinicians used an example of the telephone to emphasize the need for reliability and familiarity of teletrauma technology. Speaking of the differences between existing telehealth technology (MedEx) and the telephone, one participant explained,

> You know, as much as technology is a wonderful thing, it is not as reliable as the telephone. So I know how to work MedEx. I work with MedEx all the time. And I have failed at MedEx many times. And I don't know why. And, you know, when I pick up my phone and I dial my phone, that never happens. So technology still is a barrier in terms of its consistency and reliability. (P1)

Many others mentioned that the reliability and ubiquity of the telephone should be future goals of teletrauma. Put by a rural clinician, “there's a telephone in every rural emergency room, right? So there needs to be a virtual care setup in every rural emergency room. And virtual health is really just a telephone call with video, right? So that's all it is” (P2). Another stated that it would be ideal for everyone to have teletrauma (P3). Furthermore, when asked about having criteria for when to activate the system, rural clinicians consistently responded negatively. It

was reported that having specific activation criteria does not fit with the nature of rural health care delivery. One participant described how the use of clinical judgement should determine teletrauma activation:

> In rural medicine, I think it's the clinical judgment. I mean, if it's used from bigger centers, that might change a little bit, you know, and I accept that. But I think for us, it's what you're comfortable with dealing with. You know, there's so many different things that comes in our emergency room doors. (P5)

Another participant again made a comparison to the telephone, stating “it’s like calling a friend, right? I mean, do you have criteria when you call a friend? So no, please, no. I would discourage that. That’d be the death nail in telehealth” (P2). He went on to describe how clinicians do not have criteria as to who they reach out to for help in the hospital and in the same way, teletrauma should not have criteria;

> Virtual care is no different. And so thinking that it is, is a misstep. So, yeah, there should be no criteria. People should [if] they've got a thought they want to bounce off somebody, they've got a sick patient they need help with. Like wherever it is, the technology just supports those [interactions]. It's a way to support communication between people who trust one another. (P2)

Thus, the role of activation criteria is not fitting for the rural context and should instead be left to clinical judgement. The likening of teletrauma to the telephone also underscores the perceived role of teletrauma as an enhanced communication modality to support clinicians.

4.5.0 Interconnectedness of the healthcare system

The concept of interconnectedness applies to the main aspects of teletrauma care in the Robson Valley (clinicians, teletrauma, and team-based care) and the linkages between them. For example, rural clinicians feel connected as a result of using teletrauma, team-based care can be supported by and foster connectedness through teletrauma, and the level of connectedness between rural and urban clinicians can improve care. The degree of interconnectedness between the healthcare system also determines the quality and efficacy of care that can be provided to rural trauma patients. Across the data, interconnectedness was identified as an underlying concept that binds rural clinicians, teletrauma programs, and team-based care models, and functions individually within each aspect.

4.5.1 Teletrauma facilitates connected, compassionate care. Many rural clinicians have reported feelings of professional isolation and a lack of clinical support as a result of geographic separation. One participant noted that many Canadian medical graduates are dissuaded from practicing rurally because of a perceived lack of support (P3). These feelings can adversely affect the care that clinicians deliver and negatively impact rural clinicians' quality of life, preventing an effective team-based approach to care delivery. One participant described caring for sick patients in the rural context as being "a very isolating experience" (P2). He went on to note that reduced feelings of isolation and stress of rural clinicians improves patient outcomes and saves lives. A rural physician reported similar experiences: "if I feel supported, I'm likely to give better care… I'm going to be calmer, make clearer decisions, and be more confident" (P6).

Across the interviews, it was found that connected care as a result of teletrauma negates the isolation and lack of support felt by rural clinicians. That is, teletrauma reinforces

the view of rural health care delivery as a collective task, as opposed to being the sole responsibility of rural clinicians. Several attributes of connectedness between clinicians were identified including trust, mutual understanding, and a willingness to help. One participant mentioned that rural clinicians should be trusted to have "the competence… to know when to ask for help" (P1). A physician noted trust as a being vital precondition to effective communication between clinicians (P2), whereas an administrator highlighted the trust and confidence that develops by "[seeing] someone face-to-face" (S1). Mutual understanding between sites was another factor identified. By creating an awareness of site capabilities, resources, and unique context, empathy is developed. Beyond the practicality of understanding which services can or cannot be provided at a site, empathy cultivates feelings of support and comfort for rural clinicians, facilitating connected care. During a face-to-face interview, one physician used an example of her children being present to describe how the ability to visualize and understand context affects attitudes:

> It's the same scenario as right now: my kids don't feel like I'm taking anything away from them. But if you and I were sitting on the phone right now, they'd be telling me I don't have time for them because they can't see what I'm distracted with. But them visually having an idea that mom is right here but she's doing something, that doesn't make them feel like I'm taking time away from them. I mean, that's just in life. So it's the same there, like I said, it's maybe subconscious, but no matter what, the physician will feel supported. (P6)

In other words, consulting site clinicians may be more empathic and more willing to help when they can visualize and understand the context of rural clinicians, leading to increased feelings of

support. Willingness to help also contributed towards the development of connectedness by creating cohesiveness between teletrauma users and a mentality of 'shared care.' Rural clinicians are then able to rely on consulting clinicians without worrying about "[wasting] their time" (S2). Another stated that the consulting clinician should be "someone who wants to be there, wants to be helpful" (S3). This reliance on one another without fear of rejection may help to foster an attitude of collectivism, negating the 'us versus them' mentality that several participants expressed. One mentioned cases as 'belonging' to a site, with one site being entirely responsible: "if you're flat out… and there's only two of you staffing the emergency room, then you're probably not going to really want to spend a whole time dealing with somebody else's problems" (P4). Another talked about the obligation to their own site, potentially at the cost of not providing help to a rural site that is in need (P3). Thus, the sharing of patients and relationship-building between clinicians, based on principles of trust, empathy, and a willingness to help, support team-based care. This reinforces the view of rural trauma care as a network of connected care and not being isolated to individual sites. Teletrauma strengthens these linkages by facilitating meaningful collaboration and cultivating interprofessional relationships. Therefore, interconnectedness between rural clinicians via teletrauma may contribute towards the establishment of rural trauma care from a network perspective.

4.5.2 Clinicians as vital to rural telehealth models. The team-based model of care does not just apply to teletrauma. Participants often spoke of the need for general-use telehealth programs that cross multiple disciplines, as broad services more closely align with the rural

context. One participant elaborated on the challenges that arise in rural sites when narrow-focused telehealth programs are deployed:

> I would have concerns about a very focused program because you'll end up with multiple siloed programs and we already wrestle a lot with that… so oncology is a great example, which is already up and running. It works well for the oncologists because they have their own little routine and their own little box. But when you're at the other end and you have to deal with virtual care for oncology, plus palliative care, plus trauma, plus emergency, plus home care, plus internal medicine, plus cardiology, plus general surgery, plus orthopedics, and you have a different app or way of doing it for each one of those things, that's becomes pretty much impossible. So my feeling would be kind of a general use thing that's supported ubiquitously across the province, a tool that the various kind of groups and models can use, can afford, whatever service they're looking at. (P4)

As such, the concept of interconnectedness extends to telehealth more generally and appropriately reflects the rural context by emphasizing relationships instead of technology. For trauma, broad programs allow rural sites to become established as key players in a regionalized trauma system while also enabling rural clinicians to attend to a variety of clinical situations. Noted by one participant, “I think [telehealth will] help with morale. I think it’ll produce better team effort. I think it’s also going to start to help us establish our emergency trauma network with all the 26 sites” (S1). Another mentioned the utility rural sites play in trauma cases, particularly in performing the primary and secondary surveys of the patient (P3). To develop

broad programs responsive to rural settings, it was identified that use of telehealth should be driven by clinician experiences. As one participant suggested,

> I think if we leave [telehealth] open, we'll find the tweaks… So I think site by site you'd have to start using it and go "OK for the first three months everybody use it at their discretion." And then do a synopsis of what were the issues, what did the specialists like, what did they not like, did they feel like they were getting over telehealth, and if so, which were the cases that were the problematic ones? From a physician perspective in the emerge, it would be like "how easy did we find it to use it, you know, and then what did we learn? What did it change in all behaviors? And, you know, where was it useful? Where was it not useful?" And tweak it that way. Again, running a telehealth system like this is not that difficult. (P6)

Thus, broad, interconnected telehealth programs that are clinician-led contribute to the development of integrated networks of trauma care for rural areas.

4.6 Summary of findings

This section described the Robson Valley teletrauma program and explored perspectives on teletrauma use in a northern rural setting. Analysis of the interview data yielded four major themes. The first described the function, uses, and outcomes of teletrauma in the north. The second explored factors associated with teletrauma utilization. The third explained how teletrauma is more than just a technology, it is a tool to foster interprofessional relationship through enhanced communication. The fourth described the concept of interconnectedness as the binding force between rural clinicians, teletrauma, and team-based care.

The concepts discussed and findings identified are closely related and serve an overarching purpose within the context of rural trauma care (Figure 9). These aspects outline a

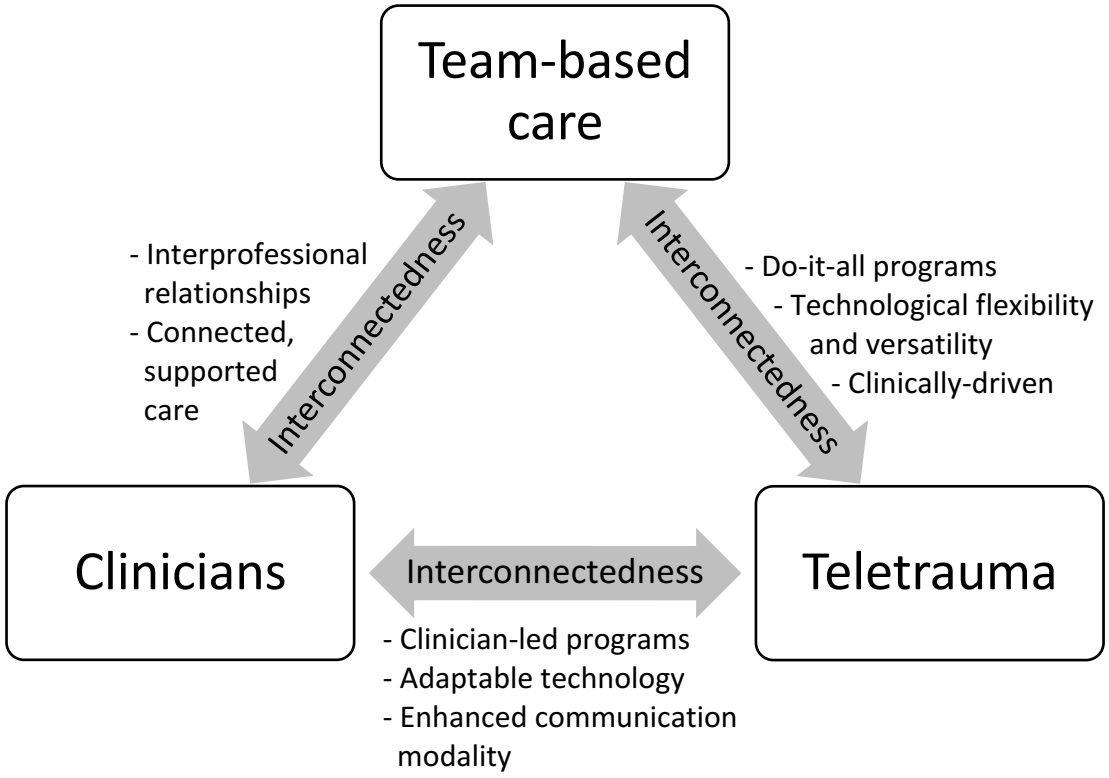

Figure 9: Interconnectedness as a Unifying Concept

model of care that incorporates the role of technology, principles and goals of rural health care, and clinician needs. This balanced model integrates the network of regionalized trauma care, enabling the provision of the best and most accessible care possible for the patient, despite their location.

5.0 Discussion and Interpretation

5.1.0 Interpretation of findings

Interpretations of findings were organized into four overarching themes: teletrauma affects the healthcare system; teletrauma creates a network of care built on interprofessional relationships; the reasons why clinicians use teletrauma are multifaceted and interrelated; and, interconnectedness of the healthcare system. Findings are discussed in relation to current research.

5.1.1 Teletrauma affects the healthcare system. The outcomes of Robson Valley teletrauma program were organized according to the Quadruple Aim (Bodenheimer & Sinsky, 2014) to aid in understanding which aspects of health care teletrauma affects and to what degree. As identified in the literature review, cost optimization and patient experience were studied the least, whereas provider experience and population health were most common. This finding was reflected across interviews with participants, who expressed less interest with cost optimization and patient experience, and more interest towards population health and provider experience.

Few participants noted instances of cost savings for the organization. Of those who did, some remarked that cost reduction should not be a goal of teletrauma. However, it was identified that teletrauma has the potential to reduce costs for the health care system by reducing emergency room visits and patient transfers to a larger center. This finding is consistent with the literature; after deployment of a teletrauma system, Duchesne et al. (2008) reported an 85% reduction in hospital costs as a result of decreased transfers. Cost savings for both the consulting and client sites is a consistently reported outcome of telehealth

(Demaerschalk et al., 2013; Natafgi et al., 2018; Wibbenmeyer et al., 2016; Yang et al., 2015b). For clinicians in the Robson Valley, the realities of rural practice and the potential to save lives via teletrauma may outweigh the possible financial costs to the organization. Several instances of death during travel were reported, which may have been potentially avoided with teletrauma. While organizational cost savings was mentioned as a potential effect of teletrauma, clinicians in the Robson Valley did not see this as an important outcome when faced with the benefits of teletrauma, such as preventable deaths from unnecessary travel. Therefore, initiatives to promote the use of teletrauma within rural settings should not rely on a promise of cost saving, but instead focus on other factors, such as provider experience and quality of patient care.

For those in the Robson Valley, the most pronounced outcomes of teletrauma were related to the population health domain and included improved care outcomes, more appropriate patient transfers, and increasesd diagnostic accuracy. Although remote communities may not be equipped with the appropriate resources necessary to manage complex trauma patients (Latifi et al., 2009), teletrauma is a recognized solution that facilitates timely access in regionalized trauma systems (Hameed et al., 2010). Rural clinicians may be able to more effectively triage patients and decide who needs a higher level of care more rapidly by including specialists at the outset. This was experienced by clinicians in the Robson Valley who were able to rapidly identify and transfer patients in need of a higher level of care. A similar finding was reported by Duchesne et al. (2008) who demonstrated that teletrauma enabled the identification of more severely injured patients thereby facilitating timely, appropriate transfers.

Participants identified that use of teletrauma changed clinical management, resulting in improved outcomes for patients. In one instance, a child had inhaled an object and presented to a clinician in the Robson Valley with difficulty breathing. After a teletrauma consultation, the rural clinician and specialist decided not to try to retrieve the object, and instead immediately transferred the patient. The clinician recalled that the change in clinical management may have saved the life of the patient. It has been commonly cited in the literature that improved patient outcomes results from teletrauma use. One study evaluating teletrauma for a pediatric population noted that physicians using teletrauma reported more changes in diagnosis and intervention as compared to telephone, resulting in a higher quality of care (Dharmar et al., 2013). Several other studies have mentioned improved patient care due to teletrauma use (Duchesne et al., 2008; Ehrlich et al., 2007; Mohr et al., 2018; Ricci et al., 2003; Rogers et al., 2001; Syed-Abdul et al., 2012). For example, Duchesne et al. (2008) noted that patients were treated more aggressively with packed red blood cell transfusions, significantly improving the evaluation and management of trauma patients. Thus, changes in clinical management, facilitated by teletrauma, leads to improved patient outcomes.

The large geographical distances between facilities in the Robson Valley and larger centers, as well as unpredictable weather, increase the likelihood of adverse health events during patient transport including death. Teletrauma circumvents this issue by ensuring appropriate stabilization and initial management prior to transfer. In one case, a pediatric head trauma patient was able to be appropriately stabilized with the help of a remote specialist before being transferred, saving his life (Rottger et al., 1997). Additional articles have reported teletrauma as being life-saving in rural settings (Ricci et al., 2003; Rogers et al., 2001). As

evidenced in this research exploring the Robson Valley, teletrauma has the ability to connect facilities that are otherwise spatially isolated, reducing the geographic barriers to appropriate and timely care.

Rural clinicians have consistently highlighted the many positive effects of teletrauma on the provider experience. By connecting clinicians at a distance, teletrauma reduces feelings of anxiety and professional disconnect experienced by clinicians who practice in rural settings. The ability for a secondary clinician to be virtually present provides clinical support and enables a sharing of responsibility during care delivery. This was consistent with other literature identified. In one study, satellite communication was used to facilitate remote consultation of injured patients, resulting in increased clinical support for rural clinicians (Ehrlich et al., 2007). Another study reported greater support for remote clinicians as a result of a teletrauma system (Westbrook et al., 2008). By enabling the sharing of responsibility and facilitating remote support during trauma cases, teletrauma also has the benefit of strengthening relationships between clinicians. This was consistently mentioned by participants. In the literature, collegiality between the client and consulting site was reportedly increased through the remote guidance and advice provided to rural clinicians during difficult cases (Dyer et al., 2008). In another study that evaluated clinician perceptions of teletrauma, 92% of respondents reported improved collegiality and feelings of appreciation between sites (Al-Kadi et al., 2009). Although not formally analyzed, the teletrauma consultations included medical trainees and physicians at the client site and consultant site working together to care for multiple patients simultaneously. This may have enhanced team-based care and feelings of cohesiveness between members of the team.

Furthermore, workflow is optimized. Because clinicians can be confident with the decisions made when remote support is available, they are able to move on to the next case without second-guessing or re-checking the previous patient case. This finding was also demonstrated in the literature. In one study, a senior physician was busy caring for multiple patients whereupon a trainee was able to use teletrauma to evaluate an additional patient, allowing the senior physician to attend to a greater number of cases (Al-Kadi et al., 2009). However, it was noted that teletrauma may increase workload on consulting sites. A study evaluating the effects of teletrauma on clinicians' work demonstrated a perceived increase in workload for specialists and feelings of greater responsibility for the remote patient (Westbrook et al., 2008). Across the interviews, however, this appeared to be more apprehension than reality; none of the participants reported actual instances of increased workload, only the potential effect that several teletrauma programs could have on a single consulting site. Professional development was another notable outcome of teletrauma for the provider experience domain. That is, after clinicians had managed a particular case using teletrauma, they then felt more confident independently managing the same case in the future. Similarly, Syed-Abdul et al. (2012) noted that the remote management of burn patients permitted facilitated continuing medical education for the client site clinicians. Thus, teletrauma provides learning opportunities for clinicians who otherwise would not be as involved in the care of complex or unfamiliar cases.

5.1.2 Teletrauma enables a network of care built on interprofessional relationships.

Teletrauma is more than the technology being deployed. Clinicians adapt the technology according to the setting in which it is implemented, driven by the needs of clinicians. In the

Robson Valley, participants explained how the teletrauma program evolved from a telehealth cart for use during emergency cases, to using iPads and cellphones to provide primary care, follow-ups, regular hospital rounds, pre-hospital care, and trauma management. Given the nature of rural medicine and the variety of clinical cases encountered, teletrauma technology must be sensitive and adaptable to the needs of clinicians. As such, teletrauma does not determine the care that is provided. Rather, it is the clinician who defines the care provided, and teletrauma is a tool to enable enhanced communication between users.

Participants described teletrauma consultations as creating a 'virtual presence' of the consulting clinician, increasing rural clinicians' feelings of support and connectedness. The ability to foster relationships during a teletrauma encounter hinges on the theory of social presence (Short, Williams, & Christie, 1976). Originally used to describe teleconferencing, social presence is the feeling that others are involved in the communication exchange. The degree of social presence is determined by the mode of communication; that is, with fewer 'channels' available in a medium, users pay less attention to other participants (Walther, 1995). In the case of teletrauma, video enhances the degree of social presence by including a visual component, which may support the development of mutual trust and empathy during remote consultations. This was in alignment with the findings from this research. Participants identified that teletrauma aided in the personalization of clinical encounters primarily because of the ability to visualize the other user. Similarly, it has been suggested that during teleconsultations, impersonal exchanges result from decreased feelings of social presence (Walther, 1995). In this way, teletrauma is seen as an enhanced modality of communication with the potential to foster relationships and develop a sense of connectedness between users at a distance.

It was identified that technology plays a role in successful teletrauma encounters. To maximize consultation effectiveness, the purpose, design, and function of the technology must revolve around the clinician. Participants compared teletrauma to the telephone to express their desire for a service that is ubiquitous, clinically versatile, easy to use, reliable, and familiar. The discussion of the 'ideal' system was not limited to a particular clinical use or scenario. Rather, value of the system was seen in the ability for teletrauma to be used by and for the clinician at the point of care, regardless of the clinical situation. In this way, teletrauma is not viewed as a modality of care, but a tool to support clinicians. Participants also emphasized that with the telephone, clinicians retain their autonomy over when and how to use it. Thus, when teletrauma is deployed as a communication tool in a similar manner to the telephone, clinicians may feel more control over the care they give while remaining sensitive to the demands of rural practice. Similarly, Permwonguswa et al. (2018) found that telehealth is empowering to clinicians, resulting in increased provider satisfaction and efficient treatment of patients. Empowerment refers to the process of individuals gaining control over a situation and having the ability to influence decisions that affect their lives (Zimmerman, 1995). This highlights the ability for teletrauma to empower clinicians where they practice. As a modality of communication, teletrauma enables clinicians to deliver high-quality trauma care in the face of a lack of resources and support.

Teletrauma drives team-based care by connecting clinicians and fostering relationships. As revealed in the analysis of the findings of this study, feelings of trust, empathy, and a willingness to help are necessary components for successful teletrauma use. In the context of collaborative care, these principles embody compassion between clinicians. These findings are

corroborated by Atkins and Parker (2012), who identified that compassion leads to positive organizational outcomes and quality relationships. Several aspects associated with compassion were also identified, including helping, trust, support, and cooperation. Similarly, West Eckert, Collins, and Chowla (2017) noted that compassion between members of a health organization supports cooperativity and collaboration. The authors went on to describe how effective teamworking relies on individuals' recognition of the needs and value of others, and their interdependence on one another to accomplish organizational goals (West et al., 2017). A collective mindset between teams or members of a team helps to establish an effective collaborative care model, a finding also reported by participants in this study. The cross-disciplinary cooperation between remote clinicians, as supported by teletrauma, facilitates team-based care. Thus, teletrauma is foundational to the development and effective functioning of team-based care in rural areas, viewed as an enhanced communication tool to support clinicians.

5.1.3.0 Reasons clinicians use teletrauma are multifaceted and interrelated.

5.1.3.1 The role of technology. Considering that traumas often involve multiple injuries and may require immediate input from several other clinicians, stationary telehealth carts with inefficient activation procedures may not be functional. This is especially true in time-sensitive situations where complicated activation processes dissuade clinicians from using the system. For example, it has been noted that technical complexity and clinician discomfort engaging with a pediatric emergency telehealth system impeded use (Uscher-Pines & Khan, 2014). This finding was echoed by several participants in this study, emphasizing that complicated technology in time-sensitive situations often leads clinicians to resort to traditional telephone consults. Thus,

seamlessness of the system is an important technological attribute that facilitates timely, effective teletrauma utilization; clinicians may be more willing to use teletrauma when the technology is seamless and easy to use.

In this study, mobility of the teletrauma system to view injuries, along with multi-caller capabilities, were other functional attributes that suit the trauma context and facilitate teletrauma consults. These findings were also consistent with those in a few studies (Joseph, Hadeed, Sadoun, Rhee, & Weinstein, 2012; Zangbar et al., 2014). For example, in programs where telehealth robots that have been deployed, users found that mobility of the system was an issue, as was visualization of the patient due to a fixed camera (Marttos et al., 2013). Similar findings were reported by participants during interviews, who identified space allocation for fixed-units and camera mobility as barriers to teletrauma use during emergency cases. In contrast, most of the identified teletrauma literature mentioned the use of mounted cameras with remote control capabilities (Duchesne et al., 2008; Ricci et al., 2003; Rogers et al., 2001; Yang et al., 2015a; Yang et al., 2015b), as opposed to cameras that were fully mobile. Connectivity is an important aspect as trauma case can rapidly change and procedures are often performed under clinical time-constraints. Connectivity was mentioned in the interviews as being a necessary precondition to telehealth use. Similarly, Duchesne et al. (2008) reported that insufficient bandwidth can create technical difficulties during telehealth consults. Lag time in video connection, for example, could delay or impede the care provided by a remote clinician, which could then be detrimental to the care of the patient. As such, connectivity is a vital consideration in rural areas that may not have the infrastructure to support the high-speed

internet required for continuous, quality audiovisual connection. This highlights appropriate infrastructure as being foundational to successful teletrauma use.

Because initial trauma management requires significant time commitment for clinicians (Grossman, Schwab, Chu-Rodgers, & Kestner, 1999), time spent away from the patient should be minimized. Therefore, the ability to immediately access necessary resources at the point of care is particularly important to facilitate high quality, timely trauma care. Many interview participants reported the ability to virtually access call lists of specialists and care documents from a single screen as being a notable facilitator to teletrauma consults. To reduce barriers to teletrauma use, technology must suit the trauma care context and must be supported by the appropriate infrastructure.

5.1.3.2 The role of individual characteristics. Participants in this study did not identify specific patient profiles or characteristics as the driving factor to determine teletrauma use. Instead, clinician characteristics, geographic and organizational factors appeared to be the main determinants. Despite the implementation of a program with a well-defined clinical purpose, system adaptations were shaped by the users and clinical context. For rural clinicians in the Robson Valley, a wide variety of cases are encountered. When a case presents that is not a 'teletrauma' case, the technology is adapted to meet the immediate needs of the clinician. This was contrary to current literature which suggests that increased teletrauma use is associated with younger patient age (Dharmar et al., 2013; Franken et al., 1997; Marcin et al., 2004; Mohr et al., 2017; Mohr et al., 2018; Yang et al., 2015a; Yang et al., 2015b), penetrating injury (Duchesne et al., 2008; Mohr et al., 2017), and high severity of illness or injury (Duchense et al., 2008; Marcin et al., 2004; Ricci et al., 2003; Rogers et al., 2001). One reason why patient factors

were identified in the literature and not the present study may be that the datasets were often large enough to perform the necessary statistical analyses. In the Robson Valley, on the other hand, low volumes of trauma patients and a lack of quantitative data preclude robust statistical analysis. That is, as patients continue to use teletrauma and more data accumulates, quantitative analysis of specific patient factors may become possible.

5.1.3.3 The role of user attitudes and relationships. Teletrauma use is dependent on interprofessional relationships and user attitudes, as demonstrated in the findings of this research. Across the interviews, it was found that when rural clinicians perceive that consultants want to help, clinicians are less hesitant to initiate a teletrauma call. In a study by Tachakra, Sivakumar, Everard, Mullett, and Freij (1996), it was noted that assessment of user attitudes was a key consideration when designing teletrauma systems. Similar results were also found by Sikka et al. (2016), who highlighted the importance of favorable attitudes and opinions towards mobile technologies as a driver of innovation in acute wound telehealth. This exemplifies the concept of teamwork during teletrauma consultations and outlines individual attitudes and cooperativeness as prerequisites to effective team functioning. The leveraging of existing interprofessional relationships was seen as vital to successful teletrauma consultations. As well, Copley et al. (2017) noted that the effectiveness of telehealth consultations depends on the relationships between those involved. Relationships between clinicians have also been mentioned as a key component to effective, collaborative care (Berendsen, Benneker, Meyboom-de Jong, Klazinga, & Schuling, 2007; Sampson, Barbour, & Wilson, 2016).

Examination of this study's findings suggest that care processes have been improved as a result of strong teamwork. For example, transfer times in the Robson Valley were reportedly

reduced when clinicians had an existing relationship with consulting clinicians. The literature also supported this finding: Butler et al. (2019) found that stronger teamwork predicted faster time to defibrillation during simulated pediatric resuscitation. While successful teletrauma depends on the attitudes and relationships between users, teletrauma also facilitates relationship-building, acting as a tool to enhance the interaction between clinicians. Westbrook et al. (2008) mentioned improved interhospital relationships and increase understanding between staff as a result of using a teletrauma service. Participants in this study also reported enhanced interprofessional relationships and collegiality as an outcome of teletrauma use. Other literature supported this finding (Al-Kadi et al., 2009; Dyer et al., 2008).

5.1.3.4 The role of geography and organizational factors. Although it was noted in the interviews that complex and severely injured patients may be more likely to receive teletrauma, this was conditional on the comfort level of clinicians. That is, clinicians' familiarity with the presentation or level of comfort with clinical management ultimately determines use. Similar findings were reported by Dharmar et al. (2013), who found that physicians were more likely to initiate a teletrauma call if they were uncertain regarding clinical management. Another described the activation and use of teletrauma to perform an unfamiliar procedure (Rottger et al., 1997). Several other teletrauma programs were adopted as a means of overcoming a lack of clinician experience and confidence in managing trauma cases (Al-Kadi et al., 2009; Wibbenmeyer et al., 2016).

Access to resources and geographic factors also play a role in a clinicians' decision to activate teletrauma. For those in the Robson Valley, immediate access to necessary resources, such as specialty care, is limited. When a patient's condition is complex or requires increased

resources, rural clinicians are likely to use teletrauma as a means of facilitating access. In the literature, Saffle et al., (2009) noted a lack of timely subspecialist involvement and vast geographical distance as reason to use a teletrauma service. The authors found that despite "extremely limited medical subspecialty" (p. 361) coverage in the area, teletrauma facilitated appropriate critical care, highlighting access to burn care as justification for program adoption.

Poor weather and large physical distance influence the threshold to use teletrauma. When inclement weather prevents the transfer a patient to a larger facility, rural clinicians are forced to manage patients locally, often for an extended period of time. In such cases, teletrauma is more likely to be used. These findings were not demonstrated in the literature; one study found that rurality and distance to a facility with a higher level of care were not associated with teletrauma use (Mohr et al., 2016). However, characteristics of the rural hospitals were cited as reasons for the lack of variability of teletrauma use. Thus, geography, clinician characteristics, and organizational factors determine utilization of teletrauma.

5.1.3.5 Interrelatedness between the determinants of teletrauma use. When examining the role of technology, patient characteristics, organizational and geographical factors through the lens of Andersen and Newman's (1973) Health Service Utilization framework, the interrelatedness between them is apparent. Under Andersen and Newman's (1973) model, societal determinants influence individual determinants directly and indirectly through the healthcare system, whereupon individual determinants (such as symptoms or diagnoses) would then strongly influence health service utilization (Figure 6). However, the context of teletrauma may alter the degree of influence that individual determinants have over service utilization. For example, when a trauma patient is encountered in a rural area,

geographic isolation and clinician discomfort may be more important than patient demographics when deciding to use trauma resources. This shift is reflected in the findings of this study, as trauma service use in the Robson Valley is reportedly more strongly influenced by clinician, organizational, and geographical factors as opposed to specific patient-level characteristics; participants did not identify that patient characteristics altered the threshold to use the teletrauma service. Teletrauma appears to limit the degree to which individual patient factors determine service utilization.

Thus, trauma service use in the Robson Valley may be best explained by the influence that teletrauma has on societal determinants and the health services system. For example, augmenting technology, supporting a virtual care culture, and focusing on clinicians and the relationships between them may maximize access to appropriate trauma care in rural areas. As virtual care becomes more culturally accepted and embedded into societal values, this relationship may shift again, emphasizing instead the role of the normative component.

5.1.4 Interconnectedness of the healthcare system. The delivery of rural trauma care is complex, having many interacting and interdependent parts. While aspects of the healthcare system can be identified and understood separately, effective functioning relies on the interworking of the parts. Plsek (2001) mentioned that the power of the system lies in the number and strength of interconnections between the elements. As such, rural teletrauma examination may necessitate a complex systems view of health care that appreciates the relationships between components, as opposed to a fragmented view that appraises each element individually. Noted by Widmer, Swanson, Zink, and Pines (2018), complex systems thinking is particularly suited to emergency medicine when designing interventions and

overcoming challenges, by moving beyond distinct processes and reductionism. Interconnectedness is one way to envision how the different parts of rural teletrauma care relate to one another and evolve to create value, influencing patient care.

Findings from this study support the view of rural trauma care as being interconnected. While the various components of the health delivery system are identifiable, guided by the findings and Andersen and Newman's (1973) Health Service Utilization framework, the relationships between them are dynamic. For care delivered in the Robson Valley, interconnectedness is the concept that binds rural clinicians, teletrauma, and effective team-based care (Figure 9). At the center of collaborative care models is the care that is delivered to the patient (Lorenz, Mauksch, & Gawinski, 1999), unifying the parts of the system under one superordinate goal. The degree of connectedness between the healthcare system may affect the care that is provided and may explain variations in trauma service utilization.

Clinicians, for example, share the care of trauma patients in the Robson Valley when consulting remote clinicians via teletrauma. This sharing of clinical responsibility and fostering of interprofessional relationships typifies connectedness between clinicians, teletrauma, and team-based care. On the other hand, the breakdown of the connections between these parts (poor communication, lack of interprofessional relationships, or ill-suited teletrauma technology) can negatively affect patient care, as demonstrated in the findings of this study. To augment the care provided to patients, it may be of use to focus on the interrelations between the system factors, rather than examining the pieces in isolation. This approach to thinking about the healthcare system was also recognized by Stange (2009), who described that understanding system components as being related and connected can foster care that is less

fragmented and of higher value. Similarly, Widmer et al. (2018) mentioned that complex systems thinking is well-suited for optimizing health care interactions and understanding system behavior. Furthermore, teletrauma may be seen as a part of a larger system of connected telehealth programs more broadly. This perspective recognizes telehealth as a clinician-centric solution to streamlined patient care access via a virtual network, as opposed to being an isolated commodity. As identified by participants in this study, the deployment of telehealth systems that act on and are designed for clinicians emphasizes relationships instead of siloed clinical scenarios. This approach to telehealth is fitting for collaborative care models and views telehealth as operating within a complex healthcare system having many interrelated parts.

Interconnectedness provides the perspective and the tools necessary to appropriately examine teletrauma care in the Robson Valley, assess challenges and opportunities, and design interventions. The delivery of optimal trauma care in the Robson Valley relies on the effective functioning of clinicians, teletrauma, and team-based care in a dynamic, interconnected model of care. Interconnectedness in the Robson Valley is exemplified through the sharing of clinical responsibility between rural and consulting clinicians, the necessity of interprofessional relationships as a prerequisite to effective teletrauma use, and the establishment of the Robson Valley as a vital component to the trauma network of care. This balanced model appreciates the interdependence of the parts of the system and integrates the network of regionalized trauma care to enable the best and most accessible care for patients, regardless of their location. Insights from this study highlight the importance of a complex systems perspective of

trauma care in rural areas and the need for interventions that are focused on clinicians and the relationships between them.

5.2.0 Implications and recommendations

This study has direct implications for practice and policy while filling an identified knowledge gap in the current teletrauma literature. Implications and recommendations are summarized below (Figure 10).

Implications

- Clinician-focused programs may reduce barriers to teletrauma use
- Strengthening interprofessional relationships may empowered to manage trauma patients
- Teletrauma facilitates the establishment of rural sites as vital components in the trauma network
- Regional teletrauma policies are necessary to guide strategic teletrauma design and implementation in other rural areas
- Clinician-centric policies enhance program sustainability

Recommendations

- Future research should engage a complex systems perspective that recognizes the interconnectedness between system components
- Investing in local solutions may drive innovation for rural health care delivery
- Medical education and training should adopt an interdisciplinary approach that appreciates the context of rural trauma care

Figure 10: Summary of Implications and Recommendations

5.2.1 Clinical implications. Exploring factors associated with teletrauma utilization in northern BC permits a deeper understanding of the functioning of the teletrauma program

within the local context and how it operates within the regionalized trauma network. Understanding teletrauma in northern BC may help clinicians to view teletrauma as a communication tool, serving the broader network of care. By allowing rural clinicians to decide which technology best suits their context, and how and when to use it, clinicians may feel more empowered. Knowledge from the study facilitates the development of team-based care and enables rural providers to establish their sites as key components in the trauma network. Specifically, rural sites are better able to effectively stabilize and manage trauma patients, contributing to integration of the trauma network.

This provides knowledge about when, how, and for whom teletrauma is being used. Opportunities may be identified to facilitate more efficient use of teletrauma by identifying situations when it is required most, enhancing effectiveness of the service and maximizing benefits for northern BC patients in need of trauma care. In addition, analysis of associated individual, clinician, and system level factors highlights in greater detail the degree of teletrauma accessibility and between-provider variability in service use. Rural clinicians using the service may also gain a better understanding of how certain organizational and geographic characteristics influence their use of teletrauma. Being more aware of how and why they use teletrauma may enable clinicians to more effectively use the system while remaining confident that teletrauma is making a difference for the patients they are treating.

5.2.2 Policy implications. Understanding how teletrauma operates as a key component of a high-functioning, complex regionalized trauma system provides insight into how telehealth may be integrated into rural settings more broadly. Being aware of how teletrauma influences the role of rural facilities within the larger system of care is integral to designing and

implementing additional telehealth services; understanding the functioning of teletrauma may help guide the leveraging of other telehealth programs to fill gaps in rural health care delivery. Knowledge gained through this project may also contribute towards strategic adoption of telehealth with a systems perspective. At the systems level, this study provides some of the groundwork necessary to design and use standardized implementation policies to create robust telehealth networks across the health region. As telehealth moves towards becoming structurally integrated into heath delivery systems, patients and clinicians can be more confident in the long-term reliability of telehealth as a standard for health care in remote areas. This study outlines an integrated model of care that includes virtual and traditional care, normalizing the use of telehealth in the health care system.

To facilitate expansion of telehealth services and guide policy creation, the use of standardized language is necessary. From the insight provided by key stakeholders during consultation, a regional definition of teletrauma can be delineated. This supports the adoption of consistent language regarding teletrauma and may drive telehealth policy that is more fitting for the nuances of rural care. Thus, guidelines can be adapted that support rural clinicians and are reflective of rural practice.

It may be of use to create policies that permit flexible, clinician-led technological innovation and utilization. While innovations may not always be successful, giving clinicians the freedom to experiment with technology is in line with the identified need for clinician-led and clinically-driven solutions to rural health care delivery. To create the conditions necessary for innovation, West et al. (2017) mentioned that clinicians must have the autonomy to discover and experiment with new ways to deliver care. Creating the space for innovation in policies

requires that rural clinicians are recognized as the experts where they practice; empowering them to decide what works best for them in their unique context is in alignment with a systems perspective of rural health care delivery and may contribute towards sustainable services. The design of teletrauma services by and for clinicians may foster feelings of ownership over the program, leading to enhanced sustainability. Practice-driven and clinician-centric policies may therefore contribute towards sustainable programs and may facilitate effective adaptations to existing programs that are sensitive to evolving clinical contexts in rural areas.

5.2.3 Recommendations. This study provides unique insight into future teletrauma research with particular regards to the dynamic relationships between various health care components. Because teletrauma functions within a complex system having many interdependent parts, researchers should adopt a systems perspective. That is, research should be reflective of the interconnectedness between healthcare system pieces instead of isolating components to be studied individually. More specifically, connectedness between teletrauma (or telehealth more broadly) and clinicians implies that research should include the clinicians and the relationships between them; teletrauma research needs to occur with the same systems perspective within which teletrauma operates. For example, examination of teletrauma technology should take into consideration the needs of rural clinicians, the rural context in which they practice, how the technology operates to support or hinder interprofessional relationships, and the interoperability of teletrauma with other telehealth programs.

To support future research and the advancement of integrated regionalized trauma networks, organizations should invest in solutions focused on linking clinicians and resources.

As opposed to isolating the technology and studying its effects on care processes, research should be clinician-centric, emphasizing the important role of interprofessional relationships embedded within networks of care. The design of teletrauma programs or other interventions should engage a similar approach. Investing in local solutions means giving rural clinicians the freedom to drive innovative solutions to local health care delivery. This recognizes the practicing clinician as the one who best knows the resources and local context and facilitates the design of interventions that are non-prescriptive and locally-relevant.

Knowledge from this study may also affect medical education, broadening the perspective of emergency medicine. This research highlights the heterogeneity in the way that emergency medicine is delivered. Rural trauma care differs from the care delivered in urban centers, owing to the unique challenges related to geography, rural institutions, and the clinicians that practice rurally. Education on emergency medicine should expand to include the nuances of rural health delivery, emphasizing the challenges of rural medicine, appropriate medical training, and the utility of alternate methods of delivering care at a distance. Education that includes this perspective may contribute towards rural-specific training and enhance the recruitment and retention of a rural workforce. Furthermore, interdisciplinary training of clinicians may be of use. Because clinicians in rural areas typically work in small teams with other professions, an interdisciplinary approach may help to solidify the principles of cross-boundary collaboration that are necessary for rural health delivery. For a summary of the implications and recommendations, see Figure 10.

5.3 Strengths and limitations

A qualitative interpretive description study was undertaken using interview data from fourteen teletrauma stakeholders to better understand teletrauma utilization in northern BC. The study had several strengths. The research approach was fitting for the research question and objectives of the study. The study also generated rich data from a variety of perspectives of teletrauma, permitting deep insight into the role and function of teletrauma in a rural setting. Prolonged engagement with the data and ongoing reflexivity supported the rigor of the research. A reflexive journal, kept throughout the study, aided in analysis and helped the researcher to remain aware of biases and how these affect the research design. Reflexive journaling also enabled transparency of the logic behind the themes and interpretations that emerged while remaining grounded in the data, facilitating the accruement of credibility.

Findings from this research address knowledge gaps in literature by focusing on clinician perspectives of teletrauma in a rural setting, and how teletrauma operates within an existing regionalized trauma system. Given the diverse set of perspectives that were examined, knowledge from this study also has implications for rural practice, policy development, healthcare system design, and future research.

There are several limitations to the study. First, the sample size may be considered small. However, this sample size is consistent with qualitative studies, which are performed to prioritize inductive analysis and depth, as opposed to breadth (Morse, 1995). While study participants practiced in a variety of rural settings and had a diverse range of experiences using teletrauma, the researcher recognizes that findings may not be representative of all rural practicing physicians. Additionally, it is notable that the pool of potential participants identified

for the study was particularly limited due to the small number of rural physicians who had experience with teletrauma and participants were sampled to generate information-rich cases. Despite these potential limitations, saturation in the analysis was achieved. Likewise, the focus of this study was limited to the Robson Valley in northern BC and may not be generalizable to other clinical settings. However, it is important to note that this research has focused on an under-researched context and as such, the findings will be transferrable to other centers with similar contexts and population. Second, interviews with participants were often limited due to the time constraints and busy schedules of the participants. Work demands shortened interview time for several participants, however, the researcher worked to prioritize key data that was most relevant to teletrauma within this context and avoid focusing on more general data. In future research, it may be beneficial to conduct repeat interviews with participants to yield different insights and richer data.

5.4 Conclusions

Teletrauma has the potential to overcome barriers to care in rural and remote areas and may enhance appropriate and timely access to care in rural contexts. This research examined the perspectives and experiences of teletrauma stakeholders to better understand rural teletrauma use in northern rural BC. Patients, clinicians, the population, and the health care system benefited from availability and use of the teletrauma program. Teletrauma was not isolated solely to trauma care, but enhanced further the system of care by enabling clinicians to attend to a variety of non-trauma situations. Teletrauma supports rural sites to participate in the trauma network by supporting rural clinicians to be connected in real-time to appropriate resources. The establishment of relationships between teletrauma users was vital to the

success of teletrauma. Rural clinicians were more likely to activate teletrauma if they felt the consulting clinician would be willing to help them in clinical management. Interprofessional relationships enabled and facilitated effective teletrauma interactions, whereas communication breakdown resulted from a lack of established relationships. The fundamental underlying concept that brought together rural clinicians, teletrauma, and team-based care in the Robson Valley teletrauma program was interconnectedness. This model of interconnected care empowers rural clinicians and establishes rural sites as vital components in the trauma network, expanding high quality trauma care to Canadians living in rural areas.

Based on findings from this research, it may be of use for future teletrauma research to fully recognize the complexity and interdependence of healthcare system factors; teletrauma was closely linked to all components of the healthcare system and affect each in unique ways. As rural health care advances and virtual care becomes increasingly integrated, understanding how teletrauma functions in the overall healthcare system will be pivotal to designing effective regionalized trauma systems. Knowledge from this study may be used to guide the development of regional policies, including a standardized regional definition of teletrauma, and strategies to design and implement teletrauma in rural areas.

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Appendix A

Search Strategy by Database using Keywords and Subject Headings

	PsycINFO	EconLit	Biomedical Reference Collection: Comprehensive	CINAHL	PubMed
Search Syntax	((telemedicine OR telemetry OR "remote consultation" OR telepathology OR tele-pathology OR teleradiology OR videoconferencing OR telenursing OR telecommunications OR telehealth OR tele-health OR ehealth OR mhealth OR telecare OR tele-care OR teleconsultation OR "mobile health" OR "online health" OR "on-line health" OR tele-dermatolog* OR teledermatolog* OR tele-psychiatry OR telepsychiatry OR telesurgery OR tele-surgery OR teleconsult* OR tele-consult* OR telecardio* OR tele-cardio* OR teleophthalmology OR tele-ophthalmology OR tele-oncology OR teleoncology OR tele-radiology OR teleneurology OR tele-neurology OR "telemental health" OR "tele-mental health" OR "e-mental health"	(telemedicine OR telemetry OR "remote consultation" OR telepathology OR tele-pathology OR teleradiology OR videoconferencing OR telenursing OR telecommunications OR telehealth OR tele-health OR ehealth OR mhealth OR telecare OR tele-care OR teleconsultation OR "mobile health" OR "online health" OR "on-line health" OR tele-dermatolog* OR teledermatolog* OR tele-psychiatry OR telepsychiatry OR telesurgery OR tele-surgery OR teleconsult* OR tele-consult* OR telecardio* OR tele-cardio* OR teleophthalmology OR tele-ophthalmology OR tele-oncology OR teleoncology OR tele-radiology OR teleneurology OR tele-neurology OR "telemental health" OR "tele-mental health" OR "e-mental health"	(telemedicine OR telemetry OR "remote consultation" OR telepathology OR tele-pathology OR teleradiology OR videoconferencing OR telenursing OR telecommunications OR telehealth OR tele-health OR ehealth OR mhealth OR telecare OR tele-care OR teleconsultation OR "mobile health" OR "online health" OR "on-line health" OR tele-dermatolog* OR teledermatolog* OR tele-psychiatry OR telepsychiatry OR telesurgery OR tele-surgery OR teleconsult* OR tele-consult* OR telecardio* OR tele-cardio* OR teleophthalmology OR tele-ophthalmology OR tele-oncology OR teleoncology OR tele-radiology OR teleneurology OR tele-neurology OR "telemental health" OR "tele-mental health" OR "e-mental health"	((telemedicine OR telemetry OR "remote consultation" OR telepathology OR tele-pathology OR teleradiology OR videoconferencing OR telenursing OR telecommunications OR telehealth OR tele-health OR ehealth OR mhealth OR telecare OR tele-care OR teleconsultation OR "mobile health" OR "online health" OR "on-line health" OR tele-dermatolog* OR teledermatolog* OR tele-psychiatry OR telepsychiatry OR telesurgery OR tele-surgery OR teleconsult* OR tele-consult* OR telecardio* OR tele-cardio* OR teleophthalmology OR tele-ophthalmology OR tele-oncology OR teleoncology OR tele-radiology OR teleneurology OR tele-neurology OR "telemental health" OR "tele-mental health" OR "e-mental health"	(telemedicine OR telemetry OR remote consultation OR telepathology OR tele-pathology OR teleradiology OR videoconferencing OR telenursing OR telecommunications OR telehealth OR tele-health OR ehealth OR mhealth OR telecare OR tele-care OR teleconsultation OR mobile health OR online health OR on-line health OR tele-dermatolog* OR teledermatolog* OR tele-psychiatry OR telepsychiatry OR telesurgery OR tele-surgery OR teleconsult* OR tele-consult* OR telecardio* OR tele-cardio* OR teleophthalmology OR tele-ophthalmology OR tele-oncology OR teleoncology OR tele-radiology OR teleneurology OR tele-neurology OR telemental health OR tele-mental health OR e-mental health OR

	OR telegeriatric* OR tele-geriatric* OR teledialysis OR tele-dialysis OR telerehabilitation OR tele-rehabilitation OR tele-conferenc* OR teleconferenc* OR "video conferenc*" OR "virtual care" OR telerenal OR telediabetes OR teleemegency OR telemergency OR tele-emergency OR teletrauma OR telemonitor* OR telestroke) OR (MM "Telemedicine" OR MM "Teleconferencing" OR MM "Online Therapy" OR MM "Teleconsultation" OR MM "Telepsychiatry" OR MM "Telepsychology" OR MM "Telerehabilitation")) AND ((rural OR rural area* OR rural communit* OR remote OR small town*) OR (MM "Rural Environments")) AND ((trauma* OR injur* OR acute OR emergent OR urgent OR emergenc* OR ed OR er) OR ((MM "Emergency Medicine" OR MM "Emergency Services" OR MM "Crisis Intervention Services") OR (MM "Injuries" OR MM "Birth Injuries" OR MM "Burns" OR MM "Electrical Injuries" OR MM "Head Injuries" OR MM	OR telegeriatric* OR tele-geriatric* OR teledialysis OR tele-dialysis OR telerehabilitation OR tele-rehabilitation OR tele-conferenc* OR teleconferenc* OR "video conferenc*" OR "virtual care" OR telerenal OR telediabetes OR teleemegency OR telemergency OR tele-emergency OR teletrauma OR telemonitor* OR telestroke) AND (rural OR rural area* OR rural communit* OR remote OR small town*) AND (trauma* OR injur* OR acute OR emergent OR urgent OR emergenc* OR ed OR er)	OR telegeriatric* OR tele-geriatric* OR teledialysis OR tele-dialysis OR telerehabilitation OR tele-rehabilitation OR tele-conferenc* OR teleconferenc* OR "video conferenc*" OR "virtual care" OR telerenal OR telediabetes OR teleemegency OR telemergency OR tele-emergency OR teletrauma OR telemonitor* OR telestroke) AND (rural OR rural area* OR rural communit* OR remote OR small town*) AND (trauma* OR injur* OR acute OR emergent OR urgent OR emergenc* OR ed OR er)	OR telegeriatric* OR tele-geriatric* OR teledialysis OR tele-dialysis OR telerehabilitation OR tele-rehabilitation OR tele-conferenc* OR teleconferenc* OR "video conferenc*" OR "virtual care" OR telerenal OR telediabetes OR teleemegency OR telemergency OR tele-emergency OR teletrauma OR telemonitor* OR telestroke) OR ((MM "Telemedicine+") OR (MM "Telehealth+") OR (MM "Telepsychiatry") OR (MM "Telerehabilitation"))) AND ((rural OR rural area* OR rural communit* OR remote OR small town*) OR ((MM "Rural Areas") OR (MM "Rural Health") OR (MM "Hospitals, Rural") OR (MM "Rural Population") OR (MM "Rural Health Services") OR (MM "Rural Health Nursing") OR (MM "Rural Health Centers") OR (MM "Rural Health Personnel"))) AND ((trauma* OR injur* OR acute OR emergent OR urgent OR emergenc* OR ed OR er) OR ((MM "Emergency Service+") OR (MM "Emergency Patients") OR (MM "Emergencies+")))	telegeriatric* OR teledialysis OR tele-dialysis OR telerehabilitation OR tele-rehabilitation OR tele-conferenc* OR teleconferenc* OR video conferenc* OR virtual care OR telediabetes OR telemergency OR tele-emergency OR teletrauma OR telemonitor* OR telestroke) AND (rural OR rural area OR rural communit* OR remote OR small town) AND (trauma* OR emergent OR urgent OR emergenc*)

	"Spinal Cord Injuries" OR MM "Wounds")))				
Initial Results	384 articles	26 articles	178 articles	903 articles	898 articles
Limiters	English language, academic articles	English language, academic articles	English language, academic articles	English language, academic articles	English language, human subjects
Results after Limiters	341 articles	11 articles	160 articles	643 articles	622 articles

Note: 'MM' denotes Subject Heading for a given database

Appendix B

Summary of Teletrauma Studies Included in the Review (N=28, article date range 1997-2018)

Reference	Year	Study location	Study type	Study objectives	Patient group	Sample size N (teletra-uma subgroup n)	Telehealth technology and function	Factors Associated with telehealth activation	Evaluation aim*	Communicatio n network	Main findings
Al-Kadi et al.	2009	Alberta, Canada	Pilot study descriptive evaluation	"In order to evaluate the acceptability of [telesonograp -hy], we surveyed the clinical users regarding their perceptions of the tele-ultraound system" (p. 251)	Trauma patients	N=14	Telesonography via real-time bidirectional videoconferenci ng to conduct Focused Assessment with Sonography for Trauma (FAST) and Extended FAST examinations for pneumothoraxe s during acute trauma resuscitations	Lack of operator experience to produce clinically-meaningful information Lack of familiarity with major trauma	Provider experience	Rural community hospital (physicians, nurses, residents, medical students) consulting a quaternary level trauma care center (emergency physicians, trauma surgeons)	The majority of users were either satisfied or very satisfied with the service and agreed or strongly agreed it could benefit injured patients in northern Canada 92% of respondents reported improved collegiality between the client and consulting sites

Ashkenazi et al.	2007	Israel	Retrospective descriptive analysis	"To assess the effect of teleradiology upon the need for transfer of head injured victims requiring hospitalisation but referred initially to a rural Level 2 trauma centre without neurosurgical capacity" (p. 550)	Trauma - All ages included (<1 year - >65 years)	N=209 (n=83 teletrauma)	Teleradiology via an online consultation to evaluate pathological head and neck CT scans	Lack of timely neurosurgical access Avoidance of unnecessary inter-hospital transfer	Population health	Rural general hospital (senior trauma surgeon) consulting a Level 1 trauma center (neurosurgeon)	Reliable, around the clock teleradiology can facilitate the safe management of head trauma patients in a Level 2 trauma center
Brebner et al.	2004	Scotland	Evaluation and retrospective review of a telemedicine service	To "[evaluate] the teleconsul-tations during a 12-month period" (p. 17)	Accident and emerge-ncy patients (mean age 40 years)	N=1322	Teleconsultation for injured patients via a videoconference system and document camera	Radiograph consultation Upper and lower limb injuries; fractures or suspected fractures	Population health Provider experience	Fourteen community hospitals (emergency nurses) consulting a larger hospital (doctor or specialist)	High levels of satisfaction with the service "The majority of teleconsultations related to fractures or suspected fractures of the limbs" (p. 19) Teleconsultation reduced travel distance by increasing local management

Dharmar et al.	2013	California, USA	Retrospective chart review with concurrent surveys	"To compare the quality of care delivered to critically ill and injured children receiving telemedicine, telephone, or no consultation in rural emergency departments " (p. 2388)	Trauma - Children older than 1 day and younger than 17 years	N=320 (n=58 teletrauma)	Telemedicine consultations via bidirectional videoconferencing system for children presenting in the highest triage category; that is, "seriously ill or injured with life or limb threatening emergencies requiring immediate physician assessment and treatment" (p. 2389)	"ED physicians may be more likely to request consultation when they are less certain of their diagnosis or treatment plan" (p. 2394) Telemedicine was used for younger patients	Patient/ family experience Provider experience Population health	Five rural emergency departments (physicians and nurses) consulting an academic children's hospital (pediatric critical care physician)	Compared to no consultation and telephone consultation, quality of care was highest for patients receiving telemedicine consultation Compared to telephone consultation, physicians more frequently reported changes in diagnosis and therapeutic interventions with telemedicine consultation Physician and parent satisfaction was higher for telemedicine consultation than for telephone

Duchesne et al.	2008	Mississippi, USA	retrospective chart review and analysis	To "analyze outcomes before (pre-TM) and after (post-TM) implementation of telemedicine in the management of rural trauma patients initially treated at local community hospitals (LCH) before trauma center (TC) transfer" (p. 92)	Trauma - All ages included (mean age 33 years)	N=402 (n=51 teletrauma)	Trauma telemedicine via two-way audio-visual videoconferencing system during trauma cases	Lack of access to quality emergency care Higher Injury Severity Score, higher initial base deficit, lower initial systolic blood pressure, less blunt trauma and more penetrating injuries, and the need for more units of packed red blood cells for transfusion	Population health Cost optimization	Seven rural community hospitals (ED physicians or nurse practitioners) consulting a Level 1 trauma center (emergency physician)	Telemedicine improves evaluation and management of rural trauma patients; more severely injured patients are identified and more rapidly transferred Decreased hospital costs associated with telemedicine use without changes in mortality Telemedicine improved care
Dyer et al.	2008	Alberta, Canada	Descriptive analysis of pilot project	"describe the development of a pilot project to communicate real-time resuscitative EFAST examinations between a rural referral center and a tertiary care receiving	Trauma - All adults >18 years	N=23	Teleultrasound via a real-time bidirectional videoconferencing system during acute trauma resuscitation	Lack of access to expert trauma care and specialists Lack of access to highly experienced ultrasonogra-phers	Provider experience Population health	Rural community hospital (emergency physicians) consulting a quaternary level trauma care center (emergency physicians and trauma surgeons)	General satisfaction with the technology and the perception that it would be useful in remote communities Improved feelings of collegiality between the

				center" (p. 1210)							client and consulting site Technical and clinical feasibility of remote ultrasound during acute trauma resuscitations
Ehrlich et al.	2007	Chechen Republic, Russia	Descriptive analysis	Describe a telemedicine service	All ages included (age range 2 weeks-56 years)	N=64	Teleconsultations for injured and ill patients via real-time videoconference or asynchronous e-mail	Lack of specialist support	Population health	Remote children's hospital (doctors) consulting a larger Pediatric and Children's Surgical hospital (doctors, specialists)	Use of satellite communication is technically feasible and provides clinical support to remote doctors Improved quality of care and reduced the need for transport
Elkaim et al.	2012	France	Case series and retrospective analysis	"to assess remote diagnosis and treatment recommendation of orthopedic trauma... and the usefulness of image transfer" (p. 296)	Pediatric patients (mean age 9.2 years, age range 2-16 years	N=20	Teleconsultation for traumatic orthopedic pediatric injuries via x-ray image transfer through a mobile camera phone	Fractures of the upper limbs	Population health	Local hospital (physician) to a larger central hospital (orthopedic surgeon)	Teleconsultation using cellphones is useful for diagnosis, treatment initiation, or for decision to transfer in emergency orthopedic cases

Franken et al.	1997	Iowa, USA	"observational … with a control population to indicate the differing nature of requests by primary care physicians for teleradiology consultation" (p. 495)	To quantitatively document "how teleradiology was used for contempora-neous consultation with a radiologist by physicians at a small rural hospital" (p. 492)	All patients with radiological consultation (age range 0 - >65 years)	N=937 (n=519 teletrauma)	Teleradiology system with real-time bilinear interpolated zoom, pan, and windowing to transmit images to a referring radiologist	Younger patient age Spine examinations Abdominal radiographs	Population health	A rural hospital (attending physicians) consulting a remote private radiology practice (radiologists)	Teleradiology is more likely to be used in acute cases, particularly spine and abdominal and in those involving infants Teleradiology improves timeliness of care
Jacobs et al.	2015	Netherlands	Retrospective, descriptive, observational before and after study	"what is the influence of the introduction of an x-ray facility in a remote [general practitioner] practice on accurately diagnosed fractures, hospital visits, number of x-rays and treatment" (p. 2)	All patients with traumatic orthopedic injury	N=794 (n=482 teletrauma)	Teleradiology via digital transmission of radiographs and phone follow-up for orthopedic injuries	Reduce unnecessary referrals (trips to the central hospital)	Population health	Two rural general practices (general practitioners) consulting a central hospital (radiologists, surgeons)	The introduction of teleradiology increased demand for x-rays Teleradiology reduces missed fractures, unnecessary travel, and increases local treatment

Lambrecht	1997	North Dakota, USA	Descriptive study	"to study the role of telemedicine in the delivery of trauma care to rural providers on a telemedicine network" (p. 265)	Trauma patients (mean age 32.3 years, range 2 – 93 years)	N=100	Trauma teleconsults via two-way interactive video conferencing to transmit images, patient information, radiographs, and electrocardiograms for trauma patients	Extremity and pelvic injuries Patients classified as 'urgent care'	Provider experience Population health	3 rural hospitals (general practitioner, family practitioner, internist, physician assistants) consulting a Level 2 trauma center (orthopedic surgeons, emergency physicians, radiologists, neurosurgeons)	Trauma teleconsultation has the ability to reduce trauma center transfers There are no adverse outcomes for patients who received a trauma teleconsult Isolation of primary care providers was reduced
Latifi et al.	2009	Arizona, USA	Retrospective chart review of a pilot program	"to report the initial experience with a telemedicine program connecting 5 rural hospitals with a level I trauma center" (p. 905)	Trauma (mean age 34.3 years, age range 1.5-80 years)	N=35	Teletrauma via real-time transmission of video, audio, and vital signs during trauma and emergency resuscitations	Blunt trauma (orthopedic or close head injuries)	Provider experience Population health Cost optimization	5 rural hospitals (physician, nurse practitioner) consulting a university hospital trauma center (trauma surgeon)	Teletrauma is potentially cost-saving by reducing unnecessary transfers Continual staff training is needed for providing teletrauma care Quality of care was enhanced
Lienert et al.	2010	Switzerland	Retrospective analysis	"to assess the occurrence of phone calls related to	Dental trauma (mean age 8.6 years,	N=672	Telemedicine via telephone triage to provide	After hours (Monday to Friday 6pm – 8am)	Population health	Patients directly consulting a large	"In rural areas, the proportion of those calling for dental

				dental trauma… and to collect information regarding patient profiles, geographic region, time of calling, and assumed type of injury" (p. 224)	age range 0-6 years)		diagnoses and propose treatment options for traumatic dental injuries	Injuries in primary dentition		telemedical center (physicians)	trauma was higher than in urban areas" (p. 226); telemedical centers can improve emergency management after trauma to patients with limited access to dental care
Marcin et al.	2004	California, USA	Non-concurrent cohort design	"to describe a pilot telemedicine project that allows remote trauma center's adult intensive care unit to obtain nontrauma, nonsurgical-related pediatric critical care consultations for acutely injured children" (p. 251)	Pediatric trauma patients less than 16 years	N=97 (n=17 teletrauma)	Telemedicine consultation via a live, interactive, two-way audiovisual connection to review the history, vital signs, lab work, radiographs, monitoring and therapeutic devices, and to perform a physical exam	Higher Injury Severity Score Younger age	Population health Provider experience Patient/ family experience	Rural Level 2 trauma center (nurses, trauma surgeons, neurosurgeons, adult intensivists) consulting a Level 1 trauma center and university children's hospital (pediatric critical care physicians)	Telemedicine consultation for remote, critically injured pediatric patients is feasible and maintains care quality Parents and clinicians were satisfied with the consultation and care received
McKerrow et al.	2017	Australia	Retrospective review	"to analyze the proportion of operative and non-	All ages of patients with clavicle fracture (median age	N=150 (n=50 teletrauma)	Telehealth via teleconferencing to consult on patients with clavicle fracture	N/A	Population health	Various rural clinics or hospitals consulting a	Telehealth patients were managed more conservatively (reflecting access

				operative treatment methods for clavicle fracture in the [telehealth clinic] and [tertiary level hospital] and to compare patient outcomes" (p. 856)	20.5 years, age range 5-82 years)					tertiary level hospital	to orthopedic services) Similar patient outcomes in the conservative (telehealth) group and operative group (tertiary care)
Mohr et al.	2016	North Dakota, USA	Observational cohort study	"to describe hospital and geographical factors that contribute to increased telemedicine utilization in ED trauma" (p. 1)	Trauma - All adults >18 years	N=3,309 (n=361 teletrauma)	Teletrauma via a two-way high-definition audio-visual connection during trauma cases	"no hospital-level factors were associated with telemedicine use" (p. 3)	Population health	Small rural hospital (physician or nurse) consulting remote experienced emergency physicians	Hospital-level or geographic factors do not influence telemedicine penetration or use Once established as a standard practice, telemedicine use remains consistent over time

Mohr et al.	2017	North Dakota, USA	Observational cohort study	"Describe patient-level factors associated with telemedicine consultation in North Dakota critical-access hospital (CAH) emergency departments (EDs) and to measure the association between telemedicine consultation and interhospital transfer" (p. 177)	Trauma - All adults >18 years	N=2,837 (n=301 teletrauma)	Teletrauma via a two-way high-definition audio-visual connection during trauma cases	More severe injuries (higher Injury Severity Score), penetrating injuries, burns, hypotension, tachycardia, and ambulance transport	Population health	Small rural hospital (physician or nurse) consulting remote experienced emergency physicians	"Telemedicine is activated for the most severely injured and for those who are likely to require interhospital transfer" (p. 183) telemedicine did not change the transfer rate
Mohr et al.	2018	North Dakota, USA	Observational cohort study	"The objective of this study is to evaluate the impact of a rural telemedicine network on trauma process of care and clinical outcomes in	Trauma - All adults >18 years	N=7,500 (n=291 teletrauma)	Teletrauma via a two-way high-definition audio-visual connection during trauma cases	Endotracheal intubation	Population health	Small rural hospital (physician or nurse) consulting remote experienced emergency physicians	The availability of telemedicine increases the proportion of transfers, length of stay, and diagnostic imaging Telemedicine availability improves trauma care and may improve

				North Dakota" (p. 195)							timeliness of tertiary care
Ricci et al.	2003	Vermont and New York, USA	Description and analysis of a teletrauma program	Describe the teletrauma system and evaluate "clinical outcomes and participant acceptability" (p. 6)	Trauma - All major trauma cases (mean age 34 years, age range 14-81 years)	N=397 (n=41 teletrauma)	Interactive, two-way audiovisual communication system for trauma consultations	More severely injured patients; higher Injury Severity Score	Population health Provider experience	4 rural hospitals (physicians and surgeons) consulting a Level 1 trauma center (trauma surgeons)	The teletrauma system was judged to be acceptable and easy to use, and was thought to improve patient care Reliability and usability are necessary features for teletrauma technology Teletrauma is feasible and potentially life-saving for rural trauma care
Roccia et al.	2005	Italy	Description of a telemedicine system	"The purpose of this article is to review the 2-year experience with PATATRAC in managing patients with cranial maxillofacial trauma" (P. 1101)	All patients needing maxillofacial treatment (median 34.8 years, age range 16-81 years)	N=18	Teleconsultation via a monitor and dedicated data transmission line to transmit patient information and radiologic images	Lack of access to specialized support	Population health	35 rural regional hospitals (emergency physicians) consulting a specialized center (specialists)	Telemedicine reduces the time to specialist intervention, enhances therapeutic participation, and reduces unnecessary transfers

Rogers et al.	2001	Vermont and New York, USA	Description and analysis of a teletrauma program	"In this study, it was hypothesized that [teletrauma] during the initial evaluation and resuscitation of the trauma patient between trauma surgeons and the community hospital providers could improve community hospital trauma care" (p. 1037)	Trauma - All major trauma cases (mean age 34 years, age range 14-81 years)	N=842 (n=26 teletrauma)	Interactive, two-way audiovisual communication system for trauma consultations	Higher Injury Severity Score Lower Revised Trauma Score; patients who are "more physiologically deranged" (p. 1038)	Population health Provider experience	4 rural hospitals (physicians and surgeons) consulting a Level 1 trauma center (trauma surgeons)	Teletrauma improves rural trauma care and should be expanded to other rural areas Providers felt that the teletrauma system improved care and was life-saving in some cases
Rottger et al.	1997	Alberta, Canada	Case report	"the following account gives a dramatic example of how telephone consultation in combination with a fax message was used in an	Critically injured 12 year old patient	N=1	C-Band radio, cellular and standard telephone and fax to consult a remote neurosurgeon for the clinical management of a trauma case	Lack of physician experience with a procedure Patient transfer unsafe	Population health	A rural community hospital (physician) consulting a large pediatric hospital (neurosurgeon)	Teletrauma facilitated local management and stabilization prior to patient transport Strong relationships between the rural physicians and the specialist was

				acute trauma case" (p. 59)							the key to success
Saffle et al.	2009	USA	Description and comparative analysis of a telemedicine program	"to evaluate the feasibility and value of telemedicine-based evaluation of acutely burned patients" (p. 359)	Acutely burned patients (median age 30 years, interquartile range 33 years)	N=108 (n=80 teletrauma)	Telemedicine via portable televideo carts with a video camera and handheld macro camera for burn wound evaluation and consultation	Lack of access to timely subspecialty involvement	Population health Provider experience Patient experience Cost optimization	3 regional remote hospitals (emergency physicians, nurses) consulting a burn center (attending surgeons, physicians)	"telemedicine evaluation helped speed provision of appropriate critical care and justify the expense and risks of air transport" (p. 361) Providers and patients were satisfied with the technology and the telemedicine experience, and felt that it enhanced local management
Syed-Abdul et al.	2012	Sao Tome and Principe Islands, and Taiwan	Case study of a telemedicine burn program	To "report on the utilization of telemedicine to support the management of the burns treatment" (p. 207)	Acutely burned patients (both patients 7 years old)	N=2	Telemedicine via videoconferencing and email to consult on and manage burn patients and to allow patients to communicate with family members	Lack of access to specialist advice, knowledge, and surgical intervention	Population health	A remote hospital (medical team) consulting a university hospital (medical specialists)	Telemedicine facilitated continuing medical education for remote doctors Telemedicine "improved care management throughout the entire patient pathway" (p. 211)

											Telemedicine helped to establish and maintain the doctor-patient relationship
Westbrook et al.	2008	Australia	Before and after study	"to evaluate whether introduction of an emergency department (ED) telemedicine system changed patient management and outcome indicators and to investigate clinicians' perceptions of the impact of the system on care provided and on their work" (p. 704)	All acutely ill patients requiring urgent care (age range 0 years - >75 years)	N=350 (n=181 teletrauma)	Virtual Critical Care Unit using an ultrabroadband connection for real-time audiovisual communication during acute care cases	Lack of an ICU and access to specialist expertise	Provider experience Population health	A district hospital (nurses, physicians) consulting a large teaching hospital (specialists)	Teletrauma facilitates triaging of patients by identifying those not requiring further care Teletrauma resulted in improved understanding between the sites but increased workload and feelings of responsibility at the consulting site

Wibben-meyer et al.	2016	Iowa, USA	Prospective cohort study	To determine the "feasibility, acceptability, accuracy, and educational impact" (p. 532) of a burn telemedicine program	Acutely burned patients (mean age 25.2 ± 20.9 years)	N=282 (n=78 teletrauma)	Telemedicine via store-and-forward and conference calling whereupon video images are uploaded to a web-based portal for burn size estimation and clinical management	Lack of burn experience	Population health Provider experience	9 rural hospitals (referring staff) consulting a Level 1 trauma center (nurses and physicians)	"visual telemedicine has facilitated the proper mode of transport" (p. 536), assisted triage decisions, and facilitated care of the patient Telemedicine improved burn size estimation and fluid management decisions
Yang et al.	2015 a	California, USA	Retrospective cohort study	"To compare the appropriateness of hospital admission in eight rural emergency departments among a cohort of acutely ill and injured children who receive telemedicine consultations from pediatric critical care physicians to	Trauma - Children older than 1 day and younger than 17 years	N=138 (n=74 teletrauma)	Live, interactive, audiovisual communications system for acutely ill and injured children assigned to the highest triage category	Younger children Lower Revised Pediatric Emergency Assessment Tool score	Population health	8 rural emergency departments (physicians and nurses) consulting an academic children's hospital (pediatric critical care physician)	Telemedicine was associated with fewer admissions and transfers as compared to telephone consultations Telemedicine may reduce unnecessary transfers and enhances the accuracy of patient disposition decisions

				a cohort of similar children who receive telephone consultations from the same group of physicians" (p. e59)							
Yang et al.	2015 b	California, USA	Retrospective review and economic analysis	"to estimate the cost, effectiveness, and return on investment (ROI) of telemedicine consultations provided to health care providers of acutely ill and injured children in rural EDs compared with telephone consultations from a health care payer prospective" (p. 773)	Trauma - Children younger than 18 years	N=135 (n=71 teletrauma)	Live, interactive, audiovisual communications system for acutely ill and injured children assigned to the highest triage category	Younger children	Cost optimization	8 rural emergency departments (physicians and nurses) consulting an academic children's hospital (pediatric critical care physician)	Telemedicine reduces interfacility transfers and reduces health care costs The telemedicine program is more effective than telephone consultation

***Note: The Quadruple Aim (Bodenheimer & Sinsky, 2014), adapted from Berwick, Nolan, and Whittington's (2008) original Triple Aim framework for health care system optimization, was used to categorize the evaluation aim of each study into four domains: patient experience, provider experience, population health, and cost optimization**

Appendix C

Preliminary Teletrauma Interview Script

- **Collect demographic data**
- **Introduction, project overview, and explanation of interview process**
- **Option to ask questions about the project or the interview**
- **Verbal consent to audio record interview**
- **Begin interview:**

1. Tell me about your role in the community that you serve
2. Describe your experience using teletrauma in northern BC
3. Describe the general process for using the teletrauma system
    a. As the patient comes in, how it is activated, communication between providers, ending the call, outcomes, etc.
    b. Can you provide me with an example of how you have used this service?
4. Since the program began, how frequently have you used the teletrauma service?
    a. Per week/per month
5. When you have used the service, how long do you use it for on average?
    a. How does the duration of use vary by context or patient situation?
6. In which situations do you find teletrauma most beneficial?
    a. How is this beneficial for you as a provider?
    b. How is this beneficial for the patient?
7. Describe the types of patients who often access teletrauma
    a. Demographics
    b. Illness or injury type
    c. Symptoms or clinical profile
8. Are there other patients you think may benefit from the service?
9. In which situations would you find the service useful? For example, unfamiliar clinical case, lack of immediate specialist access, multiple traumas at the same time…

a. Clinician factors (level of expertise)
b. Patient factors (complex cases, need for referral)
c. Organizational factors (staffing levels, availability of specialists by phone)
d. Environmental factors (weather conditions during a potential transfer)

10. What factors may lead to a patient being considered a 'trauma patient'?
   a. When you first see or learn of a patient who is coming in, how do you know to label them a 'trauma' patient?
   b. Injury Severity Score?
   c. Level of complexity?
   d. Mechanism of injury?

11. How does the organization define a trauma case and does this differ from your perspective of trauma?
   a. Are there guidelines or policies that help you to identify a trauma patient?
   b. For which patients do policies and procedures activate a trauma code?

12. In your experience, what are some clinical outcomes of using teletrauma?
   a. Transfer
   b. Local management
   c. Death

13. For the following statements, please respond with the answer that most appropriately describes your experiences and beliefs using teletrauma **(strongly agree, agree, neutral, disagree, strongly disagree)**:
   a. I was able to communicate clearly and effectively using the teletrauma technology
   b. Use of teletrauma changed my clinical management plan
   c. Use of teletrauma facilitated timely access to appropriate care
   d. I believe teletrauma to be helpful in the provision of high quality trauma care
   e. Teletrauma is beneficial for patients
   f. Teletrauma is beneficial for providers
   g. When in-person evaluation is not available, teletrauma is an acceptable alternative
   h. Overall, I am satisfied with the teletrauma service

14. Is there anything that I haven't asked you about that you think is relevant or would like to share?

- **Option to provide additional comments or ask questions**

- **Explanation of the sampling process and inquire about potential participants known to the interviewee**

- **Ask if interviewee would like a brief report of findings emailed to them**
- **Conclude interview**

***Questions are preliminary and will evolve in response to emerging data**

Appendix D

Copyright Permission for Figure 1 – Geography of British Columbia by Health Authority

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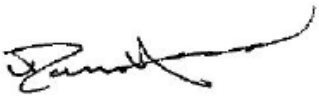

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From: **Diane Braithwaite** dbraith@uvic.ca
Subject: RE: copyright permission
Date: June 3, 2019 at 9:16 AM
To: Timothy Wood twood0@unbc.ca

DB

Hello Timothy. You have permission to use this figure in your thesis, with appropriate credit. All the best!

Diane

Diane Braithwaite
Publication Assistant
Canadian Western Geographical Series

-----Original Message-----
From: Timothy Wood [mailto:twood0@unbc.ca]
Sent: June-02-19 12:08 PM
To: Diane Braithwaite <dbraith@uvic.ca>
Subject: copyright permission

Hello,

I am writing to inquire about copyright permission for your figure about population densities across BC. I would love to be able to put this into my Master's thesis which will be a non-commercial publication. My thesis examines factors associated with telehealth use in northern regions of BC.

Digging around I have not been able to find the original source through BC Stats - I have contacted them and they confirmed they are not able to grant copyright permission because the map appears to have been 'created' by a third party (albeit with their statistics, I'm assuming). Am I able to use this figure for my thesis citing the secondary source (BC atlas - Foster et al.)?

Your insight would be greatly appreciated,

Timothy Wood

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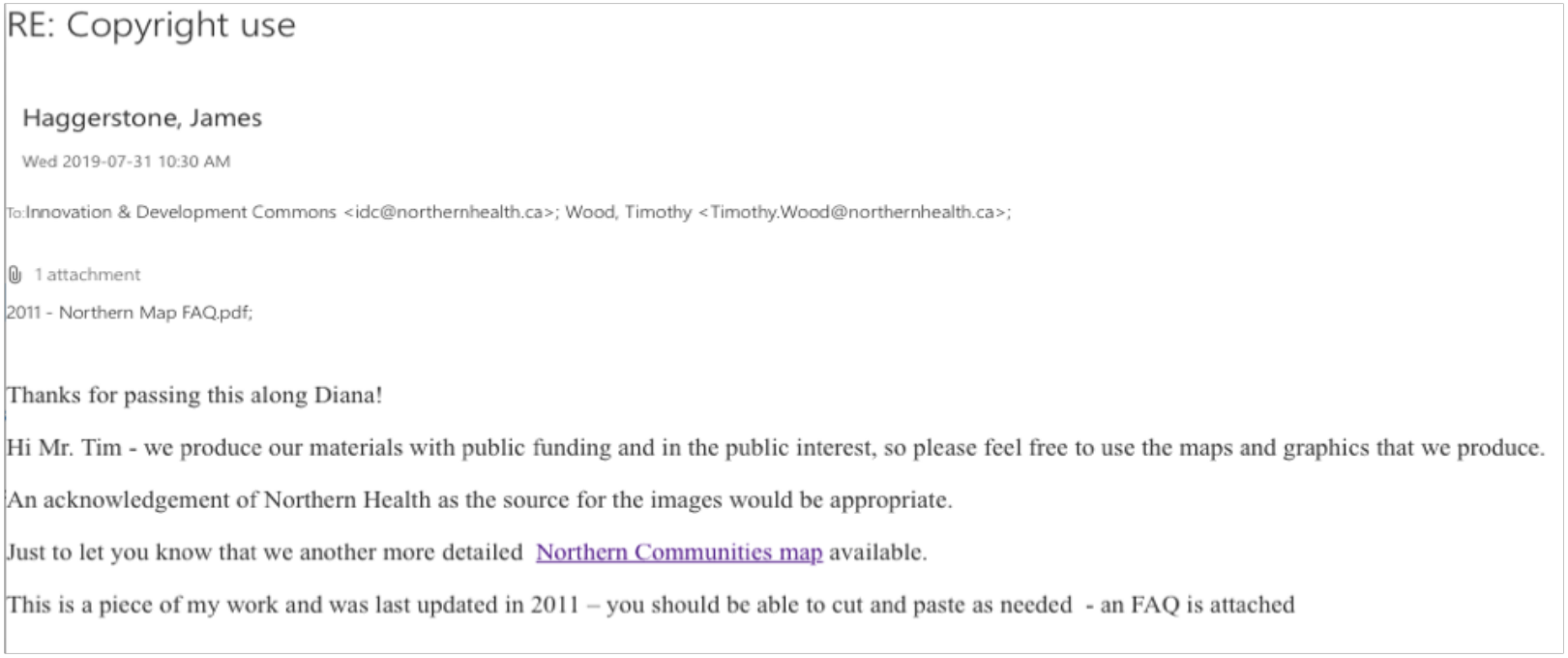

RE: Copyright use

Haggerstone, James

Wed 2019-07-31 10:30 AM

To: Innovation & Development Commons <idc@northernhealth.ca>; Wood, Timothy <Timothy.Wood@northernhealth.ca>;

1 attachment

2011 - Northern Map FAQ.pdf;

Thanks for passing this along Diana!

Hi Mr. Tim - we produce our materials with public funding and in the public interest, so please feel free to use the maps and graphics that we produce.

An acknowledgement of Northern Health as the source for the images would be appropriate.

Just to let you know that we another more detailed Northern Communities map available.

This is a piece of my work and was last updated in 2011 – you should be able to cut and paste as needed - an FAQ is attached