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Preliminary clinical algorithm to optimise remote delivery of paediatric concussion care in Canada's North

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ABSTRACT

Concussion is a form of traumatic brain injury that affects thousands of children and adolescents across Canada annually. With timely access to comprehensive medical care, the majority of patients with acute concussion will recover within 1–4 weeks. Those who develop persistent post-concussion symptoms often benefit from early recognition and referral to multi-disciplinary concussion clinics that have the personnel and resources to meet their complex needs. Youth who live in remote and isolated communities within Canada's North, a significant proportion of whom are Indigenous, face unique barriers and obstacles to accessing primary and specialised concussion care. Although telemedicine has recently emerged as a tool that can help address these gaps in care, there are presently no clinical guidelines or tools available to assist multi-disciplinary concussion clinics in providing remote concussion care to these medically underserved patients. Here we incorporate literature from a scoping review and our early institutional experience to present an evidence-informed preliminary clinical algorithm and resources to help guide and optimise remote paediatric concussion care delivery in Canada's North. We also discuss how innovative technologies and partnerships can be leveraged to enhance the delivery of safe, equitable, cost-effective and culturally appropriate care to these communities.

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Concussion is an injury sustained by thousands of Canadian youth annually [1,2]. With comprehensive medical assessment and complete follow-up, the majority of paediatric acute concussion patients will experience clinical recovery and a full return to school and sport activities within one-month post-injury [3]. Patients who do not have timely access to up-to-date medical care following concussion are at risk of returning to sports prematurely and suffering additional injury or developing persistent post-concussion symptoms, defined as symptoms lasting longer than 4 weeks post-injury (PPCS) [3,4].

People living in remote and isolated communities in Canada's North, an important proportion of whom are Indigenous, can experience unique geographic, socio-economic and cultural barriers to accessing primary and specialised healthcare [5–8]. Canada's North includes the northern regions of Canada's provinces as well as its three territories. The challenges of delivering care to vast and sparsely populated regions of northern Canada contribute to significantly higher per capita healthcare expenditures and worse health outcomes as compared to more southern regions of the country [9,10]. Because access to healthcare is an important social determinant of health, there is an urgent need for national healthcare leaders to develop innovative approaches, tools and partnerships that facilitate the delivery of safe, equitable, cost-effective and culturally appropriate care to these medically underserved communities.

Over the past two decades, telemedicine has emerged as a valuable tool that can enhance access to specialised healthcare for patients with a wide spectrum of neurological disorders including acute stroke, headache, epilepsy and mental health disorders [11,12]. More recently, preliminary research has demonstrated that telemedicine can provide timely access to safe and cost-effective paediatric concussion care within medically underserved communities [13]. Similar to established systems of care for acute stroke, additional work suggests that telemedicine-based networks may provide an innovative approach that connects paediatric concussion patients living in rural, remote and isolated

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communities to regional multi-disciplinary concussion programmes located in distant urban settings [14]. Although clinical care of paediatric concussion in Canada is directed by up-to-date and harmonised national evidence-based clinical guidelines [15,16], none provide guidance on the appropriate use of telemedicine. Furthermore, there are presently no available clinical tools tailored for the delivery of remote paediatric concussion care. Given these persistent knowledge gaps, it is important for centres with established telemedicine programs to report their clinical experiences, share their approaches and resources and explore innovative solutions to outstanding challenges.

Here we highlight the challenges of accessing healthcare in Canada's North, outline the principles of paediatric concussion medical assessment and management and perform a scoping review of the published literature on the remote delivery of paediatric concussion care in Canada. Using this background, we present an evidence-informed preliminary clinical algorithm and resources to help guide the "real-world" care of paediatric concussion patients living in Canada's North. Lastly, we highlight additional work using remote presence technology in medically underserviced communities and postulate how this technology could be leveraged to improve paediatric concussion care across provincial and territorial borders.

Challenges of accessing healthcare in Canada's North

Youth living in Canada's North face a number of barriers and challenges to accessing primary and specialised healthcare. Primary healthcare within many remote and isolated communities in northern Canada is provided by community healthcare centres that are primarily staffed by nurses and supported by periodically visiting physicians. These healthcare centres can experience high staff turnover and inconsistent access to physicians and lack of access to healthcare providers with specialised expertise in fields such as emergency medicine and paediatrics [5,8,17]. Patients who require specialised medical care are routinely required to travel to regional hospitals or tertiary centres hundreds or thousands of kilometres away. Systems of care that depend greatly on medical travel can be impacted by numerous factors including seasonal weather conditions, personal access to ground transportation, lack of childcare and the inability of parents to miss work for prolonged periods of time. The overall healthcare expenditures associated with medical travel for Canada's northern communities are enormous and continue to increase. Depending on the accessibility of the community and distance to a tertiary hospital, the cost of an individual return flight can range from $500 to 5000, CAD a cost that is doubled for youth who require an escort or parent to accompany them. In order to serve residents living within 25 isolated communities, the Government of Nunavut spent over $70 CAD million on medical travel during the 2015–2016 fiscal year [18] and anticipates spending over $100 CAD million during 2020–2021 [19]. In addition to these geographic and social obstacles, people living in northern communities in Canada (a significant proportion of who are Indigenous) can also face cultural and language barriers to accessing patient-centred care. Some Indigenous patients can have difficulty accessing information that is provided in their preferred language and considers their cultural-specific perspectives on health and wellness. For others, exposure to systemic racism and discrimination during previous interactions with the healthcare system present barriers to obtaining prompt diagnosis and treatment [7,20]. In the context of historical legacies of colonialism including the residential school system, the forceful placement of children into foster care (termed, Sixties Scoop) and the high number of missing and murder Indigenous women and girls throughout Canada, the Truth and Reconciliation Commission has urged Canadians to prioritise healthcare access for Indigenous people as a means to eliminate the gaps in health equity [21]. Therefore, it is important that novel models of healthcare delivery that serve Canada's northern and Indigenous populations are developed in close partnership with community healthcare and Indigenous leaders allowing these programs to provide the highest standard of inequity-responsive, contextually tailored, trauma and violence-informed and culturally safe care [22].

Principles of paediatric concussion medical assessment and management

Over the past decade, paediatric concussion care in Canada has benefitted from the development of harmonised evidence-based clinical guidelines including the *Canadian Guideline on Concussion in Sport* developed by Parachute [16] and the Ontario Neurotrauma Foundation's *Living Guideline for the Diagnosing and Managing Paediatric Concussion* [15]. These guidelines recommend that all children and adolescents who sustain a suspected acute concussion undergo urgent medical assessment. Patients who sustain head or neck trauma can experience non-specific symptoms such as headache, dizziness, blurred vision, neck pain, fatigue and sadness. Therefore, the medical diagnosis of concussion can be made only after medical exclusion of more severe forms of traumatic brain injury (TBI), cervical spine injury as well as medical and neurological conditions that can present with these symptoms [23]. A comprehensive medical assessment includes a careful clinical history, comprehensive physical examination and the

evidence-informed use of diagnostic tests such as imaging (e.g. plain radiographs, computerised tomography). Symptoms should be assessed with validated symptom inventories. The physical examination should include evaluation of mental status and speech as well as cranial nerve, motor, sensory, reflex, and cerebellar functioning, as well as gait, balance and the cervical spine. With appropriate expertise, objective evaluation of oculomotor functioning including convergence, accommodation, smooth pursuits and saccades may be considered [24]. Following cervical spine clearance, peripheral vestibular functioning can be assessed using Dix-Hallpike and head thrust testing as indicated [25]. Depending on the patient presentation, physical examination of other organ systems may be warranted (e.g. cardiac examination in patients presenting with syncope; otoscopic examination in patients with hearing impairments).

Once a medical diagnosis of concussion has been confirmed, patients should be provided with written education on expected symptoms and prognosis, warning signs that indicate when to return for medical re-assessment and what steps they can take to make a safe and gradual return to school, work and sport-related activities. Patients should also be provided a Medical Assessment or Medical Clearance Letter that indicates which activities they have been medically cleared to return to. In general, concussion patients should undergo medical follow-up every 1–2 weeks depending on their rate of recovery. Follow-up assessments should focus on the whether the patients' symptoms have resolved, improved, worsened or remained stable, the patient's predominant symptoms as well as their progress through the necessary steps to achieve a complete return to school, work and sports as applicable. In general, patients should be considered clinically recovered when they are symptom-free or have returned to their pre-injury symptom status, are tolerating a full return to school or work activities where applicable and have a normal neurological examination [23]. In-season athletes returning to sports should also be able to complete non-contact practice without any concussion-like symptoms prior to obtaining a Medical Clearance Letter to allow them to return to full contact practices, and if tolerated without any concussion-like symptoms, full game play.

While the majority of paediatric patients with acute concussion make a complete neurological recovery with education, guidance and conservative management, some will experience PPCS, defined as symptoms lasting longer than 4 weeks [3]. National concussion guidelines recommend that patients with PPCS be referred to multidisciplinary concussion clinics that have access to physicians with experience in concussion and TBI (e.g. sports medicine or rehabilitation physician, neurologist or neurosurgeon) who work with a collaborative team of healthcare providers such as those with expertise in neuropsychology, vestibular and cervical spine physiotherapy, neurology, neuro-ophthalmology and psychiatry [15,16]. Previous research using online searches suggests that most concussion clinics are located within urban centres with a paucity of specialised concussion-related service providers identified within Canada's northern territories [26].

What is known about remote paediatric concussion care in Canada's North

To ensure we identified all pertinent research related to the remote delivery of paediatric concussion care in Canada's North, we performed a scoping review. Pubmed was searched from its inception to 18 September 2020 using the following search strategy: Concussion AND (Telemedicine OR Telehealth) AND (Pediatrics OR Child*) AND (Remote OR Rural). In total, five studies were identified and independently reviewed by two authors to determine if the studies addressed remote care of paediatric concussion patients in Canada's North. Only two manuscripts were identified. Both manuscripts were published by the current authors (M.E and K.R) and review the development of a paediatric concussion telemedicine programme and network to enhance access to medical and multidisciplinary care to patients living in rural, remote and isolated regions of Canada. The two publications are described below.

Preliminary experience of the Pan Am Clinic CONNECT Program

The Pan Am Concussion Program is a provincial government program located in Winnipeg, Manitoba, Canada that provides multi-disciplinary care to paediatric patients with concussion and TBI. All patients evaluated through this program undergo medical assessment and management by a neurosurgeon who works closely with provincial experts in neuropsychology, exercise science, vestibular and cervical spine physiotherapy, neurology, neuro-ophthalmology, radiology and adolescent psychiatry. To improve access to care among paediatric patients living in northern and remote communities in Manitoba, the Pan Am Concussion Program partnered with Thompson General Hospital to develop a pilot project of a paediatric concussion telemedicine program (now termed the Pan Am Clinic CONcussion in the North EConsultation and Telemedicine, CONNECT Program) [13]. The distance between the two centres is approximately 760 km, which is an 8–10-h drive (depending on seasonal road conditions) or a 1.5-h flight by airplane. Patients who were eligible for consultation via telemedicine included paediatric patients (<20 years of age) with acute head injury/concussion or PPCS and who had undergone a previous medical assessment by a physician or nurse

practitioner in the emergency department or primary care setting. All patient referrals were screened by a single neurosurgeon to decide whether initial medical assessment could be safely performed via in-person videoconferencing or whether an in-person assessment was required. During the pilot project, 20 patients were evaluated through the telemedicine program. Eighteen patients (90%) underwent initial medical assessment via in-person videoconferencing. One patient referral was screened and selected for in-person initial medical assessment due to the presence of transient monocular visual disturbance and a documented orbital floor fracture while another patient was referred from a local emergency department and underwent in-person assessment prior to returning to their remote community. The median time from the date the referral was received and reviewed at the concussion program to initial specialist consultation was 2 days. The initial medical assessment performed via in-person videoconferencing consisted of a clinical history, assessment of symptoms using the Post-Concussion Symptom Scale (PCSS), review of diagnostic imaging studies and a focused physical examination performed without the aid of a remote examiner. Following initial medical assessment, 17 patients were diagnosed with acute concussions, one patient was diagnosed with PPCS and post-traumatic migraine headaches and two toddlers were diagnosed with head injuries. Four patients underwent assessment by other members of the multi-disciplinary team including a headache neurologist (2 patients), vestibular physiotherapist (1 patient), neuro-ophthalmologist (2 patients), paediatric ophthalmologist (1 patient), plastic surgeon (1 patient), exercise physiologist for graded aerobic treadmill testing (1 patient), mobile crisis (1 patient) and adolescent psychiatrist (1 patient). One patient was arranged an MRI of the brain. At the end of the study period, 90% of patients achieve clinical recovery, one was discharged to the care of a headache neurologist and one remained in treatment. Eighty per cent of patients were managed exclusively by telemedicine. The estimated cost avoidance based on regional health authority road travel reimbursement rates associated with the 66 telemedicine appointments (57 in-person videoconferencing appointments and 9 telephone follow-ups) was $40, 973 CAD or $2049 CAD per patient. Delayed follow-up (>1 month) among 16 patients who experienced clinical recovery revealed that no one experienced recurrent symptoms or a new concussion following clinical discharge.

In a second manuscript identified in our scoping review, Ellis and Russell (2019) concluded that, similar to models of care established for acute stroke, provincial paediatric concussion programs and clinics can use telemedicine to partner with smaller regional hospitals and community healthcare centres to establish hub-and-spoke type networks that improve access to specialised primary and multi-disciplinary care for patients living in rural and remote regions of Canada [14].

Indeed, following a successful pilot project, the Pan Am Concussion Program has collaborated with leaders from Ongomiizwin Health Services, First Nations and Inuit Health Branch, First Nations Health and Social Secretariat of Manitoba, Jordan's Principle, Manitoba Keewatinowi Okimakanak and MBTelehealth to expand the CONNECT program to provide access to all youth throughout Manitoba. Because paediatric patients with acute head trauma living within the Kivalliq region of Nunavut are often sent to Winnipeg for emergency care, the program also partnered with leaders from the Government of Nunavut to expand program access to youth living in these communities.

As detailed in both of these outlined manuscripts and noted by other authors [12], the most important clinical limitation of using telemedicine to manage patients with neurological conditions is the inability to perform a complete physical examination. Without the aid of a remote examiner or telepresenter, which are often unavailable to patients undergoing assessment at healthcare centres in Canada's North, certain important aspects of the physical examination including testing of motor and sensory functioning, tone, reflexes, fundoscopic, otoscopic and cardiac examinations cannot be performed. Depending on the visual resolution and capabilities of the in-person videoconferencing system, which are highly variable across Canada's North, clinicians may not be able to appreciate more subtle findings of the oculomotor examination. Comprehensive evaluation of the peripheral vestibular system in patients with head trauma requires palpation and clinical clearance of the cervical spine as well as Dix-Hallpike and head thrust testing, all of which cannot be performed via in-person videoconferencing. Despite these limitations, several clinical understandings suggest that concussion is a condition that is uniquely suited for telemedicine and remote care approaches. First, the vast majority of patients with acute concussion have normal findings on examination of cranial nerve, motor, sensory, reflex and cerebellar functioning. Those who do demonstrate these abnormalities often report localising symptoms or red flags on clinical history (weakness or numbness of the extremities, monocular visual disturbance, vertigo) that by themselves herald the presence of a structural brain injury or co-existing condition such as structural or functional cervical spine injury, cranial neuropathy or peripheral vestibular disorder [24,27,28]. Second, clinical studies suggest that some acute concussion patients present with objective evidence of visual, oculomotor and vestibular dysfunction on initial assessment, however, the majority of these patients experience spontaneous recovery of these impairments without any additional supplemental testing or treatment [29–31]. Lastly, patients with

normal physical examination findings on initial assessment are unlikely to develop new clinically meaningful abnormalities on follow-up examinations. Together, these factors suggest that under unique circumstances, it is feasible for physicians to apply multiple levels of risk stratification to acute concussion patients to help guide the form of care, remote or in-person, they may receive during different post-injury time points.

Preliminary clinical algorithm for remote concussion care in Canada's North

Taking into consideration the challenges of delivering healthcare to youth in Canada's North, the general principles of concussion management, and the strengths and limitations of using telemedicine in paediatric concussion patients, we present an evidence-informed preliminary clinical algorithm to help guide remote concussion care for this unique population (Summarised in Figure 1).

In order to meet national standards of care, it is important that all children and adolescents who sustain a suspected acute concussion undergo an urgent medical assessment. Because of the previously outlined limitations of performing a complete physical examination via telemedicine, all patients should ideally undergo an initial in-person medical assessment performed by a medical doctor, nurse practitioner or nurse. Physician specialists (sports or rehabilitation medicine physicians, neurologists, neurosurgeons) working at concussion clinics who receive referrals for concussion patients who have undergone a previous medical assessment by another primary care provider should review referrals for dangerous mechanisms of injury, clinical red flags or worrisome features (e.g. orbital trauma, seizure, focal neurological deficits, abnormal diagnostic imaging studies) that may suggest the presence of alternative diagnoses or additional co-existing conditions that may not be able to be comprehensively evaluated via telemedicine. In the absence of these features, the physician should assess whether the patient and their caregiver are agreeable to a remote medical assessment and has access to secure, high-quality in-person videoconferencing at a local healthcare centre or hospital. In general, patients without access to secure high-quality in-person videoconferencing should be considered for in-person medical assessment. For these patients, obstacles to accessing non-urgent in-person care should be carefully considered (e.g. geographic distance, mode of travel, weather conditions, other travel restrictions).

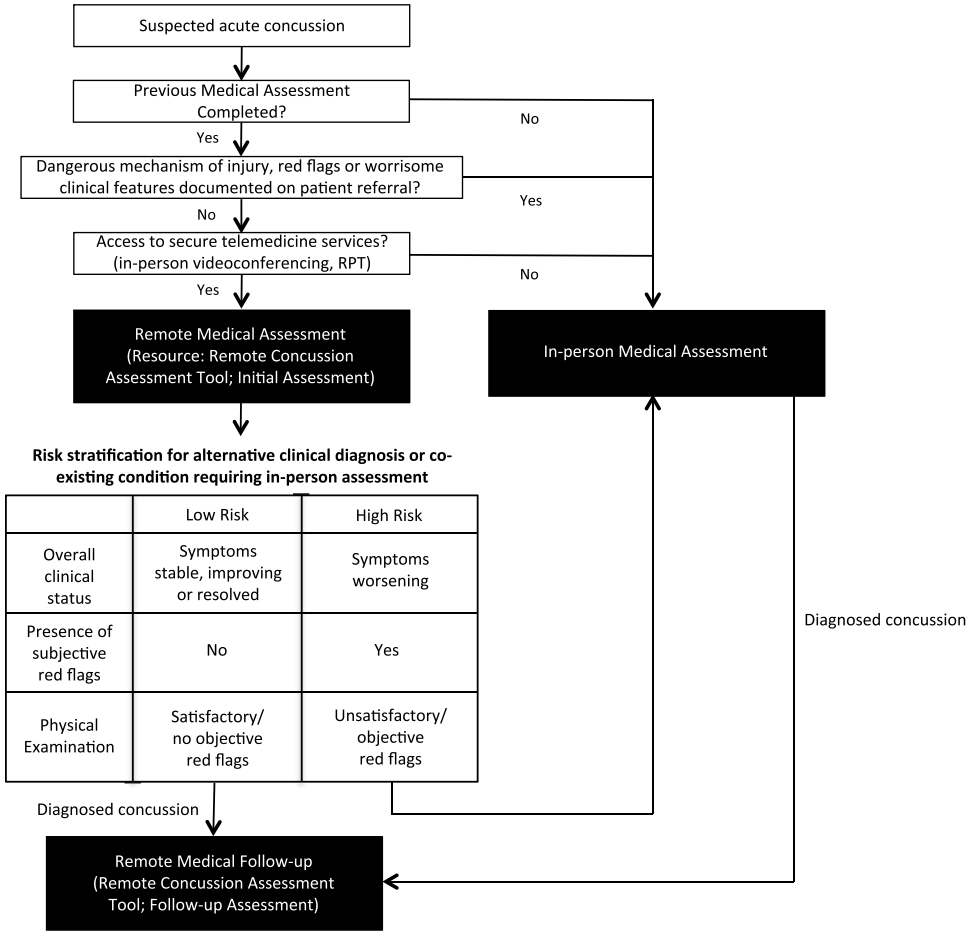

Figure 1. Preliminary clinical algorithm for remote paediatric concussion care in Canada's North.

Patients who have been carefully selected for remote medical assessment should undergo evaluation in a quiet and private room at the nearest healthcare facility that ideally has ample space to perform all aspects of the physical examination. Prior to beginning the clinical assessment, the physician should confirm the patient's identity, demographic and contact information and obtain informed consent from the patient's parent or guardian to proceed with the consultation. To aid physicians in performing remote medical assessment, the authors introduce the Remote Concussion Assessment Tool: Initial Assessment (Supplemental file 1). This two-page document provides a standardised method of documenting the results of a careful clinical history and an assisted or unassisted physical examination, medical diagnoses as well as clinical recommendations including medical clearance to return to certain activities or additional investigations or consultations. Where possible, a validated concussion symptom inventory can be faxed to the healthcare centre for the patient to complete. The physical examination section includes a collection of tests that can be completed without the aid of a telepresenter but provides space for additional test results to be documented if a telepresenter is available (for description of tests and interpretation see Table 1). The tool also allows providers to document certain aspects related to the telemedicine assessment and quality control. Following the assessment, patients should be faxed or electronically provided a Canadian Guideline on Concussion in Sport Medical Assessment or Clearance Letter as well as a Parachute Post-Concussion Education Sheet that has also been adapted for First Nations and Nunavut youth (available free to download at https://www.panamclinic.org/patients-visitors/patient-resources/#concussion-education).

Based on the results of the remote medical assessment, the physician should be able to identify those patients at low- or high-risk for the presence of an alternative diagnosis, co-existing condition or other circumstances that require an in-person medical assessment to facilitate additional physical examination testing or supplemental investigations. Those with worsening symptoms, subjective red flags (worsening headache, repetitive vomiting, blurred or double vision, weakness or numbness of the extremities, neck pain, vertigo) or in whom the results of the physical examination are unsatisfactory or reveal objective red flags (positive pronator drift, reported diplopia on testing of extraocular movements, dysarthric speech, restricted or painful range of motion of the cervical spine) should be arranged an in-person medical assessment as soon as possible. However, patients with stable, improving or resolved symptoms, no subjective red flags and in whom a satisfactory physical examination is performed without any objective red flags may be considered for remote medical follow-up. For patients who have been previously transferred to a tertiary centre for urgent emergency assessment and have undergone an in-person medical assessment by the consulting physician, future follow-up assessments may be arranged remotely. To assist physicians and other primary care providers with remote medical follow-ups, the authors introduce the Remote Concussion Assessment Tool: Follow-up Assessment (Supplemental file 2). This two-page document provides a standardised method of documenting the patient's updated clinical and return to activity status, physical examination findings, results of additional diagnostic tests or consultations, treatment plan as well as medical clearance to return to certain activities.

For patients who develop PPCS or who require non-urgent travel to tertiary centres for additional investigations or multi-disciplinary assessments, physicians should always work with patient, families and other healthcare providers to coordinate the scheduling of these clinical appointments as to limit trips and time away from their family and community. During these visits, in-person assessments with the treating physician can also be arranged to conduct more comprehensive physical examinations that could not be completed via telemedicine.

Future directions

Although previous research suggests that the clinical approach outlined here is safe, feasible and cost-effective, additional work is needed to optimise patient and provider satisfaction as well as comprehensively identify the social and economic benefits of this model of care. This approach will also benefit from future refinement and validation of additional clinical tools and tests that are tailored to remote concussion assessments.

As this approach is heavily reliant on high-quality bidirectional audiovisual videoconferencing, weather conditions as well as disparities in bandwidth can contribute to heterogeneous connectivity and audiovisual quality across communities in Canada's North. Videoconferencing workstations and examination room configurations can also differ across communities, which in some cases can present limitations to performing certain aspects of the telemedicine-based physical examination. Accumulating research and clinical work outside the field of concussion suggests that some of these limitations may be overcome by the use of remote presence technology (RPT) [32]. Systems such as the RP-VITA robots (In-Touch Health Inc., Santa

Table 1. Remote physical examination for concussion.

Indicate whether the physical examination was performed with the help of a remote examiner or telepresenter (assisted) or not (unassisted).
Glasgow Coma Scale: Record best eye, verbal and motor response [37].
Speech: Speech may be assessed during clinical interview or on examination.
Abnormal: document any evidence of dysarthria, word finding difficulty, apraxia, aphasia etc.
Cranial nerves:
Extraocular movements/smooth pursuits: Ask the patient to positioned themselves close to the camera. Ask the patient to look directly at the camera. Observe ocular alignment in the primary position assess for any evidence of ptosis or nystagmus. Ask the patient to keep their head still and hold their finger up at eye level approximately half an arms length away from their face. While following their finger with their eyes, ask the patient to slowly move their finger to the right and left and then trace an "H" allowing the examiner to evaluate the six cardinal positions of gaze. Ask the patient if they experience any diplopia during gaze in any direction.
Abnormal: Note any abnormal alignment of the eyes in the primary position or any restriction in eye movement during testing. Note any patient-reported diplopia during testing. Evaluate the patient's ability to follow their finger without frequent saccadic corrections.
Facial symmetry: Ask the patient to look directly at the camera. Ask the patient to smile. Ask the patient to elevate their eyebrows and then close their eyes tightly.
Abnormal: Note any facial asymmetry at rest or during testing.
Facial sensation: Ask the patient to take the index finger of each of their hands and lightly touch their face along the ipsilateral V1, V2, and V3 distributions of the trigeminal nerve. Ask the patient to indicate whether sense of touch is perceived in all distributions and is equal when comparing both sides.
Abnormal: Note any evidence of decreased sensation.
Movement of palate and tongue: Ask the patient to positioned themselves close to the camera. Ask the patient to open their mouth and say "ah". Ask the patient to stick out their tongue move it to the right and left and retract it.
Abnormal: Note any asymmetry or abnormal findings. Note any restricted movement of the jaw/mouth opening.
Motor/coordination:
Pronator drift: In a standing position, ask the patient to raise their arms forward to shoulder level (90 degrees of shoulder flexion) and position their hands with palms facing upwards. Ask the patient to close their eyes and maintain this position. Note any pronation of the hand or downward drift of the arm.
Rapid alternating hand movements: In a standing position, ask the patient to place one hand palm upwards in front of them and place the opposite hand palm down on top of the other hand. Ask the patient to rapidly flip the top hand quickly back and forth from a palm up and down position. Ask the patient to switch hands and repeat the same movements.
Abnormal: Note any differences in speed or coordination between sides.
Cervical spine: In a standing position, ask the patient to slowly flex their neck forward, extend their neck backwards, and flex their neck to the left and right as far as comfortably possible. Ask the patient to slowly rotate their neck to the left and right as far as comfortably possible. Ask the patient whether they experience any pain during any movements. Note any restricted range of motion or any reported pain.
Balance/Gait:
Feet together stance: With the patient positioned so their entire body is visible to the examiner, ask the patient to stand with their feet together and their hands on their hips. Ask the patient to close their eyes and hold the position for 20 seconds.
Abnormal: Note any instability, stumbling out of position or eye opening.
Tandem stance: With the patient positioned so their entire body is visible to the examiner, ask the patient to stand with their dominant foot heel-to-toe in front of their non-dominant foot with their hands on their hips. Ask the patient to close their eyes and hold the position for 20 seconds.
Abnormal: Note any instability, stumbling out of position or eye opening.
Tandem gait (eyes open): With the patient positioned so their entire body is visible to the examiner, ask the patient to walk in the forward direction heel-to-toe with their eyes open.
Abnormal: Note any instability, stumbling out of position or eye opening.
Tandem gait (eyes closed): With the patient positioned so their entire body is visible to the examiner, ask the patient to walk in the forward direction heel-to-toe with their eyes closed.
Abnormal: Note any instability, stumbling out of position or eye opening.
Memory: Explain to the patient that you are going to test their memory. Provide the patient with a list of five items. Ask the patient to immediately repeat back the items back in any order. Record the number of correctly repeated items out of five (immediate recall). After a set time period (e.g 5-10 minutes) has elapsed, ask the patient if they can remember the five items provided. Record the number of correctly repeated items out of five (delayed recall).
Vestibulo-ocular:
Horizontal saccades: Ask the patient to positioned themselves close to the camera. Ask the patient to hold up their index fingers and place them at half arms length away from the face and 30 cm apart from each other. While keeping their head still, ask the patient to look quickly and accurately back and forth between each index finger for a total or 10–15 repetitions. Ask the patient whether performing these eye movements worsen or elicit any concussion symptoms (e.g dizziness, headache)
Abnormal: Note evidence of over- or undershooting of the target or saccadic corrections. Note slowed or delayed initiation of saccades.
Symptomatic: Note whether the movements elicit or worsen any concussion-like symptoms (e.g dizziness, headache)
Gaze stabilisation: Ask the patient to hold their thumb up at the level of the eyes and at arms length distance from the face. Ask the patient to fix their eyes on their thumb and quickly but comfortably shake their head back and forth within 15–20 degrees of rotation for 10–20 repetitions.
Symptomatic: Note whether the movements elicit or worsen any concussion-like symptoms (e.g dizziness)
Note: Do not perform test unless patient has full and painless range of motion of the cervical spine.

Note: The physical examination section of the Remote Concussion Assessment Tools also provides space to include findings from additional tests that are completed with and without the aid of a telepresenter (e.g. motor, sensory, near point of convergence testing, cervical spine palpation, orthostatic blood pressure).

Barbara, CA) have been designated as a class II medical devices by the US Food and Drug Administration and can be effectively used in clinical settings where patient monitoring and clinical action are needed. These robots (see Figure 2) are controlled wirelessly by a laptop computer using a standard 802.11 Wi-Fi internet link or by a smartphone or iPad using cellular networks with at least 3 G telecommunication infrastructure. The robots contain a head fitted with a mobile flat screen monitor and cameras that permit bi-directional

Figure 2. Remote presence technology (RPT). A) RP-7 robot; B) RP-VITA robot.

videoconferencing, a base that includes a digital stethoscope and printer that can dispense patient hand-outs, as well as a wheeled triangular base. These features allow the robot to be deployed to any room within a healthcare centre and allow the physician to adjust the position of the robot as well as the direction and zoom of the cameras to optimise patient interactions and physical examinations. The RP-VITA robot is an autonomous system that can safely navigate the clinical environment to preset locations such as patient wards, emergency departments and outpatient clinics.

Previous work demonstrated that remote primary and emergency care using the RP-7 robot in an Inuit community in northern Newfoundland and Labrador was associated with a 60% reduction in patient air transfers [33]. Furthermore, 100% of physicians and nurses who participated in the study felt the capabilities of the RP-7 robot were superior to conventional in-person videoconferencing. In an additional study within a remote First Nations community in northern Saskatchewan, 63% of acutely ill children assessed by RPT were safely treated within their home community and did not need to be transported to tertiary level hospitals to receive care. The use of RPT in this study also demonstrated considerable savings in the care of these children by reducing transport and hospital admission costs [17]. Because the RPT creates a sense that the remote physician is present at the patient's bedside, can facilitate collaborative treatment plans and can be used to promote self-determined approaches to healthcare priorities, this technology offers the potential to deliver culturally safe specialised emergency and paediatric care to communities throughout Canada's North [34]. Furthermore, because the RPT does not rely on other technological infrastructure and can be deployed to any room within a facility, it also offers greater scheduling flexibility for patients and healthcare centres.

Given these notable advantages over conventional in-person videoconferencing, we believe that the incorporation of RPT into our existing paediatric concussion clinical algorithm may improve the detection of more subtle physical examination findings, offer the opportunity to collect additional clinical information (e.g

cardiac auscultation, vital signs), enhance patient-physician rapport and offer greater access to remote care across Canada's North. As a first step, leaders from the University of Saskatchewan and the Pan Am Clinic are in the process of establishing a pilot project that will evaluate the use of RPT to deliver specialised concussion care to remote northern communities in the province of Saskatchewan.

Technological advances in telecommunications such as the advent of 5 G digital infrastructure, the expansion of cellular networks to northern remote locations and the continued development of telehealth hardware and software solutions will facilitate the delivery of concussion care to underserviced populations. The current COVID-19 pandemic has demonstrated the value of virtual care strategies and has helped remove some barriers to the implementation of remote clinical assessments such as appropriate remuneration for virtual care [35,36]. This type of legislation will facilitate the establishment of remote paediatric concussion assessments as a viable service to rural and urban populations across Canada and beyond.

Conclusions

In summary, youth living in remote and isolated communities in Canada's North can face important barriers and obstacles to receiving primary and specialised concussion care. Telemedicine-based platforms, including in-person videoconferencing and RPT hold great promise as tools that can be used to enhance access to specialised concussion care for remote, isolated and medically underserviced communities. The clinical algorithm and tools presented here may serve to empower multi-disciplinary concussion clinics to work together to provide more comprehensive and standardised clinical coverage and support across Canada's North.

Disclosure statement

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References

[1] Canadian Institite of Health Information. [cited 2019 Jun 17]. https://www.cihi.ca/en/heads-up-on-sport-related-brain-injuries-0

[2] Zemek RL, Grool AM, Rodriguez Duque D, et al. Annual and seasonal trends in ambulatory visits for pediatric concussion in Ontario between 2003 and 2013. J Pediatr. 2017;181:222–8 e2.

[3] Davis GA, Anderson V, Babl FE, et al. What is the difference in concussion management in children as compared with adults? A systematic review. Br J Sports Med. 2017;51(12):949–957.

[4] Kamins J, Giza CC. Concussion-mild traumatic brain injury: recoverable injury with potential for serious sequelae. Neurosurg Clin N Am. 2016;27(4):441–452.

[5] Huot S, Ho H, Ko A, et al. Identifying barriers to healthcare delivery and access in the Circumpolar North: important insights for health professionals. Int J Circumpolar Health. 2019;78(1):1571385.

[6] Marrone S. Understanding barriers to health care: a review of disparities in health care services among indigenous populations. Int J Circumpolar Health. 2007;66(3):188–198.

[7] National Collaborative Centre For Aboriginal Health. (2011) Access to health services as a social determinant of First Nations, Inuit and Metis health.

[8] Oosterveer TM, Young TK. Primary health care accessibility challenges in remote indigenous communities in Canada's North. Int J Circumpolar Health. 2015;74:29576.

[9] Young TK, Chatwood S. Health care in the north: what Canada can learn from its circumpolar neighbours. CMAJ. 2011;183(2):209–214.

[10] Young TK, Chatwood S, Marchildon GP. Healthcare in Canada's North: are we getting value for money? Healthcare Policy. 2016;12(1):59–70.

[11] Patel UK, Malik P, DeMasi M, et al. Multidisciplinary approach and outcomes of tele-neurology: a review. Cureus. 2019;11(4):e4410.

[12] Wechsler LR, Tsao JW, Levine SR, et al. Teleneurology applications: report of the Telemedicine Work Group of the American Academy of Neurology. Neurology. 2013;80(7):670–676.

[13] Ellis MJ, Boles S, Derksen V, et al. Evaluation of a pilot paediatric concussion telemedicine programme for northern communities in Manitoba. Int J Circumpolar Health. 2019;78(1):1573163.

[14] Ellis MJ, Russell K. The potential of telemedicine to improve pediatric concussion care in rural and remote communities in Canada. Front Neurol. 2019;10:840.

[15] Ontario Neurotrauma Foundation: Living Guideline on Diagnosing and Managing Pediatric Concussion. 2019. [cited 2020 Jun 17]. https://braininjuryguidelines.org/pediatricconcussion/wp-content/uploads/2019/09/Living-Guideline-for-Diagnosing-and-Managing-Pediatric-Concussion-v09.2019.pdf

[16] Parachute: Canadian Guideline on Concussion in Sport. 2017. [cited 2020 Jun 17]. https://parachute.ca/wp-content/uploads/2019/06/Canadian-Guideline-on-Concussion-in-Sport.pdf

[17] Holt T, Sari N, Hansen G, et al. Remote presence robotic technology reduces need for pediatric interfacility transportation from an isolated northern community. Telemed J E Health. 2018;24(11):927–933.

[18] Office of the Auditor General of Canada. Report of the Auditor general of Canada: health services- Nunavut. 2017 March [cited 2020 Jun 17]. https://www.oag-bvg.gc.ca/internet/English/nun_201703_e_41998.html

[19] Nunatsiaq News. Health care sees the biggest boost in Nunavut's 2020–21 budget. 2020 Feb 20. [cited 2020 Jun 17]. https://nunatsiaq.com/stories/article/health-care-sees-the-biggest-boost-in-gns-planned-2020-21-budget/
[20] Browne AJ. Moving beyond description: closing the health equity gap by redressing racism impacting Indigenous populations. Soc Sci Med. 2017;184:23–26.
[21] Truth and Reconciliation Commission of Canada. Truth and reconciliation commission of Canada: calls to action. 2015 [cited 2020 Jun 17]. http://trc.ca/assets/pdf/Calls_to_Action_English2.pdf
[22] Browne AJ, Varcoe C, Lavoie J, et al. Enhancing health care equity with indigenous populations: evidence-based strategies from an ethnographic study. BMC Health Serv Res. 2016;16(1):544.
[23] Ellis MJ, Bauman S, Cowle S, et al. Primary care management of concussion in Canada. Paediatr Child Health. 2019;24(3):137–142.
[24] Ventura RE, Balcer LJ, Galetta SL. The neuro-ophthalmology of head trauma. Lancet Neurol. 2014;13(10):1006–1016.
[25] Reneker JC, Clay Moughiman M, Cook CE. The diagnostic utility of clinical tests for differentiating between cervicogenic and other causes of dizziness after a sports-related concussion: an international Delphi study. J Sci Med Sport. 2015;18(4):366–372.
[26] Ellis MJ, Ritchie L, Selci E, et al. Googling concussion care: a critical appraisal of online concussion healthcare providers and practices in Canada. Clinical J Sport Med. 2017;27(2):179–182.
[27] Ellis MJ, McDonald PJ, Olson A, et al. Cervical spine dysfunction following pediatric sports-related head trauma. J Head Trauma Rehabilitation. Mar/Apr 2019; 34 (2): 103–110.
[28] Fife TD, Giza C. Posttraumatic vertigo and dizziness. Semin Neurol. 2013;33(3):238–243.
[29] Ellis MJ, Cordingley D, Vis S, et al. Vestibulo-ocular dysfunction in pediatric sports-related concussion. J Neurosurg Pediatr. 2015;16(3):248–255.
[30] Ellis MJ, Cordingley DM, Vis S, et al. Clinical predictors of vestibulo-ocular dysfunction in pediatric sports-related concussion. J Neurosurg Pediatr. 2017;19(1):38–45.
[31] Storey EP, Master SR, Lockyer JE, et al. Near point of convergence after concussion in children. Optometry Vision Sci. 2017;94(1):96–100.
[32] Mendez I, Van den Hof MC. Mobile remote-presence devices for point-of-care health care delivery. CMAJ. 2013;185(17):1512–1516.
[33] Mendez I, Jong M, Keays-White D, et al. The use of remote presence for health care delivery in a northern Inuit community: a feasibility study. Int J Circumpolar Health. 2013;72.
[34] Holt T, Hansen G, McKinney V, et al. Contemplating remote presence technology for culturally safe health care for rural indigenous children. AlterNative. 2019;15(1):31–33.
[35] College of Physicians and Surgeons of Saskatchewan. [cited 2020 Jul 29]. https://www.cps.sk.ca/imis/CPSS/CPSS/PANDEMIC/COVID-19/Virtual_Care.aspx
[36] Saskatchewan Medical Association. https://www.sma.sk.ca/170/pandemic-compensation.html
[37] Teasdale G, Jennett B. Assessment and prognosis of coma after head injury. Acta Neurochir. 1976; 34(1-4):45–55.