Health Care Provider Utilization and Cost of an mHealth Intervention in Vulnerable People Living with HIV in Vancouver, Canada.

Amber R. Campbell, BSc\textsuperscript{1,2}, Karen Kinvig, RN\textsuperscript{1}, Hélène C.F. Côté, PhD\textsuperscript{2,3,4}, Richard T. Lester, MD\textsuperscript{5}, Annie Q. Qiu, BSc\textsuperscript{1}, Evelyn J. Maan, RN\textsuperscript{1,2}, Ariane Alimenti, MD\textsuperscript{1,6}, Melanie C.M. Murray, MD, PhD\textsuperscript{1,2,5}.

(1) Oak Tree Clinic, BC Women’s Hospital, Vancouver, Canada.
(2) Women’s Health Research Institute, Vancouver, Canada
(3) Centre for Blood Research, UBC, Vancouver, Canada.
(4) Department of Pathology and Laboratory Medicine, UBC, Vancouver, Canada.
(5) Division of Infectious Disease, Department of Medicine, UBC, Vancouver, Canada.
(6) Department of Pediatrics, UBC, Vancouver, Canada.

Correspondence:
Dr. Melanie Murray
E600B – 4500 Oak Street
Vancouver, BC, Canada, V6H 3N1
Tel: (604) 875-2212; Fax: (604) 875-3063
Email: Melanie.Murray@cw.bc.ca

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ABSTRACT

Background: Improving adherence to combined antiretroviral therapy (cART) can be challenging, especially among vulnerable populations living with HIV. Even where cART is available free of charge, social determinants of health act as barriers to optimal adherence rates. Patient-centered approaches exploiting mobile phone communications (mHealth) have been shown to improve adherence to cART and promote achievement of suppressed HIV plasma viral loads. However, data are scarce on the health care provider (HCP) time commitments and health care costs associated with such interventions. This knowledge is needed to inform policy and programmatic implementation.

Objective: The purpose of this study was to approximate the resources required and to provide an estimate of the costs associated with running an mHealth intervention program to improve medication adherence in people living with HIV (PLWH).

Methods: This prospective study of HCP utilization and costs was embedded within a repeated measures effectiveness study of the WelTel short-message service (SMS) mHealth program. The study included 85 vulnerable, non-adherent, PLWH in Vancouver, Canada. Study participants were provided mobile phones with unlimited texting (where required), and received weekly bidirectional text messages to enquire on their status, for a period of one year. A clinic nurse triaged and managed participant’s responses, immediately logging all patient interactions by topic, HCP involvement, and time dedicated to addressing issues raised by participants. Interaction costs were determined...
in Canadian dollars (CAD), based on HCP type, median salary within our health authority, and their time utilized as part of the intervention.

Results: Participant-identified problems within text responses included health-related, social, and logistical issues. Taken together, management of problems required a median of 43 minutes (IQR = 17 – 99) of HCP time per participant per year, for a median yearly cost of $36.72 CAD (IQR = 15.50 – 81.60) per participant who responded with at least one problem. The clinic nurse who monitored the texts solved or managed 65% of these issues, and the remaining were referred to a variety of other HCPs. The total intervention costs, including mobile phones, plans, and staffing was a median $347.74/highly vulnerable participant/year or $383.18/highly vulnerable participant/year that responded with at least one problem.

Conclusions: Bidirectional mHealth programs improve HIV care and treatment outcomes for PLWH. Knowledge about the HCP cost associated, here less than $50/year, provides stakeholders and decision makers with information relevant to determining the feasibility and sustainability of mHealth programs in the real-world setting.

Trial Registration: ClinicalTrials.gov NCT02603536
https://clinicaltrials.gov/ct2/show/NCT02603536

Key Words: HIV; mHealth; health care provider; cost; health care utilization; adherence
INTRODUCTION

With the success of combined antiretroviral therapy (cART), the health of people living with HIV (PLWH) has greatly improved [1], and life expectancies are now approaching those of the general population [2]. However, cART effectiveness is dependent on high rates of medication adherence. Among vulnerable populations such as individuals at high-risk for disengagement from treatment due to various social determinants of health (housing or food insecurity, substance use issues, and advanced HIV infection), being adherent is often a challenge [3-5]. This can be due to a combination of demographic, structural and psychosocial barriers, and results in PLWH’s engagement being lost along the cascade of care continuum [4, 6]. Adherence is also crucial at the population level, as non-adherence can result in high HIV viremia, which places others at higher risk of acquiring the virus [7, 8]. Consequently, tools to assist in cART adherence and engagement in care bring value for both personal and population health. It is known that patients’ improved connection to health care providers (HCPs) can enhance their engagement in care [9-13]. This can be achieved through the use of mobile health (mHealth) technology, whereby a mobile phone is used to connect a patient with an HCP [14, 15]. When provided in a bidirectional fashion, mHealth provides a patient with the ability to request and receive assistance when not physically present at clinic. This allows “problems” to be managed in timely fashion, as they arise [16, 17]. In addition, mHealth enables HCPs to connect with patients and monitor their wellness between clinic visits [17].
Communication through mHealth technology with PLWH was first shown to significantly improve adherence to cART and plasma viral load (pVL) suppression in a text-messaging intervention study conducted in Kenya (WelTelKenya) [14]. This bidirectional outpatient management service was then tested for acceptability and feasibility at Oak Tree Clinic (OTC), Vancouver, British Columbia (BC) in a prospective mixed methods pilot study (WelTelBC1) [17, 18]. HCPs involved with the pilot reported that, although workload increased initially, intervention benefits went beyond improving pVL, and addressed the social determinants of health that act as barriers to engagement in care and to medication adherence [17, 18]. This pilot was followed by the WelTel OakTree study which examined the effectiveness of this weekly text-messaging intervention over one year, with 85 highly vulnerable PLWH [19]. Its results demonstrated an improvement in cART adherence and HIV pVL among PLWH who received the intervention [19].

While the benefits of mHealth are clear, little is known regarding HCP time utilization and the costs involved in enacting such an intervention. Assessing the true financial and personnel costs to the health care system is crucial to the translation of this research into clinical care, and necessary information for health care system officials who may elect to provide such a service to their population. Prospectively and throughout the WelTel OakTree study [19], detailed data were collected on all HCP-participant interactions. We herein report the estimated HCP utilization and cost of providing an mHealth intervention for vulnerable PLWH in Canada.
METHODS

Study Setting

The Oak Tree Clinic (OTC) is a provincial referral center for women and families living with HIV throughout BC, many of whom have multiple barriers to engagement in care. The OTC hosts an interdisciplinary team that provides holistic care for the health needs of women and their families in a single setting. The HIV population receiving its care at OTC spans all HIV-acquisition risk factor groups.

Study Participants

Details of the WelTel OakTree study, its participants, and results were reported elsewhere [19]. Briefly, 85 participants were recruited between April 2013 and May 2014 at OTC in Vancouver, Canada.

Patients were eligible for study participation if they met the following inclusion criteria: attendance at OTC for at least one year prior to study entry (with the one year prior to study start representing the control year), an indication for cART, detectable HIV pVL (≥200 copies/mL) in the control year, age ≥14 years, and being “vulnerable”. The latter was defined as being high-risk/vulnerable for disengagement from treatment according to a list of predetermined criteria. High-risk individuals were identified based on consensus by the care team where at least one of the following was required: intimate partner violence, unstable housing, advanced HIV infection/AIDS, mental health illness, cART non-adherence, difficulty to contact, poor appointment attendance, substance use, long distance from care, and recent incarceration. We excluded those not meeting the above criteria, living in an area with no mobile phone service, or otherwise
unable to communicate via the text-messaging system.

Participants were provided with a basic mobile phone with unlimited text messaging capability if they did not have one. Where required, participants received instruction on how to use text messaging for communication. In addition to the intervention, participants continued to receive their regular care through the interdisciplinary OTC team. This included follow-up appointments every 1-4 months, as clinically indicated by overall health status and HIV pVL. In BC, cART for PLWH is fully covered through the provincial drug treatment program and was prescribed according to published provincial therapeutic guidelines [20]. The study was reviewed and approved by the University of British Columbia Research Ethics Board (H12-03002).

WelTel Program

Participants received a weekly interactive text message of “How are you?” to check-in on their health status for one year. An automated software platform sent the text every Monday at noon from a number not traceable to the clinic. Participants were asked to respond each week within 48 h if they were “OK” or had a “problem”. A study nurse monitored responses daily (except weekends) and responded to all “problem” texts from participants during working hours, as shown in Figure 1. The study nurse triaged “problem” responses and involved additional HCP as required. Participants who did not respond to the initial text were sent a second message on Wednesday, “Haven’t heard from you. How’s it going?” The clinic nurse called participants who had not responded by Thursday. HCPs never texted information relating to HIV status or the clinic unless asked explicitly to do so by the participant.
Data Collection and Analysis

All communications related to the program were recorded and encoded prospectively by participant ID in an electronic study log maintained exclusively by the single study nurse. The number of minutes required to triage and solve each “problem” response was also recorded in the log. At the time of the interaction, the study nurse thematically coded all problems based upon the nature of each interaction, and the classification of the HCP involved with the interaction. Where multiple providers were consulted, time taken and theme of interaction was recorded for each one. The cost of each interaction was then determined based upon HCP time utilized and the mean salary of each HCP type, within our health authority (British Columbia’s Provincial Health Services Authority) [21]. Clinical data, including HIV pVL, CD4 counts, appointment attendance and medication adherence, are reported elsewhere [19].
RESULTS

Participant Characteristics

Of the 85 participants recruited, 80 remained enrolled for the entire duration of the study, and five withdrew for personal reasons. Baseline demographics of these 85 participants are shown in Table 1. Of the participants, 44 had their own mobile phone at study start, and 41 were given phones with unlimited text-messaging capability.

Table 1: Baseline demographics of a high-risk Canadian HIV-positive cohort (N=80).

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>72 (90)</td>
</tr>
<tr>
<td>Male</td>
<td>6 (8)</td>
</tr>
<tr>
<td>Transgender</td>
<td>2 (3)</td>
</tr>
<tr>
<td><strong>Age (years), median (range)</strong></td>
<td>38 (15-61)</td>
</tr>
<tr>
<td><strong>Ethnicity, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>30 (38)</td>
</tr>
<tr>
<td>First Nations</td>
<td>27 (34)</td>
</tr>
<tr>
<td>African Canadian</td>
<td>18 (22)</td>
</tr>
<tr>
<td>South Asian</td>
<td>5 (6)</td>
</tr>
<tr>
<td><strong>Income source, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Disability</td>
<td>57 (71)</td>
</tr>
<tr>
<td>Welfare</td>
<td>6 (8)</td>
</tr>
<tr>
<td>Employed</td>
<td>4 (5)</td>
</tr>
<tr>
<td>Other</td>
<td>13 (16)</td>
</tr>
<tr>
<td><strong>Cell phone ownership, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>43 (54)</td>
</tr>
<tr>
<td>No</td>
<td>37 (46)</td>
</tr>
</tbody>
</table>

Text Messaging Responses

Over the intervention year, a total of 3764 “How are you?” texts were sent to participants, less than the predicted total of 4420 texts. Texts were not sent either due to planned participant absences (n=125), participant losing their phone (n=366), or participant withdrawal (n=165). At the participant level, a wide range of individual
response rates to text messages were observed (0-98%). The mean response rate was 50% (median 52%) among participants continuing to study completion. Of the 3764 text messages sent, 46.7% resulted in an initial “OK” response, 9.6% indicated a “problem”, and 43.7% returned no response. While 362 “problem” responses were received in response to the Monday text message, an additional 203 “problem” responses were received later in the week, either as a second “problem”, or as a new problem after an initial “OK” response. Thus, at study completion, there were a total of 565 “problem” responses received.

As more than one HCP was often required to address an issue, a total of 761 distinct HCP interactions resulted from the 565 problem responses. Figure 2 illustrates the number of HCP-participant interactions by HCP type (Figure 2a), mean time of each interaction (Figure 2b), and total time per HCP (Figure 2c) over the study period. The study nurse managed 64.9% (494/761) of problem interactions, and spent the most time (53.9%, 2443/4533 minutes) on problem solving overall, among all HCPs. The counselor spent the greatest amount of time per interaction, averaging 27 minutes. Overall, managing “problem” responses required a total of 75.5 hours, with a median [IQR] of 43 [17 – 99] minutes of HCP time /year for participants who responded with problems (Table 2). Additionally, approximately 78 hours (55 minutes/participant/year) of HCP time was required for sending unscheduled text messages, weekday monitoring of the platform, and making phone calls to participants who did not respond to text messages.
Figure 2a-c: Health care provider total number of interactions (a), time per interaction (b), and total interaction time (c) during the study year. Bars are expressed as median (IQR), with whiskers representing range (b). *refers to the mean.
Table 2. Median time and cost per problem and per year for all participants and problem responders during WelTel intervention.

<table>
<thead>
<tr>
<th></th>
<th>All Participants</th>
<th>Problem Responders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=85</td>
<td>n=65</td>
</tr>
<tr>
<td><strong>Median Time/Problem (min)</strong></td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Time/Year (min)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>22</td>
<td>43</td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>3 - 85</td>
<td>17 - 99</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 335</td>
<td>2 - 335</td>
</tr>
<tr>
<td><strong>Median Cost/Problem ($)</strong></td>
<td>4.08</td>
<td>4.08</td>
</tr>
<tr>
<td><strong>Cost/Year ($)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>17.95</td>
<td>36.72</td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>2.45 - 71.40</td>
<td>15.50 - 81.60</td>
</tr>
<tr>
<td>Range</td>
<td>0 - 273.37</td>
<td>1.63 - 273.37</td>
</tr>
</tbody>
</table>
WelTel participants reported a great breadth of “problems”, encompassing medical problems, as well as issues related to social determinants of health. Figure 3

Figure 3: Nature and frequency of problem-response interactions that health care providers solved over intervention year.
depicts the nature and frequency of these “problem” related interactions between HCPs and participants.

Text Messaging Costs

Figure 4 displays the cost per interaction and total costs over the study period for each HCP in managing “problem” responses. All costs are expressed here in Canadian dollars. Interactions involving the counselor carried the greatest cost,

4a:

![Cost per Interaction Diagram]

4b:

![Total Cost Diagram]

Figure 4a-b: Cost per interaction per HCP (a) and total cost per HCP over intervention year (b). Costs determined based on average salary of HCP. Total of 761 interactions for all HCPs.
averaging $19.11 per interaction, due to their length. However, these interactions were
few (total cost $191.13). In contrast, interactions with the study nurse carried an average
cost of $3.63 per interaction, for a total cost of $1791.70. The median cost of all HCP
time for managing all “problem” responses in the study was $36.72 (IQR = 15.50 – 81.60)
per participant who had replied with “problem” responses, and median cost of HCP time
was $17.95 (IQR = 2.45 – 71.40) per highly vulnerable participant for 1 year of service
(Table 2).

The study nurse spent approximately 90 minutes each week monitoring
participant responses, for a total cost of $3432.31 (including 20% benefits cost). The
automated software platform cost for this study was $5000. Where a phone and phone
plan were given to participants (n=50 over course of study), basic phone cost was $50,
and cost of phone plans was $28.50/person/month (including taxes). The total cost of
providing phones and plans to 50/85 participants was thus $392/person/year, or a total
cost of $19,600/year. Study cost per participant when a basic phone and unlimited
texting plan were included was therefore $509.15/person/year for all participants or
$527.92/person/year for problem responders. Study cost for participants who used their
own phone was $117.15/person/year for all participants or $135.92/person/year for
problem responders. Therefore, the intervention overall cost $347.74/highly vulnerable
participant/year or $383.18/highly vulnerable participant/year that responded with at
least one problem (Table 3).
Table 3: Deconstructed costs of WelTel OakTree Study during intervention year.

<table>
<thead>
<tr>
<th>Item</th>
<th>Median Cost Per Participant (n=85)</th>
<th>Median Cost Per Problem Responder (n=65)</th>
<th>Total Cost (85 participants, 50 provided with phone)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated Software Platform</td>
<td>$58.82</td>
<td>$58.82</td>
<td>$5000*</td>
</tr>
<tr>
<td>Study Nurse Checking Responses</td>
<td>$40.38</td>
<td>$40.38</td>
<td>$3,432.31</td>
</tr>
<tr>
<td>Managing “Problem” Responses</td>
<td>$17.95</td>
<td>$36.72</td>
<td>$3,699.20</td>
</tr>
<tr>
<td>Phones (n=50)</td>
<td>$50.00</td>
<td>$50.00</td>
<td>$2,500.00</td>
</tr>
<tr>
<td>Phone Plans (n=50)</td>
<td>$342.00</td>
<td>$342.00</td>
<td>$17,100.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>$31,731.20</td>
</tr>
<tr>
<td>Own phone</td>
<td>$117.15</td>
<td>$135.92</td>
<td></td>
</tr>
<tr>
<td>Given phone &amp; plan (50 phones &amp; plans)</td>
<td>$509.15</td>
<td>$527.92</td>
<td>$31,731.20</td>
</tr>
<tr>
<td>Total (50 phones &amp; plans)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>$347.74</td>
<td>$383.18</td>
<td></td>
</tr>
</tbody>
</table>

Note: *fixed cost, does not change with enrollment and subject to change

At study end, 38/80 (47.5%) participants had undetectable pVL (previously published [19]). Thus, WelTel program and HCP cost per undetectable pVL achieved was $835.03/year.
DISCUSSION

MHealth interventions are effective at improving cART adherence and pVL in PLWH [14, 15, 19], however, translating this program from research to clinical care requires the buy-in and support of decision-makers and payers. This study provides policy makers with the real-world cost and staff requirements to roll out such a program as a part of care for PWLH who are vulnerable to disengagement in care, in a Canadian setting.

Data was captured at the time of each event; hence results presented here precisely reflect the nature of “problems” and time utilization for each HCP/participant interaction in the study. The study nurse was able to address the majority (64.9%) of “problem” responses without referral to a secondary HCP. Many of these responses were medically related. Thus, when implementing bidirectional mHealth interventions into the real-world setting, it would be advantageous to employ HCPs capable of giving basic medical advice when answering text messages. Other “problems” were related to social determinants of health, reflecting the vulnerability of our study population. These were managed through a variety of OTC care providers. In the case of a limited resource setting, however, many of these issues could be managed by a skilled nurse, with the aid of a social worker in some instances. A situation with fewer care providers, though providing a less specialized service, may provide the added benefit of further strengthening patient-HCP relationships through increased interaction. This could be beneficial, as enhancing patient-provider relationships has been associated with improved adherence self-efficacy [22], as well as improvement in cART adherence [9,
viral suppression [23], and overall health outcomes [24]. The possible downside of a small team, however, may include a larger effect on participants if and when a staffing change occurs.

The total HCP time for managing “problem” responses was 75.5 hours, or 43 minutes/participant/year. It should be noted that the highly vulnerable and complex nature of the study participants might have resulted in more problems, inflating HCP time above what may be expected in a more mixed cohort. An additional 78 hours (55 minutes/participant/year) was required for sending unscheduled text messages, weekday checking of the platform, and making phone calls to participants who did not respond to text messages. However, phoning non-responders later in the week was time consuming with low yield, and is not recommended going forward. Without these calls, considerable savings (30-60 minutes/week) could be achieved. Overall, the time spent by HCPs per participant over the study year was lower than anticipated – amounting to a similar cost of that of a single physician visit ($130/hour) [21]. This small time investment may be worthwhile, since mitigating problems as they arise can prevent progression of illness and decrease morbidity, thus reducing costs of health care over time [25, 26].

Indeed, it is known that PLWH with sustained viral suppression have considerably lower non-cART direct medical costs [27]. As complications involving medication tolerance and adherence are solved, adherent individuals become healthier over time [1], requiring less frequent medical appointments and fewer hospital admissions [27, 28]. These costs would add up, as the average cost of a hospital stay in BC is
approximately $6,000 [29]. Furthermore, stable, virally suppressed individuals could use the WelTel program for viral-load-informed differentiated care, where text messaging would be sufficient to follow stable patients, and allow less frequent patient-provider visits [30]. Thus, the WelTel intervention could potentially avoid some of these costs.

Through improved cART adherence and HIV viral suppression, the WelTel mHealth program can also be expected to lower risk of HIV transmission from participants to others, an important public health consideration [25, 31-33]. The cost of treatment for individuals newly diagnosed with HIV in Canada is estimated at $250,000 over their lifetime [34]. When also including quality of life years ($380,000) and productivity loss ($670,000), the estimated lifetime cost of those newly diagnosed increases to $1.3 million [34]. Consequently, fewer HIV transmissions and therefore fewer new cases of HIV per year would result in a lower cost of HIV care [35]. These cost reductions would likely offset the cost of our mHealth intervention, making the cost of $835.03 per newly undetectable PLWH/year a seemingly worthwhile investment.

Importantly, the clinical and economical information from our intervention can be applied to other aspects of health care, such as diabetes care [36, 37], eldercare [38], and a myriad of other chronic diseases where patient treatment fatigue is a known barrier [39, 40]. As mHealth offers patients real-time advice from HCPs and improves self-management of chronic diseases, the benefits may extend beyond what we are able to quantify. Implementing a triage system could be beneficial, such that the WelTel service is provided to our most vulnerable patients, but also more selectively to those most likely to use it and benefit from it, optimizing usage of health care funds. MHealth
is an accessible and practical method of communication, as the majority of Canadians have mobile phones. In our study approximately half of participants had phones at baseline, speaking to the vulnerability of our cohort. This increased the costs of our service, and would thus likely overestimate the costs of implementing mHealth programs into health care practices where a higher percentage of individuals had a mobile phone. Taken together, information on the costs and time required by HCPs to provide the WelTel service gives valuable insight into what implementation would mean in our and other settings.

Limitations

Since HCP resource usage data was not collected during the control year, we cannot comment on any change in HCP resource utilization relative to the past or future, were the program extended. In addition, this study was carried out by engaging the most vulnerable patients in our clinic, thus, resource use for a more stable population may be different than that presented here.

Conclusion

To our knowledge, this is the first study detailing HCP time and resource utilization for an mHealth intervention in Canada. While further studies should address the question of change in resource utilization over time, both prior to and in the context of providing an mHealth intervention (e.g. less time needed for social work/outreach, fewer clinical appointments, etc.), our study shows that weekly patient contact does not require a considerable amount of HCP time. When compared to the cost of a physician
visit or hospital admission, it carries only a modest cost per participant for PLWH who are most vulnerable to morbidity and death.

**Acknowledgements**

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**Conflicts of Interest**

**Ms. Amber R. Campbell, Ms. Karen Kinvig, Ms. Annie Q. Qiu, Ms. Evelyn J. Maan, Dr. Hélène C.F. Côté, and Dr. Ariane Alimenti:** No conflicts of interest.

**Dr. Richard T. Lester:** Dr. Lester is the founder of WelTel. This technology platform has been developed by a non-profit organization and a private company. Dr. Lester has financial as well as professional interests in both organizations.

**Dr. Melanie C.M. Murray:** Dr. Murray received unrestricted grants from both Gilead Sciences and Bristol-Meyers-Squibb for the purpose of conducting the effectiveness study and the cost-analysis of the study respectively.
Author’s Contributions

All authors contributed significantly to the manuscript and roles are as follows:

Amber R. Campbell: Ms. Campbell was responsible for literature search, data analysis, data interpretation, formation of figures, and writing of the manuscript.

Karen Kinvig: Ms. Kinvig did all of the data collection involved in the study, including collection of health care provider time, and recording and thematically coding interaction data. She has reviewed and had input into the manuscript.

Hélène F. C. Côté: Dr. Côté assisted in data analysis and designing figures, and has reviewed and extensively edited the manuscript.

Richard T. Lester: Dr. Lester aided in study design, data interpretation and has reviewed and had input into the manuscript. Dr. Lester is also the inventor of the WelTel computer based program used in the study.

Annie Q. Qiu: Ms. Qiu was involved in ethics submission, participant recruitment, study design, and has reviewed and had input into the manuscript.

Evelyn J. Maan: Ms. Maan was involved in ethics submission, participant recruitment, study design, and has reviewed and had input into the manuscript.

Ariane Alimenti: Dr. Alimenti was involved with study design and has reviewed and had input into the manuscript.

Melanie C. M. Murray: Dr. Murray designed the study, including setting up of the initial thematic coding framework for interaction data, led statistical analysis, data interpretation, and helped with figures in the paper. Dr. Murray also oversaw and significantly helped with the writing of the manuscript.
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Abbreviations
BC – British Columbia

CAD – Canadian Dollars

cART – Combined Antiretroviral Therapy

HCP – Health Care Provider

HIV – Human Immunodeficiency Virus

mHealth – Mobile Health

OTC – Oak Tree Clinic

PLWH – People Living with HIV

pVL – Plasma Viral Load

UBC – University of British Columbia