Ellie J. C. Goldstein, Section Editor

# Use of Telemedicine Technologies in the Management of Infectious Diseases: A Review

**Parmvir Parmar,[1] David Mackie,[2] Sunil Varghese,[2] and Curtis Cooper[1,2,3]**

[1]Faculty of Medicine, University of Ottawa, [2]Ottawa Hospital and Regional Viral Hepatitis Telemedicine Program, and [3]Division of Infectious Diseases, Department of Medicine, University of Ottawa, Ontario, Canada

**Telemedicine technologies are rapidly being integrated into infectious diseases programs with the aim of increasing access to infectious diseases specialty care for isolated populations and reducing costs. We summarize the utility and effectiveness of telemedicine in the evaluation and treatment of infectious diseases patients. The use of telemedicine in the management of acute infectious diseases, chronic hepatitis C, human immunodeficiency virus, and active pulmonary tuberculosis is considered. We recapitulate and evaluate the advantages of telemedicine described in other studies, present challenges to adopting telemedicine, and identify future opportunities for the use of telemedicine within the realm of clinical infectious diseases.**

***Keywords.*** telemedicine; hepatitis C virus; HIV; infectious diseases; tuberculosis.

Telemedicine refers to the use of telecommunication and information technologies with the goal of providing clinical healthcare to distant or isolated individuals. The utilization of this technology can eliminate distance barriers and improve medical services access that otherwise would not be available. Telemedicine technologies are increasingly prevalent tools used to deliver healthcare services. Telemedicine remotely links patients to specialty healthcare providers in an effort to increase accessibility to healthcare systems for isolated and rural populations [1–7]. As many infectious diseases physicians practice in or near academic centers, telemedicine has the potential to provide much-needed specialty infectious diseases care to patients outside these areas. Telemedicine has been described in the management of acute infectious diseases as well as chronic infections including hepatitis C virus (HCV), human immunodeficiency virus (HIV), and tuberculosis [1–16]. With respect to infectious diseases, telemedicine has been used to link patients directly to specialty healthcare providers, to facilitate consultations between primary care providers and specialists, and to deliver continuing medical education (CME) [8, 9, 13, 14]. Many studies cite common reasons in support of implementing telemedicine programs: telemedicine promises increased access, increased uptake of treatment, and potential cost-effectiveness [1–9, 13–15, 17, 18].

We summarize the usage of telemedicine technologies in the management of acute and chronic infectious diseases and consider the potential advantages and disadvantages of incorporating telemedicine into infectious diseases practices (Table 1). We also identify areas within infectious diseases that telemedicine technologies have yet to engage but could prove beneficial.

## METHODS

The authors searched the following databases for randomized trials: PubMed, Cumulative Index to Nursing and Allied Health Literature, and Embase. Reference lists of included articles were also reviewed. Key search terms included *telemedicine* plus *infectious diseases*, *HIV*, *HBV*, *HCV*, *tuberculosis*, *chronic diseases*, and *cost-effectiveness*. In this review, we included publications that specifically evaluated telemedicine or related technologies and infectious diseases. Publication evaluation and information synthesis were completed jointly by each author.

Received 29 August 2014; accepted 10 December 2014; electronically published 16 December 2014.

Correspondence: Curtis Cooper, MD, FRCP(C), University of Ottawa, The Ottawa Hospital, Rm G12-501, Smyth Rd, Ottawa, ON K1H 8L6, Canada (ccooper@toh.on.ca).

**Clinical Infectious Diseases® 2015;60(7):1084–94**



DOI: 10.1093/cid/ciu1143

**Table 1. Summary of Publications Reporting Telemedicine Infectious Disease Management by Infection Type**

| Infection | Study Design | Sample Size | Conclusion | Limitations |
|---|---|---|---|---|
| HIV | León et al [19]<br>• Open-label, 2-arm, prospective, randomized study<br>• Internet-based care model covering the entire management of chronic HIV-infected patients (Virtual Hospital) | 42 Virtual Hospital (arm 1)<br>41 standard care (arm 2) | • Clinical parameters (*P* = .21), compliance levels (*P* = .58), and psychological measures similar between arms<br>• Virtual Hospital is a cost-effective alternative to in-clinic visits<br>• Constitutes a feasible, fairly satisfactory, safe, and low-cost tool for the clinical care of stable HIV-infected patients<br>• Has no negative effect on HIV clinical parameters and health services utilization<br>• TM is an appropriate support service for HIV management | • Small sample size<br>• Single center |
| HIV | Young et al [7]<br>• Retrospective cohort study.<br>• Compare efficacy of HIV specialty management via TM in a large prison population vs on-site management by a correctional physician without specialty training | 1201<br>Pre-TM DB = 514<br>TM DB = 687 | • TM specialty care resulted in a greater proportion of patients with virologic suppression (*P* < .001), lower community viral load (geometric mean of viral load of each subject) (*P* < .001), and better patient adherence (*P* < .001) compared with nonexpert care | • Observational, retrospective study design, potential overlap of study subjects in each group, exclusion of inmates incarcerated for short periods of time |
| HCV | Arora et al [9]<br>• Prospective cohort study<br>• Compare HCV Tx at UNM HCV clinic vs primary care clinicians at 21 ECHO TM sites in rural areas and prisons in New Mexico | 407<br>UNM HCV Clinic = 146<br>ECHO sites = 261 | • SVR difference rates between sites, 0.7% (95% CI, −9.2 to 10.7; *P* = .89)<br>• Treatment for HCV infection delivered via ECHO model was associated with high rates of cure. SVR rate did not differ between sites. ECHO model is effective in treating HCV infection in rural and underserved communities | • No comparison group comprising patients treated in rural settings without ECHO model. Nonrandomized. Multivariate models cannot address characteristics that are not or cannot be measured |
| HCV | Khatri et al [13]<br>• Case study<br>• Implementation of ECHO model at large Connecticut Community Health Center | 63 | • Created care plans for 48 unique HCV patients in 12 clinic sessions | • Nonrandomized |
| HCV | Lloyd et al [1]<br>• Multisite prospective cohort study<br>• Protocol-driven assessment, triage, and management of AV therapy by trained nurses with specialist physician support via TM | 391 consecutive patients enrolled<br>108 patients initiated Tx; 85 of these qualified for specialist review by TM | • SVR rate of those completing follow-up (n = 68): 69% (ITT analysis: 44%)<br>• Data illustrate the feasibility, efficacy, and safety of nurse-led and specialist-supported assessment and treatment of inmates with chronic HCV utilizing TM | • Nonrandomized |
| HCV | Nazareth et al [2]<br>• Compare SVR rates between TM (videoconference) and FTF clinics for rural/remote patients treated with peg-IFN/RBV | TM = 50<br>FTF = 528 | • 36/50 achieved SVR (72%; 95% CL, 58%–84%)<br>• G1: 22/30 TM patients achieved SVR (73%; 95% CL, 54%–88%) vs 142/279 FTF patients (51%; 95% CL, 45%–57%; NS)<br>• G2–3: 14/20 TM patients achieved SVR (70%; 95% CL, 46%–88%) vs FTF clinics: 169/249 (68%; 95% CL, 62%–74%, NS) | • Effect of confounding factors on the SVR was not analyzed. No controls. *IL28B* data not available |

*Table 1 continued.*

| Infection | Study Design | Sample Size | Conclusion | Limitations |
|---|---|---|---|---|
| | | | • TM treatment noninferior to FTF<br>• TM patients (35 completed survey) were happy with the program and would participate again<br>• Study confirms TM is an effective option for HCV Tx in rural and remote areas | |
| HCV | Rossaro et al [14]<br>• Prospective cohort study<br>• Compare impact of multipoint VC vs ST on primary care providers' HCV education | Physicians (n = 68)<br>Nurse practitioners (n = 27)<br>Registered nurses (n = 80) | • Improvement in knowledge scores for MDs: VC = 3.56 ± 1.92 vs ST = 2.13 ± 1.89, $P < .001$<br>• All groups: VC = 4.37 ± 1.92 vs ST = 3.06 ± 1.89, $P < .001$<br>• VC is equivalent, if not better, than standard continuing medical education. Potential to eliminate financial and geographic barriers to professional education for rural practitioners | • Pretest score showed that the ST group had more baseline knowledge than the VC group ($P < .05$) |
| HCV | You et al [6]<br>• Multisite prospective cohort study<br>• Controlled. Pharmacist-to-patient TM consultations (education for groups, Tx follow-up for individuals) vs in-clinic visits | TM = 96<br>(18 completed survey) | • 82% preferred TM to FTF for HCV clinic<br>• 78% preferred TM to FTF for any disease state management<br>• In terms of pharmacist–patient interaction, patients were more satisfied with TM visits, than FTF (convenient, shorter travel distances, satisfied with setup and level of healthcare received) | • Volunteer survey–poor rate of return (18/96). No health professional available to provide immediate attention if needed (nurse available, but response would be delayed) |
| HCV | Saifu et al [15]<br>• Convenience sample; pre–post intervention study<br>• Compare TM with in-person specialty clinic visits for HIV and HCV in rural Veterans Affairs population | 43<br>(94 TM visits, 128 FTF visits)<br>(30 completed survey) | • Clinic completion rate: TM = 76% vs FTF = 61%<br>• TM predictive of clinic completion. (OR, 2.2; 95% CI, 1.0–4.7)<br>• Adjusted effect of TM on clinic completion rate: 13% (95% CI, 12–13)<br>• Associated with improved access, high patient satisfaction and reduced health-visit time | • Convenience sample of patients with stable disease<br>• No included patients were started on treatment during study period<br>• Patient selection may positively bias results |
| HCV | Rossaro et al [4]<br>• Multisite (n = 5) nonrandomized retrospective cohort pilot study (controlled)<br>• Determine treatment response and side effect profile among patients treated with peg-IFN/RBV via TM vs in-patient consultations in remote and underserved area | 80<br>(TM = 40; FTF = 40) | • Equivalent SVR (TM = 55% vs FTF = 43%, $P = .36$)<br>• TM group therapy completion was superior (TM = 78% vs FTF = 53%, $P = .03$), TM patients had more visits/ week (TM = 0.61 vs FTF = 0.07, $P < .001$), incidence of anemia was lower in TM group than FTF (TM = 25% vs FTF = 53%, $P = .02$)<br>• TM can potentially close the gap of access to specialty care in remote areas without sacrificing patient care quality | • Study design, small sample size, number of TM sites Limited power to detect minute differences in the primary endpoint. Only 1 academic center was selected as a control. At time of publication, patient satisfaction data had not been collected |
| HCV | Rossaro et al [3]<br>• Retrospective, single-site cohort study | 103 | • Tx naive = 65 (64%)<br>• Tx recommended = 19 (23%) | • Uncontrolled, retrospective, single-site cohort study |

*Table 1* *continued.*

| Infection | Study Design | Sample Size | Conclusion | Limitations |
|---|---|---|---|---|
| | • Determine whether TM consultations with a hepatologist will increase access to specialty HCV care in a poor, rural community lacking such access | | • Initiated Tx = 14<br>• SVR = 5<br>• Evaluated for liver transplant = 15<br>• Acceptable for listing = 2<br>• Early evaluation by specialist via TM may increase the number of patients eligible for treatment and liver transplant | • Numbers to small to evaluate treatment starts and SVR rates |
| Tuberculosis | DeMaio et al [10]<br>• Single-center prospective cohort pilot study<br>• Examine application of TM to reduced short-term costs of a DOT program in Pierce County, Washington | 6 | • Adherence to Tx<br>• Standard DOT: 97.5%; videophone DOT 95%—VDOT adherence would have been 98% if no tech issues<br>• In selected cases, use of videophone can maintain a high level of adherence to DOT in a cost-effective manner | • Small sample size<br>• Study design |
| Tuberculosis | Gassanov et al [12]<br>• Single-center prospective cohort pilot study<br>• Determine usefulness of videophone DOT as a supplement to community DOT (Toronto Public Health) | 13 | • VDOT is a patient-friendly and cost-effective method of delivering DOT to carefully selected patients with tuberculosis<br>• Compliance rates were similar for both community DOT and VDOT patients<br>• VDOT visit time less than CDOT visit<br>• Cons: less personal interaction, difficulty conducting a physical assessment | • Sample highly selected. Single center, small sample size. Letter to editor, no detailed methodology or results |
| Tuberculosis | Gennai et al [20]<br>• Observational prospective cohort study<br>• Describe patterns of solicited consultations provided by ID consultation hotline at a university affiliated, public, or private hospitals, and ambulatory medicine in Grenoble | Tuberculosis = 89 of 3990 total | • High number of HIDC requests suggests hotline responds to a need of attending physicians<br>• Provide rapid answers and replace certain formal consultations and hospitalizations<br>• Questions raised on the quality of information exchanged, transfer of responsibility, and payment | • Could not identify whether several consultations were made for the same patient (analysis unit was the consultation)<br>• Did not assess the quality of the recommendations given by specialist<br>• Study conducted in a single university hospital |
| Tuberculosis | Wade et al [16].<br>• Retrospective cohort study<br>• Evaluate the clinical and cost-effectiveness of a TM (videophone) service delivering direct observation, compared to an in-person drive-around service | 128 | • Home videophone could offer a means of supplying a high rate of direct observation<br>• Did not improve the number of observations missed due to patient absence or refusal<br>• Video service was cost-effective compared to a drive-around service—may cost more than many tuberculosis services can afford | • Retrospective cohort design, effect of confounding factors unknown, different demographic characteristics between videophone and nonvideophone groups |
| Community- acquired pneumonia | Eron et al [21]<br>• Case-control pilot study<br>• Use of TM in the home to monitor moderately to severely ill patients with | 16 | • Cost effectiveness—pilot trial would have saved $135 000–$540 000 over 1 year | • Limited number of patients<br>• Weak statistical power<br>• Lack of randomization may have introduced biases |

*Table 1 continued.*

| Infection | Study Design | Sample Size | Conclusion | Limitations |
|---|---|---|---|---|
| | acute infections who would normally be hospitalized | | • Patients returned to normal function sooner than hospitalized patients ($P < .001$)<br>• TM group was more comfortable at home ($P = .35$), but would have felt safer in the hospital ($P = .09$) | • Charlson, Karnofsky, and severity of illness scores were similar between groups |
| Community-acquired pneumonia | dos Santos et al [22].<br>• Single-center prospective cohort study<br>• Prospective audit and formulary restriction and preauthorization orders of antimicrobial use by 2 ID specialists delivered by TM to a remote community hospital in southern Brazil | 54 | • Rate of inappropriate prescriptions at remote hospital similar to other studies<br>• TM appears to have a useful potential role in antimicrobial stewardship programs | • Small sample size from a single center<br>• No controls<br>• Unable to assess the effect of the intervention in terms of antimicrobial resistance (no + culture results) |
| Upper respiratory tract infection | Gennai et al [20]<br>• Observational prospective cohort study<br>• Describe patterns of solicited consultations provided by ID consultation hotline at university-affiliated, public, or private hospitals, and ambulatory medicine in Grenoble | URTI = 392 of 3990 total | • High number of HIDC requests suggests hotline responds to a need of attending physicians<br>• Provide rapid answers and replace certain formal consultations and hospitalizations<br>• Questions raised on the quality of information exchanged, transfer of responsibility and payment | • Could not identify whether several consultations were made for the same patient (analysis unit was the consultation)<br>• Did not assess the quality of the recommendations given by Infectious Disease service<br>• Study conducted in a single university hospital |
| Upper respiratory tract infection | Assimacopoulos et al [23]<br>• Retrospective, comparative review of medical records<br>• Compare records of inpatients at urban hospital receiving in-person consultation with an ID specialist (A) and patients from sister hospitals receiving treatment via TM with an ID specialist (B) | Group A: 19<br>Group B: 9 | • Patients spent fewer days hospitalized ($P = .01$) and fewer days on IV antibiotics ($P < .01$) than patients receiving in-person visits<br>• TM consultation and subsequent care via ID specialist is equally as effective as in-person ID consultation in a rural population | • Study did not account for all elements of population variability between groups (comorbid conditions)<br>• Small sample size |
| Skin and soft tissue infection | Eron et al [21]<br>• Case-control pilot study<br>• Use of TM in the home to monitor moderately to severely ill patients with acute infections who would normally be hospitalized | 6 | • Cost effectiveness—pilot trial would have saved \$135 000–\$540 000 over 1 year.<br>• Patients returned to normal function sooner than hospitalized patients ($P < .001$)<br>• TM group was more comfortable at home ($P = .35$), but would have felt safer in the hospital ($P = .09$) | • Limited number of patients<br>• Weak statistical power<br>• Lack of randomization may have introduced biases<br>• Charlson, Karnofsky, and severity of illness scores were similar between groups |
| Skin and soft tissue infection | dos Santos et al [22].<br>• Single-center prospective cohort study<br>• Prospective audit and formulary restriction and preauthorization orders of antimicrobial use by 2 ID specialists delivered by TM to a remote community hospital in southern Brazil | 6 | • Rate of inappropriate prescriptions at remote hospital similar to other studies<br>• TM appears to have a useful potential role in antimicrobial stewardship programs | • Small sample size from a single center<br>• No controls<br>• Unable to assess the effect of the intervention in terms of antimicrobial resistance (no + culture results) |

*Table 1 continued.*

| Infection | Study Design | Sample Size | Conclusion | Limitations |
|---|---|---|---|---|
| Skin and soft tissue infection | Gennai et al [20]<br>• Observational prospective cohort study<br>• Describe patterns of solicited consultations provided by ID consultation hotline at university-affiliated, public, or private hospitals, and ambulatory medicine in Grenoble | SSTI = 378 of 3990 total | • High number of HIDC requests suggests hotline responds to a need of attending physicians<br>• Provide rapid answers and replace certain formal consultations and hospitalizations<br>• Questions raised on the quality of information exchanged, transfer of responsibility, and payment | • Could not identify whether several consultations were made for the same patient (analysis unit was the consultation)<br>• Did not assess the quality of the recommendations given by Infectious Disease service<br>• Study conducted in a single university hospital |
| Skin and soft tissue infection | Assimacopoulos et al [23]<br>• Retrospective, comparative review of medical records<br>• Compare records of inpatients at urban hospital receiving in-person consultation with an ID specialist (A) and patients from sister hospitals receiving treatment via TM with an ID specialist (B) | Group A: 27<br>Group B: 26 | • Patients spent fewer days hospitalized ($P = .02$) and fewer days on IV antibiotics ($P = .73$) than patients receiving in-person visits<br>• TM consultation and subsequent care via ID specialist is equally as effective as in-person ID consultation in a rural population | • Study did not account for all elements of population variability between groups (comorbid conditions) |
| Urinary tract infection | Eron et al [21]<br>• Case-control pilot study<br>• Use of TM in the home to monitor moderately to severely ill patients with acute infections who would normally be hospitalized | 2 | • Cost effectiveness—pilot trial would have saved $135 000–$540 000 over 1 year<br>• Patients returned to normal function sooner than hospitalized patients ($P < .001$)<br>• TM group was more comfortable at home ($P = .35$), but would have felt safer in the hospital ($P = .09$) | • Limited number of patients<br>• Weak statistical power<br>• Lack of randomization may have introduced biases<br>• Charlson, Karnofsky, and severity of illness scores were similar between groups |
| Urinary tract infection | Gennai et al [20]<br>• Observational prospective cohort study<br>• Describe patterns of solicited consultations provided by ID consultation hotline at university-affiliated, public, or private hospitals, and ambulatory medicine in Grenoble | UTI = 316 of 3990 total | • High number of HIDC requests suggests hotline responds to a need of attending physicians<br>• Provide rapid answers and replace certain formal consultations and hospitalizations<br>• Questions raised on the quality of information exchanged, transfer of responsibility, and payment | • Could not identify whether several consultations were made for the same patient (analysis unit was the consultation)<br>• Did not assess the quality of the recommendations given by Infectious Disease service<br>• Study conducted in a single university hospital |
| Bacterial endocarditis | Eron et al [21]<br>• Case-control pilot study<br>• Use of TM in the home to monitor moderately to severely ill patients with acute infections who would normally be hospitalized | 1 | • Cost effectiveness—pilot trial would have saved $135 000–$540 000 over 1 year<br>• Patients returned to normal function sooner than hospitalized patients ($P < .001$)<br>• TM group was more comfortable at home ($P = .35$), but would have felt safer in the hospital ($P = .09$) | • Limited number of patients<br>• Weak statistical power<br>• Lack of randomization may have introduced biases<br>• Charlson, Karnofsky, and severity of illness scores were similar between groups |
| Bacteremia | dos Santos et al [22].<br>• Single-center prospective cohort study | 7 | • Rate of inappropriate prescriptions at remote hospital similar to other studies | • Small sample size from a single center<br>• No controls |

*Table 1 continued.*

| Infection | Study Design | Sample Size | Conclusion | Limitations |
|---|---|---|---|---|
| | • Prospective audit and formulary restriction and preauthorization orders of antimicrobial use by 2 ID specialists delivered by TM to a remote community hospital in southern Brazil | | • TM appears to have a useful potential role in antimicrobial stewardship programs | • Unable to assess the effect of the intervention in terms of antimicrobial resistance (no + culture results) |
| Bacteremia | Gennai et al [20]<br>• Observational prospective cohort study<br>• Describe patterns of solicited consultations provided by ID consultation hotline at university-affiliated, public, or private hospitals, and ambulatory medicine in Grenoble | 209 of 3990 total | • High number of HIDC requests suggests hotline responds to a need of attending physicians<br>• Provide rapid answers and replace certain formal consultations and hospitalizations<br>• Questions raised on the quality of information exchanged, transfer of responsibility, and payment | • Could not identify whether several consultations were made for the same patient (analysis unit was the consultation)<br>• Did not assess the quality of the recommendations given by Infectious Disease service<br>• Study conducted in a single university hospital |
| Bone and joint infection | | 530 of 3990 total | | |
| Abdominal infection | | 320 of 3990 total | | |
| Unexplained fever or inflammatory syndrome | | 278 of 3990 total | | |
| Colonization, contamination, or false-positive result | | 215 of 3990 total | | |
| Material infection | | 191 of 3990 total | | |
| Viral infection | | 164 of 3990 total | | |
| Central nervous system infection | | 162 of 3990 total | | |
| Cardiovascular infection | | 152 of 3990 total | | |
| Noninfectious pathology | | 141 of 3990 total | | |
| Parasitology/mycology | | 119 of 3990 total | | |
| Anthropozoonosis | | 107 of 3990 total | | |
| Antimicrobial adverse event | | 67 of 3990 total | | |
| Ear, nose, and throat infection | | 51 of 3990 total | | |
| Other infectious disease | | 109 of 3990 total | | |
| Neutropenic fever | Assimacopoulos et al [23]<br>• Retrospective, comparative review of medical records<br>• Compare records of inpatients at urban hospital receiving in-person consultation with an ID specialist (A) and patients from sister hospitals receiving treatment via TM with an ID specialist (B) | Group A: 13<br>Group B: 13 | • Patients spent fewer days hospitalized ($P = .06$) and fewer days receiving IV antibiotics ($P = .05$) than patients receiving in-person visits<br>• TM consultation and subsequent care via ID specialist is equally as effective as in-person ID consultation in a rural population | • Study did not account for all elements of population variability between groups (comorbid conditions)<br>• Small sample size |

Abbreviations: AV, audiovisual; CDOT, community direct observed treatment; CI, confidence interval; CL, confidence limits; DB, database; DOT, directly observed therapy; ECHO, Extension for Community Healthcare Outcomes; FTF, face-to-face; HCV, hepatitis C virus; HIDC, Hotline for Infectious Disease Consultation; HIV, human immunodeficiency virus; ID, infectious diseases; ITT, intent to treat; IV, intravenous; MD, physicians; NS, not significant; OR, odds ratio; peg-IFN, pegylated interferon; RBV, ribavirin; ST, standard lecturing; SSTI, skin and soft tissue infection; SVR, sustained virologic response; TM, telemedicine; Tx, treatment; UNM, University of New Mexico; URTI, upper respiratory tract infection; UTI, urinary tract infection; VC, videoconferencing; VDOT, videophone direct observed treatment.

### Acute Infectious Diseases

Telemedicine technologies have been used to diagnose, treat, and follow up patients suffering from acute infectious diseases including community-acquired pneumonia, upper respiratory tract infections, skin and soft tissue infections, urinary tract infections, and bacterial endocarditis [18, 20–23]. Although these conditions are entirely treatable with appropriate antimicrobial therapy, complications are not infrequent and often require consultation and/or follow-up with an infectious diseases specialist. A Brazilian study described improved antibiotic utilization by use of a telemedicine program. Two independent infectious diseases physicians reviewed antibiotic prescriptions written by hospitalists. They found that 55% of initial prescriptions were for an inappropriate choice of antibiotic [22]. Feedback was provided to the original prescribers via telemedicine, and in all cases the prescribing physicians accepted the advice of the reviewer and corrected the prescription [22].

One rationale for following general infectious diseases patients via telemedicine is to decrease the length of time patients spend in hospital. When hospitalists were surveyed, they indicated a belief that >20% of hospital inpatients remained in hospital beyond the point at which they achieved clinical stability [18]. These prolonged hospital stays were due to concerns that premature discharge would be followed by subsequent clinician deterioration and adverse outcomes [18, 20, 21]. The potential for malpractice litigation due to suboptimal follow-up was also identified as a concern. Telemedicine can address issues related to timely follow-up after discharge, thereby averting costly, lengthy hospital stays [21]. A US study found that telemedicine patients spend fewer days in hospital and had fewer days of antibiotic therapy [21, 23].

Telemedicine use in acute infection does have limitations. Use is predicated on the patient being in stable condition. Because critically ill patients require frequent monitoring and are at risk for deterioration requiring urgent medical interventions, unstable patients are poor candidates to be followed via telemedicine [18, 21]. In addition, discharged patients must be healthy enough to travel to their local telemedicine facility for follow-up assessment.

### Chronic Infectious Diseases

The use of telemedicine to treat chronic medical conditions is increasing and has been described in the management of congestive heart failure, diabetes, and chronic obstructive pulmonary disease [24–29]. Telemedicine technologies have also been used to manage patients with chronic infectious diseases including HIV, HCV, and HIV/HCV coinfection [1, 2, 4, 6, 7, 15, 19]. Although manageable as chronic medical conditions by nonspecialized healthcare providers, HIV and HCV care often requires the involvement of a specialist to supervise medication dosing and regimen selection, treatment initiation, and drug side effect management [1, 6, 15]. Assuming patient stability, infectious diseases specialist follow-up with HIV patients at intervals of 6–12 months has been demonstrated to enhance adherence, to optimize viral response to antiretroviral therapy and to be useful in the evaluation of routine blood work [19, 30, 31]. Similarly, HCV specialists can follow clinically stable patients not on antiviral therapy on a semiannual or yearly basis by utilizing telemedicine infrastructure.

There is also an important role for telemedicine in the delivery of antiviral therapy for HCV. Recent studies demonstrate that telemedicine and nontelemedicine HCV patients can achieve similar sustained virologic response rates when treated with pegylated interferon and ribavirin–based regimens [2, 4]. Furthermore, the rate of HCV therapy side effects was similar between groups. Of note, nontelemedicine patients were more likely to independently discontinue antiviral therapy due to an adverse drug reaction [4, 9]. It seems likely that the role for telemedicine technologies in HCV care delivery will increase as new, well-tolerated, simple-to-dose antiviral regimens become broadly available. However, there are currently no studies published that evaluate HCV treatment outcomes in recipients of interferon-free, direct-acting antiviral regimens receiving care via telemedicine programs. Among HIV patients on antiretroviral therapy, telemedicine and nontelemedicine patients had similar clinical responses to therapy, adherence to treatment, and quality-of-life scores as well as psychological and emotional states [19]. Another HIV telemedicine study conducted in a US prison cohort demonstrated that HIV patients on ART followed by a specialist via telemedicine were more likely to achieve virologic suppression and had greater CD4 cell recovery than patients who received their HIV care in person from a prison primary care physician [7]. Acknowledging the potential influence of selection and publication biases, the literature suggests that HIV and HCV telemedicine patients are able to achieve similar clinical outcomes to their nontelemedicine counterparts.

Tuberculosis, including active pulmonary, extrapulmonary, and latent infection, is another chronic infectious disease in which telemedicine may have an important role. Several public health pilot studies have evaluated treatment adherence of select, stable tuberculosis patients [10–12, 16]. Each study reported similar levels of treatment adherence in patients observed taking their tuberculosis therapy via telemedicine and those who were seen in person by a public health staff member [10–12, 16]. Thus far, tuberculosis telemedicine studies have only recruited sample patient cohorts and have focused only on directly observed therapy [10–12, 16]. Tuberculosis telemedicine programs could be expanded to involve initial patient evaluation (including clinical history, blood work, and chest radiographs), treatment initiation and management of treatment side effects. Following the example of HIV and HCV telemedicine programs, tuberculosis programs could also incorporate an element of CME to develop primary healthcare provider skills in comanaging patients with tuberculosis.

We were unable to identify any published studies detailing the use of telemedicine technologies to manage patients infected with hepatitis B virus (HBV). Like HCV, HBV is a chronic infectious disease affecting populations that are marginalized and face challenges to engaging traditional healthcare systems [32]. Unlike HCV, HBV is not curable. However, it can be suppressed using long-term antiviral therapy, thereby minimizing damage to liver parenchyma and preventing hepatocellular carcinoma. Because many clinically stable HBV patients can be followed by specialists on a semiannual or annual basis, they are ideal telemedicine candidates.

### Advantages and Drawbacks of Telemedicine

As with other chronic diseases, patients with HIV, HCV, and tuberculosis receiving telemedicine care report feeling more satisfied with and more involved in their care [6, 7, 10–12, 16, 18]. Patients were pleased with the level of privacy during telemedicine appointments and the quality of the patient–healthcare professional relationship [6]. Telemedicine patients also claim that attending remote appointments through telemedicine saved them time, diminished the distance traveled, and reduced missed workdays [2, 4, 6, 7, 15, 18]. This is a clear benefit for patients. If they had to select again, the majority of telemedicine patients indicated that they would once more choose to have their appointments via telemedicine [15]. The risk for late appointment arrival and clinic visit cancellations are reduced. Beyond these advantages, the hazards involved with travel, particularly during periods of inclement weather conditions, are eliminated.

A primary advantage of telemedicine is increased accessibility to specialty care. This is a particular benefit for isolated populations including nursing home residents, individuals in prisons, and people living in rural communities [1–7]. A lack of specialty care for HIV- or HCV-infected individuals has been identified as a major obstacle to optimal care [15]. Rural HCV patients without access to specialty care are less likely to initiate antiviral treatment [4]. Increased access to specialty care through telemedicine allows many more patients to be promptly evaluated, triaged, and treated. In the case of acute infectious diseases, access to infectious disease specialists via telemedicine permits patients to be followed in the community instead of in the hospital.

Another allure of incorporating telemedicine into existing infectious diseases practices is the potential cost-effectiveness of telemedicine. Although many studies suggest that telemedicine is cost-effective, this claim remains debatable. Most telemedicine studies have not included a formal cost-effectiveness analysis [17]. Systematic analyses investigating the cost-effectiveness of telemedicine suggest that telemedicine may be no more cost-effective than traditional clinic visits [33]. If this is the case, the patient would still benefit, but the specialist and/or the funding system would not. Furthermore, the cost-effectiveness varies tremendously from one region to another and from program to program. Therefore, cost-effectiveness cannot be generalized. More studies are needed to formally investigate the cost-effectiveness of telemedicine programs [33, 34].

The application of telemedicine for the care of incarcerated patients is particularly advantageous [7]. The expense involved with transportation with guards and the risk of escape is eliminated. The timeliness of assessment and initiation of treatment can be accelerated. In addition, the use of telemedicine is an excellent opportunity to provide infectious diseases and infection control education to the incarcerated patient and the correctional facility staff.

In addition to directly linking patients and specialist healthcare providers, telemedicine technologies have been used by primary healthcare providers to facilitate consults with specialists [8, 9, 13]. This enables delivery of competent care and comanagement of patients between primary care and specialty services [9]. For HCV, the link connecting primary care providers to hepatitis specialists has increased the numbers of HCV patients evaluated and treated [8, 9, 13]. Telemedicine has also been successfully used to deliver HCV-related CME to primary healthcare providers [8, 9, 13, 14]. In these US-based programs, infectious diseases experts and gastroenterologists prepare pedagogical CME slideshow presentations for primary healthcare providers on topics related to HCV and/or HIV and deliver them via telemedicine [8, 9, 13]. As part of the CME element, primary healthcare providers are responsible for presenting case reports on patients with particularly interesting or challenging cases of HIV or HCV [8, 9, 13]. One study focusing on HCV CME found that CME delivered via videoconference was as effective, if not more effective, than traditional CME [14].

Key impediments to more widespread use of telemedicine in some jurisdictions include lack of reimbursement, tedious licensing and credentialing requirements, and concerns about security. This has created a scenario in which the potential benefits to the patient have not been realized due to poor physician adoption. In the United States, Medicare restrictions on telemedicine include requirements that the patient reside in a rural location and that the interview must be conducted in an approved healthcare facility (ie, not their home) [35]. In contrast, the Ontario Telemedicine Network has been proactive in facilitating physician access without arduous regulation or restriction [36]; this physician service is also reimbursed by the Ontario provincial government. Other technologies, including Skype and FaceTime, could eliminate the need for patient travel to a healthcare facility. This approach would mitigate infection control concerns for patients with transmissible infections and protect them from hospital-acquired infections. Security breaches must be protected against. However, there are security risks irrespective of how and where healthcare is provided and does not justify failure to provide access to the benefits of telemedicine-based medical services to those in need.

A key disadvantage with telemedicine-based care over traditional in-clinic visits is the inability to perform full physical examination. Physical examinations through telemedicine are especially difficult if the picture quality of the telemedicine equipment is poor [12, 16]. Current telemedicine technologies do not allow for complete physical examinations to be performed remotely over the telemedicine platform. Of course, this is not an insurmountable obstacle. If a physical examination is required, telemedicine healthcare staff can either call patients into the clinic to perform the examination in person or rely on the findings of local healthcare professionals. Furthermore, the availability of peripheral devices such as teleauscultation devices can overcome this particular limitation [37].

## CONCLUSIONS

Telemedicine technologies are increasingly becoming incorporated into infectious diseases practices and have been described in the management of acute and chronic infectious diseases. Patients consistently report high levels of satisfaction with telemedicine-based care. Respiratory, urinary tract, skin and soft tissue, and other acute general infectious diseases have been treated using telemedicine. HIV, HCV, and tuberculosis patients have been successfully followed and treated with favorable clinical outcomes. Telemedicine studies evaluating HBV management and HCV treatments with interferon-free, all-oral antiviral therapies should be pursued. A key telemedicine advantage is increased access to healthcare for isolated populations. Telemedicine technology can also successfully deliver infectious diseases–related CME to primary healthcare professionals. Although many studies assert that telemedicine is cost-effective, systematic cost-analysis studies are few in number and conflicting in conclusions. Additional formal studies focused on this should be a priority.

### Notes

***Acknowledgments.*** C. C. acknowledges the Ontario Ministry of Health and Longterm Care for program support. Vertex, Gilead, Merck, and Janssen are acknowledged for unrestricted educational support.

***Financial support.*** This work was supported by the National CIHR Research Training Program in Hepatitis C (to P. P.) and the Ontario HIV Treatment Network (to C. C.).

***Potential conflicts of interest.*** All authors: No reported conflicts.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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