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Impact of a University-Based Outpatient Telemedicine Program on Time Savings, Travel Costs, and Environmental Pollutants

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ABSTRACT

Objective: The objective of this study was to estimate travel-related and environmental savings resulting from the use of telemedicine for outpatient specialty consultations with a university telemedicine program. **Methods:** The study was designed to retrospectively analyze the telemedicine consultation database at the University of California Davis Health System (UCDHS) between July 1996 and December 2013. Travel distances and travel times were calculated between the patient home, the telemedicine clinic, and the UCDHS in-person clinic. Travel cost savings and environmental impact were calculated by determining differences in mileage reimbursement rate and emissions between those incurred in attending telemedicine appointments and those that would have been incurred if a visit to the hub site had been necessary. **Results:** There were 19,246 consultations identified among 11,281 unique patients. Telemedicine visits resulted in a total travel distance savings of 5,345,602 miles, a total travel time savings of 4,708,891 minutes or 8.96 years, and a total direct travel cost savings of $2,882,056. The mean per-consultation round-trip distance savings were 278 miles, average travel time savings were 245 minutes, and average cost savings were $156. Telemedicine consultations resulted in a total emissions savings of 1969 metric tons of CO_2, 50 metric tons of CO, 3.7 metric tons of NO_x, and 5.5 metric tons of volatile organic compounds. **Conclusions:** This study demonstrates the positive impact of a health system's outpatient telemedicine program on patient travel time, patient travel costs, and environmental pollutants.

Keywords: cost analysis, health economics, telemedicine.

Introduction

Telemedicine is frequently regarded as a model of care that is patient-centric and environmentally friendly [1–3]. This model of care can be especially useful for outpatient services when travel distance, time, and cost can be a barrier. From the community and patient perspective, telemedicine allows quality health care to be delivered to patients in communities where in-person subspecialty services are not available, providing support and training for complex medical conditions to local providers, increasing accessibility for families to specialists, and minimizing time away from work and home [1,4–7]. Greater travel distances for services can result in a reduced number of physician visits, increased rates of attrition, and inadequate management of chronic conditions [8]. Telemedicine has been reported as more convenient than traveling to meet a specialist and has resulted in equal or higher patient satisfaction and comparable patient outcomes compared with in-person appointments [9–12], making this a viable and beneficial option of care.

Although research has documented the benefits of telemedicine from the patient's perspective, most studies have evaluated a relatively small sample over a short period of time, and have frequently relied on subjective survey data [4,5,13]. Similarly, there is limited evidence documenting the environmental impact of reduced travel associated with telemedicine due to relatively small sample sizes and data collected over a short time frame [1,3,14]. To date, there has not been a comprehensive evaluation of the benefits of telemedicine with regard to aggregated travel mileage, travel time, travel cost, and greenhouse gas emission over the life of a telemedicine program. The present study evaluated these outcomes resulting from the University of California, Davis (UC Davis) telemedicine program. Specifically, this study sought to estimate reductions in distances traveled for telemedicine appointments and to calculate the potential reduction in pollution and greenhouse gases associated with the estimated reductions in distances traveled.

Methods

Overview of University of California Davis Health System's Telemedicine Program

Data were evaluated from the University of California Davis Health System's (UCDHS's) telemedicine program, which began

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in 1998 and has conducted more than 48,000 outpatient and inpatient interactive, video-based consultations [15,16]. The program is based out of the UCDHS, located in Sacramento, California, and primarily provides subspecialty consultations in more than 30 clinical specialties and to more than 120 locations across California. The primary focus of the program, consistent with the mission of the University of California, is to provide services that are otherwise unavailable to rural and underserved regions of California.

This retrospective study was designed to compare telemedicine services with hypothetical in-person consultations—under the assumption that patients would have traveled to different clinic sites if telemedicine was not used—with a focus on the patient travel time, patient travel costs, and environmental reduction in pollution and greenhouse gas emissions related to travel. The UCDHS telemedicine database includes demographic and clinical data on all telemedicine encounters, a unique patient identification number, the date of telemedicine consultations, the telemedicine client site visited, and the type of subspecialty telemedicine service provided. The unique patient identification number is linkable to individual telemedicine consultations.

Selection of Patients

Patients who were California residents and who received an outpatient telemedicine consultation with the UCDHS between July 1996 and December 2013 were included. Patient records were excluded if there was no home address listed or if a particular unique identification number or medical record number associated with the patient consultation was associated with more than one patient with different names and birth dates. Patients in the database who received a telemedicine consultation while serving time in a California Department of Corrections and Rehabilitation facility were also excluded because analyzing this population would not provide insight into savings from a patient's perspective. Telemedicine outpatient services were provided to 157 client sites located in 56 of California's 58 counties (97%).

Outcome Measures

The four outcome measures for this study were as follows:

1. *Potential travel savings*, defined as the round-trip distance savings arising from the use of telemedicine, calculated as the difference between the distance traveled from the patient's home address to the telemedicine client site and the distance the patient would have traveled for an in-person consultation at the UCDHS.
2. *Potential time savings*, defined as the round-trip time savings arising from the use of telemedicine, calculated as the difference between the time required to travel from the patient's home address to the telemedicine client site and the time that would have been required to travel for an in-person consultation at the UCDHS.
3. *Potential cost savings*, defined as the round-trip cost savings arising from the use of telemedicine, calculated as the difference between the travel costs associated with traveling from the patient's home address to the telemedicine client site and the travel cost associated with traveling for an in-person consultation at the UCDHS.
4. *Potential reduction in pollution and greenhouse gas emissions*, defined as the amount of vehicle emission pollutants that were not emitted as a result of reductions in travel distance, calculated by multiplying per-mile emissions by the travel distance savings.

Distance Calculation

Distances were calculated by doubling the difference between the one-way distance from the patient's home to the UCDHS and the one-way distance from the patient's home to the telemedicine client site. For addresses listed as a P.O. Box, the ZIP code centroid associated with the P.O. Box address was used as the patient's address. MapPoint 2013 (Microsoft Corporation, Redmond, Wash) was used to geocode patient and telemedicine client site addresses. MP Mileage 2.5 (Winwaed Software Technology LLC, Irving, Texas) was used to calculate the travel distances between patient address and client site as well as the travel distances between patient addresses and the UCDHS. The "quickest route" option was selected instead of "shortest route" or "straight line" for these calculations. To calculate the distance savings, the round-trip mileage to travel to the telemedicine client site was subtracted from the round-trip distance that would been traveled to receive an in-person consultation.

Travel Time and Travel Cost

The following travel speeds were used to calculate travel time: interstates (motorways) were set at 65 miles per hour (mph); limited access roads were set at 55 mph; other (major) roads were set at 50 mph; arterial (minor) roads were set at 35 mph; and streets were set at 25 mph. These speeds were set in accordance with California standard practices [17]. To calculate the cost of travel, an inflation-adjusted Internal Revenue Service annual standard mileage reimbursement rate was used [18]. Inflation calculations were made using the Bureau of Labor Statistics consumer price index (CPI) Inflation Calculator, setting the buying power equivalence to 2014. This federally established rate is set to reflect the cost of vehicular travel including insurance, fuel, and vehicle maintenance for the miles driven.

Environmental Impact of Telemedicine

The 2008 Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks report, produced by the U.S. Environmental Protection Agency Office of Transportation and Air Quality, was used to obtain average pollutant values for passenger vehicles [19]. To estimate the environmental impact of the travel distance savings, the emissions per mile driven were multiplied by the total distance savings (Table 1).

Sensitivity Analysis

For primary analyses, all telemedicine consultation encounters were assumed to have replaced in-person consultations, and that without access to telemedicine, these encounters would have otherwise occurred in-person at the UCDHS. However, it is likely that not all telemedicine encounters actually replaced in-person encounters either because the referring primary care provider would not have made an in-person referral or some patients may have forgone in-person consultations given the inconvenience of travel. Sensitivity analyses were therefore conducted by varying this assumption to determine the impact on results. Specifically, calculations were repeated assuming in-person encounter rates of 90%, 75%, and 50%.

Statistical Analysis and Human Subjects

Python 2.7 (Python Software Foundation, Wilmington, Del) was used to edit, merge, and link data sets. Microsoft Access 2013 SQL queries were also used for data analysis. Statistical analyses were performed using Microsoft Excel 2013.