Physical Medicine and Rehabilitation Research

Research Article

ISSN: 2398-3353

Systematic review on tele-wound-care in spinal cord injury (SCI) patients and the impact of telemedicine in decreasing the cost

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Abstract

Telehealth refers to health care interactions that leverage telecommunication devices to provide medical care outside the traditional face-to-face, in-person medical encounter. Technology advances and research have expanded use of telehealth in health care delivery. Physical medicine and rehabilitation providers may use telehealth to deliver care to populations with neurologic and musculoskeletal conditions, commonly treated in both acute care and outpatient settings. Patients with impaired mobility and those living in locations with reduced access to care may particularly benefit. Video-teleconferencing has been shown to be effective for management of burn patients during acute rehabilitation, including reduced health care use expenses and less disruptions to care. Telehealth can facilitate developing inter-professional care plans. Patients with neurologic conditions including stroke, spinal cord injury, traumatic brain injury, and amyotrophic lateral sclerosis may use telehealth to monitor symptoms and response to treatment. Telehealth also may facilitate occupational and physical therapy programs as well as improve weight management and skin care in patients with chronic conditions. Other applications include imaging review in sports medicine, symptom management and counselling in concussion, traumatic brain injury, and pain management programs. Limitations of telehealth include barriers in establishing relationship between medical provider and patient, ability to perform limited physical examination, and differences in payment models and liability coverage. The expansion of telehealth services is expected to grow and has potential to improve patient satisfaction by delivering high quality and value of care.

Introduction

A spinal cord injury (SCI) is damage to the spinal cord that causes changes in its function, either temporary or permanent. These changes translate into loss of muscle function, sensation, or autonomic function in parts of the body served by the spinal cord below the level of the lesion. Injuries can occur at any level of the spinal cord and can be classified as complete injury, a total loss of sensation and muscle function, or incomplete, meaning some nervous signals are able to travel past the injured area of the cord. Depending on the location and severity of damage along the spinal cord, the symptoms can vary widely, from pain or numbness to paralysis to incontinence. The prognosis also ranges widely, from full recovery in rare cases to permanent tetraplegia (also called quadriplegia) in injuries at the level of the neck, and paraplegia in lower injuries. Complications that can occur in the short and long term after injury include muscle atrophy, pressure sores, infections, and respiratory problems.

In the majority of cases the damage results from physical trauma such as car accidents, gunshots, falls, or sports injuries, but it can also result from nontraumatic causes such as infection, insufficient blood flow, and tumors. Efforts to prevent SCI include individual measures such as using safety equipment, societal measures such as safety regulations in sports and traffic, and improvements to equipment. Known since ancient times to be a catastrophic injury and long believed to be untreatable, SCI has seen great improvements in its care since the middle of the 20th century. Treatment of spinal cord injuries starts with stabilizing the spine and controlling inflammation to prevent further damage. Other interventions needed can vary widely depending on the location and extent of the injury, from bed rest to surgery. In many cases, spinal cord injuries require substantial, long-term physical and occupational therapy in rehabilitation, especially if they interfere with activities of daily living. Research into new treatments for spinal cord injuries includes stem cell implantation, engineered materials for tissue support, and wearable robotic exoskeletons [1].

Spinal cord injury can be traumatic or nontraumatic, [2] and can be classified into three types based on cause: mechanical forces, toxic, and ischemic (from lack of blood flow) [3]. The damage can also be divided into primary and secondary injury: the cell death that occurs immediately in the original injury, and biochemical cascades that are initiated by the original insult and cause further tissue damage. These secondary injury pathways include the ischemic cascade, inflammation, swelling, cell suicide, and neurotransmitter imbalances [4]. They can take place for minutes or weeks following the injury [5].

At each level of the spinal column, spinal nerves branch off from either side of the spinal cord and exit between a pair of vertebrae, to innervate a specific part of the body. The area of skin innervated by a specific spinal nerve is called a dermatome, and the group of muscles innervated by a single spinal nerve is called a myotome. The part of the spinal cord that was damaged corresponds to the spinal nerves at that level and below. Injuries can be cervical 1–8 (C1–C8), thoracic 1–12 (T1–T12), lumbar 1–5 (L1–L5), [6] or sacral (S1–S5) [7]. A

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Key words: *tele-wound-care, spinal cord injury (SCI), telemedicine, rehabilitation*

Received: June 03, 2019; **Accepted:** June 11, 2019; **Published:** June 14, 2019

person's level of injury is defined as the lowest level of full sensation and function [8]. Paraplegia occurs when the legs are affected by the spinal cord damage (in thoracic, lumbar, or sacral injuries), and tetraplegia occurs when all four limbs are affected (cervical damage) [9].

SCI is also classified by the degree of impairment. The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI), published by the American Spinal Injury Association (ASIA), is widely used to document sensory and motor impairments following SCI [10]. It is based on neurological responses, touch and pinprick sensations tested in each dermatome, and strength of the muscles that control key motions on both sides of the body [11]. Muscle strength is scored on a scale of 0–5 according to the table on the right, and sensation is graded on a scale of 0–2: 0 is no sensation, 1 is altered or decreased sensation, and 2 is full sensation. Each side of the body is graded independently [12].

Epidemiology

Worldwide, the incidence (number of new cases) since 1995 of SCI ranges from 10.4 to 83 people per million per year [13]. This wide range of numbers is probably partly due to differences among regions in whether and how injuries are reported [14]. In North America, about 39 people per every million incur SCI traumatically each year, and in Western Europe the incidence is 16 per million [15,16]. In the United States, the incidence of spinal cord injury has been estimated to be about 40 cases per 1 million people per year or around 12,000 cases per year [17,18]. In China, the incidence is approximately 60,000 per year [17]. The estimated prevalence (number of people living with SCI) in the world ranges from 236 to 4187 per million. [19]. Estimates vary widely due to differences in how data are collected and what techniques are used to extrapolate the figures [20]. Little information is available from Asia, and even less from Africa and South America [21,22]. In Western Europe the estimated prevalence is 300 per million people and in North America it is 853 per million [21]. It is estimated at 440 per million in Iran, 526 per million in Iceland, and 681 per million in Australia [23]. In the United States there are between 225,000 and 296,000 individuals living with spinal cord injuries, [24] and different studies have estimated prevalences from 525 to 906 per million [25].

SCI is present in about 2% of all cases of blunt force trauma [26]. Anyone who has undergone force sufficient to cause a thoracic spinal injury is at high risk for other injuries also [27]. In 44% of SCI cases, other serious injuries are sustained at the same time; 14% of SCI patients also suffer head trauma or facial trauma [28]. Other commonly associated injuries include chest trauma, abdominal trauma, pelvic fractures, and long bone fractures [29].

Males account for four out of five traumatic spinal cord injuries [30]. Most of these injuries occur in men under 30 years of age [31]. The average age at the time of injury has slowly increased from about 29 years in the 1970s to 41 [32]. Rates of injury are at their lowest in children, at their highest in the late teens to early twenties, then get progressively lower in older age groups; however rates may rise in the elderly [33]. In Sweden between 50 and 70% of all cases of SCI occur in people under 30, and 25% occur in those over 50 [34]. While SCI rates are highest among people age 15–20, [35] fewer than 3% of SCIs occur in people under 15 [36]. Neonatal SCI occurs in one in 60,000 births, e.g. from breech births or injuries by forceps [37]. The difference in rates between the sexes diminishes in injuries at age 3 and younger; the same number of girls are injured as boys, or possibly more [38]. Another cause of pediatric injury is child abuse such as shaken baby syndrome [39]. For children, the most common cause of SCI (56%) is vehicle crashes [40]. High numbers of adolescent injuries are attributable in a large part to traffic accidents and sports injuries [41]. For people over 65, falls are the most common cause of traumatic SCI [42]. The elderly and people with severe arthritis are at high risk for SCI because of defects in the spinal column [43]. In nontraumatic SCI, the gender difference is smaller, the average age of occurrence is greater, and incomplete lesions are more common [44].

Telemedicine and tele-wound-care

Telemedicine is the use of telecommunication and information technology to provide clinical health care from a distance. It has been used to overcome distance barriers and to improve access to medical services that would often not be consistently available in distant rural communities. It is also used to save lives in critical care and emergency situations. Although there were distant precursors to telemedicine, it is essentially a product of 20th century telecommunication and information technologies. These technologies permit communications between patient and medical staff with both convenience and fidelity, as well as the transmission of medical, imaging and health informatics data from one site to another. Early forms of telemedicine achieved with telephone and radio have been supplemented with videotelephony, advanced diagnostic methods supported by distributed client/server applications, and additionally with telemedical devices to support in-home care [44].

Materials and methods

Telerehabilitation is the delivery of rehabilitation services over telecommunication networks and the Internet. Most types of services fall into two categories: clinical assessment (the patient's functional abilities in his or her environment), and clinical therapy. Some fields of rehabilitation practice that have explored telerehabilitation are neuropsychology, speech-language pathology, audiology, occupational therapy, and physical therapy. Telerehabilitation can deliver therapy to people who cannot travel to a clinic because the patient has a disability or because of travel time. Telerehabilitation also allows experts in rehabilitation to engage in a clinical consultation at a distance.

Most telerehabilitation is highly visual. As of 2014, the most commonly used mediums are webcams, videoconferencing, phone lines, videophones and webpages containing rich Internet applications. The visual nature of telerehabilitation technology limits the types of rehabilitation services that can be provided. It is most widely used for neuropsychological rehabilitation; fitting of rehabilitation equipment such as wheelchairs, braces or artificial limbs; and in speech-language pathology. Rich internet applications for neuropsychological rehabilitation (aka cognitive rehabilitation) of cognitive impairment (from many etiologies) were first introduced in 2001. This endeavor has expanded as a teletherapy application for cognitive skills enhancement programs for school children. Tele-audiology (hearing assessments) is a growing application. Currently, telerehabilitation in the practice of occupational therapy and physical therapy is limited, perhaps because these two disciplines are more "hands on".

Two important areas of telerehabilitation research are (1) demonstrating equivalence of assessment and therapy to in-person assessment and therapy, and (2) building new data collection systems to digitize information that a therapist can use in practice. Ground-breaking research in telehaptics (the sense of touch) and virtual reality may broaden the scope of telerehabilitation practice, in the future.

In the United States, the National Institute on Disability and Rehabilitation Research's (NIDRR) [45] supports research and the development of telerehabilitation. NIDRR's grantees include the "Rehabilitation Engineering and Research Center" (RERC) at the University of Pittsburgh, the Rehabilitation Institute of Chicago, the State University of New York at Buffalo, and the National Rehabilitation Hospital in Washington DC. Other federal funders of research are the Veterans Health Administration, the Health Services Research Administration in the US Department of Health and Human Services, and the Department of Defense [46]. Outside the United States, excellent research is conducted in Australia and Europe.

Only a few health insurers in the United States, and about half of Medicaid programs, [47,48] reimburse for telerehabilitation services. If the research shows that teleassessments and teletherapy are equivalent to clinical encounters, it is more likely that insurers and Medicare will cover telerehabilitation services.

Telenursing refers to the use of telecommunications and information technology in order to provide nursing services in health care whenever a large physical distance exists between patient and nurse, or between any number of nurses. As a field it is part of telehealth and has many points of contacts with other medical and non-medical applications, such as telediagnosis, teleconsultation, telemonitoring, etc. [49]. Telenursing is achieving significant growth rates in many countries due to several factors: the preoccupation in reducing the costs of health care, an increase in the number of aging and chronically ill population, and the increase in coverage of health care to distant, rural, small or sparsely populated regions. Among its benefits, telenursing may help solve increasing shortages of nurses; to reduce distances and save travel time, and to keep patients out of hospital. A greater degree of job satisfaction has been registered among telenurses [50].

In Australia, during January 2014, Melbourne tech startup Small World Social collaborated with the Australian Breastfeeding Association to create the first hands-free breastfeeding Google Glass application for new mothers [51]. The application, named Google Glass Breastfeeding app trial, allows mothers to nurse their baby while viewing instructions about common breastfeeding issues (latching on, posture etc.) or call a lactation consultant via a secure Google Hangout, who can view the issue through the mother's Google Glass camera [52]. The trial was successfully concluded in Melbourne in April 2014, and 100% of participants were breastfeeding confidently [53]. Small World Social Breastfeeding Support Project

Phase 1-Development of clinical scenarios

In Phase 1, clinical experts in SCI care developed clinical scenarios that represent common patient situations. Each scenario depends on whether the patient resides within (100 miles or a two-hour drive) or outside the SCI homecare catchment area. We describe typical care without telehealth and different alternative care options with telehealth. The scenarios assume that the patient is in a private home residence that includes a caregiver, or in a skilled nursing facility. SCI Center refers to a specialized SCI treatment center at a VA hub facility [54].

Patient Scenario 1-Primary prevention for a newly injured patient discharged to home from an sci center after rehabilitation and without a PU

Within SCI Homecare Catchment Usual care for patients within the homecare catchment is for a registered nurse (RN) from the SCI homecare staff to visit the patient in his/her residence for preventative, educational, and monitoring purposes. Patients typically return to the SCI Center for an outpatient visit and/or an inpatient stay for a 1-year annual follow-up examination [55].

Home telehealth care option 1 involves the use of a videoconferencing unit that is attached to a land-line telephone as a complement to standard homecare visits. The telehealth unit is placed in the patient's home or in a nursing care residential home (which could serve more than one patient). The videoconferencing unit allows the SCI homecare practitioners to substitute 50% of the usual care visits with home telehealth visits [56].

Outside SCI Homecare Catchment Usual care for a patient who resides outside of the SCI homecare catchment boundary is follow-up telephone contact at 3 and 6 months after discharge. An in-person follow-up examination at the SCI Center takes place at 12 months. The patient is also advised to visit a local outpatient clinic or VA medical facility near his/her residence for any care, as needed. This scenario assumes that the patient does not have any active diagnoses upon discharge. The PU itself may be treated if the patient seeks care for skin or PUs at a non-SCI specialty clinic or facility, but the contributing factors and intricacies of SCI specialty care may not be adequately addressed. This lack of SCI expert care may impact the successful treatment of existing wounds and may not be optimal for preventing additional skin compromise [57].

Home telehealth care option 1 uses the same videoconferencing unit and the same schedule as option 1 for patients within the homecare catchment. The unit allows the practitioners to interact and assess the patient on a regularly scheduled basis and via home telehealth visits as needed. A patient telehealth unit is placed in the patient's home or in a nursing home setting [58].

Home telehealth option 2 is designed to leverage the SCI Center expertise through the hub and spoke model of care. The patient is sent home with the same videoconferencing unit as per telehealth scenario 1 and follows the same schedule. In this scenario, the patient connects with the SCI center; this provides oversight by the SCI Center with appropriate clinical attention and intervention as identified via patient response. In addition, the patient has a planned visit with a local SCI consultation clinic (a local spoke VA hospital or outpatient clinic) at 1, 3, 6, and 9 months after discharge. The local clinic spoke would connect via videoconferencing with the SCI Center clinician. The patient and clinician are present at the spoke clinic [59].

Patient Scenario 2-An established SCI patient diagnosed with a PU that requires dressing changes until healed

Within the SCI Home Care Catchment, Usual care for a patient with one or more PUs is regular home visits by a homecare RN. The nurse changes dressings and takes a digital photo for the medical record and potential physician review. There is currently no telehealth option for this situation.

Outside the SCI Home Care Catchment Usual care is for a patient to be managed by a contracted private home care agency or admitted to a skilled nursing facility until the PU is healed. In the model below, we assume that an agency is used. Home telehealth option 3 involves store-and-forward telemedicine integrated with telehealth consultation. The patient is managed by a homecare agency or nursing facility as in usual care. A digital camera and instruction kit are provided to the caregiver or nurse. If it is the caregiver, we assume that he or she is willing and able to operate the digital camera. This option also assumes that secure internet access is available for transmitting the photos via e-mail. Digital photos of the PU and surrounding skin are taken every week. They are then forwarded to the SCI Center for review by a nurse and for documentation in the medical record. The nurse contacts the managing agency for any treatment recommendations. SCI telehealth consultation with a nurse practitioner or physician at a local VA spoke facility is scheduled if the wound is either getting worse or appears healed. In case of poor healing or complications, expeditious intervention and treatment plan alterations would be implemented [60].

Patient Scenario 3-Prevention of recurrence after surgical treatment

Within the SCI Home Care Catchment, Usual care for a patient discharged after a two-month inpatient stay that included plastic surgery to repair a PU involves one return visit to the SCI outpatient clinic after one month to recheck the site and follow-up visits as needed [61].

Telehealth model of care option 1 incorporates both home telehealth and store-and-forward telehealth. After discharge to home, the patient videoconferences with a nurse using the same home unit previously described. Digital still photos of the surgical site are taken using the telehealth equipment (rather than a digital camera) during a telehealth visit. These photos are forwarded into the medical record and made available for the plastic surgeons to review, if a consultation is requested by the SCI Center staff. This model works for patients regardless of the distance of their residence from the SCI Center.

Telehealth model of care option 3 substitutes a digital camera for the home video telehealth unit. Digital cameras provide a greater resolution (3.3 megapixels minimally required) than a video still-shot and are the standard for documenting skin and plastic surgery repairs. The photo is taken and forwarded to the SCI Center for review and incorporation into the electronic medical record [62].

Outside the SCI Home Care Catchment, Usual care is the same except for follow-up. If the patient lives over 100 miles or two hours from the nearest SCI Clinic, care is provided by a VA medical center or other facility near the patient's home. Telehealth model of care option 1 incorporates both home telehealth and store-and-forward telehealth. After discharge to home residence, the patient videoconferences with a nurse. In addition, digital still photos of the surgical site are taken using the telehealth equipment. These photos are forwarded for incorporation into the medical record and made available for the plastic surgeons to review, if a consultation is requested by the SCI Center staff. If the patient and surgical site require further assessment, a telehealth consultation can be scheduled for those patients living over 100 miles or two hours from the SCI Center. The telehealth consultation would take place between a patient at an SCI spoke site and clinicians (including plastic surgery specialists) at the SCI Center hub site. Telehealth model of care option 3 incorporates utilizing digital cameras in place of the home video telehealth unit and is the same as option 3 within the SCI home catchment. If the patient and surgical site require further assessment, a telehealth consultation can be scheduled with the SCI center. The telehealth consultation would take place between a patient at an SCI spoke site and clinicians at a hub site [63].

Phase 2-Estimation of costs

In Phase 2, we determined the cost of each scenario under usual care (without telehealth) and under alternative scenarios that included telehealth technology options. Probabilities of developing ulcers came from the expertise of the clinicians on the project. Most figures were drawn from VA administrative data. About 20,000 individuals are treated for SCI in the VA system each year. Of these, roughly half will live in the catchment area of a VA medical center. About one-third (32%) will be eligible for telehealth; the remainder either lack sufficient functional independence (20%) or lack a standard land-line telephone (48%) [64].

Costs Associated with VA Care, Costs were extracted from the VA Decision Support System (DSS) National Data Extracts (NDEs). The DSS allows for the estimation of costs for every inpatient and outpatient VA encounter. Information on costs of VA-funded care for home-based health care and for care at certain non-VA facilities, such as rehabilitation hospitals and community nursing homes, was extracted from the VA Fee Basis program files.

Costs Associated with Telehealth A second set of VA costs pertained to the telehealth system. Its elements included equipment, training, and telecommunication line costs. Equipment costs were found in the Federal Supply Schedule and from VA staff in the Acquisition and Material Management Service. Training costs were based on national-average VA staff costs in a technical report from the Health Services Research and Development (HSR&D) Health Economics Resource Center [65]. Other supply costs, such as for telecommunication lines, were drawn from published studies [66,67].

Miscellaneous costs

There were also several non-VA costs to estimate. These included travel costs under various modes of transportation and the cost of any paid home caregiver. We used the IRS standard mileage reimbursement rate for car travel. We estimated the costs of other modes of transportation through internet research of private firms providing transportation. Home caregiver costs were estimated using average national wage rates for such care, as determined by the US Department of Labor, Bureau of Labor Statistics. Cost Analysis For each scenario and treatment option, we multiplied probabilities, frequencies, and costs to estimate the cost over the entire expected treatment period. We generated low-, medium-, and high-cost estimates based on reasonable ranges of costs and probabilities.

Model inputs

Improving medical care can have secondary impacts on the VA health care system. The prevalence of SCI is relatively low, and we assumed that the availability of telehealth would not be a sufficient incentive for patients with SCI to enroll in the VA health care system if they had not done so earlier. Consequently, demand for SCI care only among current SCI patients was explicitly modeled here. We assumed no change in demand for other conditions because there was no guidance for predicting such changes and because the variation in changes could be large. Finally, we assumed no changes in staffing at the VA as a result of telehealth use.

We present costs associated with each scenario, both for standard care without telehealth and for telehealth-enhanced care. We did not conduct any statistical tests comparing the costs across scenarios because these are modeled costs rather than averages from individual observations.

Telehealth-Costs Digital cameras range in cost from $200 to $300 and are assumed to last three years. The home videoconference machine commonly used in the VA in 2007 was the American Telecare Life View machine (Eden Prairie, MN). Its cost of $11,325 came from a national contract with the VA and hence has no variation. We assumed that it lasts three years. Telephone calls and the Life View station both use telephone land lines. Based on actual experience, we expected that 52% of individuals eligible for telehealth would have standard (landline) telephones. No cost was assigned for them because this program does not purchase or repair telephones, and their use would not noticeably shorten their lifetimes. We assumed that the VA clinicians initiated all calls in order to eliminate any cost to the patient. Based on our assumption that transmission costs were part of the fixed overhead assigned to encounters in the SCI clinic, we did not account for their costs separately.

Home-Based care encounters

There were three types of home-based care encounters: one with a VA registered nurse (RN), one with a contract RN, and one with a VA nurse or doctor at an SCI clinic via the Life View machine. Nurse wages in the VA are not unusually high, but the costs for VA nurses were more than five times those for contract nurses. We conclude that the difference stems from overhead costs in the SCI service of VA medical centers. Finally, we assumed that using a digital camera would not lengthen the time it takes to examine a patient for PUs, and thus did not account separately for the cost of using a digital camera.

Facility-Based encounters

There were five types of facility-based encounters. The first three reflect encounters at VA hospitals. The fourth (telehealth call) includes the patient and a hospital-based staff member. The fifth refers to office visits by contract physicians. VA payments to office-based physicians are often similar to Medicare payments for the same encounters. The relatively low cost for the contract physician visits reflects the lack of a hospital facility component in the payment.

Inpatient care

There were two types of inpatient care. The first was plastic surgery and all inpatient recovery following detection of a severe PU. The second was the 30-day average cost of VA payments to community skilled nursing facilities (SNFs). In our models, the time spent in SNFs was measured in 30-day increments. Although the VA has its own SNF units, most VA convalescent patients are treated in community facilities. This is particularly true for individuals living far from a VA hospital.

Transportation

Transporting persons with SCI requires wheelchair accessibility. The low estimate reflects only mileage costs and assumes that the patient uses a private vehicle. The medium and high estimates reflect a reasonable range of costs for private transportation by a medical transportation firm.

Conclusion

Most patients receive teleconsultation as follow-up to a recent BoNT injection. The majority of patients in the survey found the service of high quality and found the service useful to their care. Previous studies in the literature have shown that telehealth can be of benefit to patients' physical and mental well-being, whereas this study provides strong evidence for continuing such service from the patients' perspective. In addition, we anticipate that the health economists might be interested in developing this assessment and follow-up models. The use of telehealth technologies has much potential in developing countries, as well as being a major tool of collaboration between centers. International Spinal Cord Injury Society is currently putting a lot of emphasis in developing and extending the treatment of SCI in South Asia, Africa and South America [8]. Furthermore, according to a recent study within the World Health Organization global regions, [9] there has been an increase in SCI injuries from motor transport in developing countries due to trends in transport mode (transition to motorized transport), poor infrastructure and regulatory challenges. We believe telemedicine will be an extremely valuable tool on that front due to the limited amount of experts and other resources available. This study reflects the fact that, specific to the telehealth service in NSIC, patients do value it very highly and believe that it would improve their care. However, we acknowledge that the study is limited by the low number of participants and the error in patients recalling their encounter with the clinician retrospectively. The low number of participants in this study reflects the difficulty in performing such service, because doctors and patients often have busy schedules. It is important that both sides should try to adhere to specific consultation times.

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