TELEMEDICINE AND e-HEALTH
Volume 13, Number 6, 2007

DOI: 10.1089/tmj.2007.9971

Original Research

The Effects of TeleWound Management on Use of Service and Financial Outcomes

RILEY S. REES, M.D., and NOURA BASHSHUR, M.H.S.A.

ABSTRACT

This study investigated the effects of a TeleWound program on the use of service and financial outcomes among homebound patients with chronic wounds. The TeleWound program consisted of a Web-based transmission of digital photographs together with a clinical protocol. It enabled homebound patients with chronic pressure ulcers to be monitored remotely by a plastic surgeon. Chronic wounds are highly prevalent among chronically ill patients in the United States (U.S.). About 5 million chronically ill patients in the U.S. have chronic wounds, and the aggregate cost of their care exceeds $20 billion annually. Although 25% of home care referrals in the U.S. are for wounds, less than 0.2% of the registered nurses in the U.S. are wound care certified. This implies that the majority of patients with chronic wounds may not be receiving optimal care in their home environments. We hypothesized that TeleWound management would reduce visits to the emergency department (ED), hospitalization, length of stay, and visit acuity. Hence, it would improve financial performance for the hospital. A quasi-experimental design was used. A sample of 19 patients receiving this intervention was observed prospectively for 2 years. This was matched to a historical control group of an additional 19 patients from hospital records. Findings from the study revealed that TeleWound patients had fewer ED visits, fewer hospitalizations, and shorter length of stay, as compared to the control group. Overall, they encumbered lower cost. The results of this clinical study are striking and provide strong encouragement that a single provider can affect positive clinical and financial outcomes using a telemedicine wound care program. TeleWound was found to be a credible modality to manage pressure ulcers at lower cost and possibly better health outcomes. The next step in this process is to integrate the model into daily practice at bellwether medical centers to determine programmatic effectiveness in larger clinical arenas.

INTRODUCTION

THIS STUDY WAS AIMED at investigating the effects of a TeleWound program on the use of service and financial outcomes among homebound patients with chronic wounds. The TeleWound program was internally developed at the University of Michigan Health System (UMHS), jointly designed by the Telemedicine Resource Center and Department of Plastic

Wound Care Center, Department of Plastic Surgery, University of Michigan Health System, Ann Arbor, Michigan.

Surgery. The program allows homebound patients with pressure ulcers to receive distance care and remote monitoring from their plastic surgeon. It utilizes a store-and-forward system and consists of Web-based digital photography and standardized clinical protocols. Measures of use of service include frequency of emergency department (ED) visits, outpatient clinic visits, hospitalization and length of hospital stay, number of outpatient clinic contacts (other than visits), and outpatient visit acuity. Financial outcome measures were limited to the UMHS's direct and indirect costs.

MATERIALS AND METHODS

Chronic wounds are highly prevalent among chronically ill patients in the United States (U.S.). Typically, the cost of care for such patients is quite substantial. Overall, it has been estimated that about 5 million chronically ill patients in the total population of the U.S. have chronic wounds, and the aggregate cost of care for them exceeds $20 billion annually. Moreover, this cost increases with advancing age at the rate of about 10% per year.[1] Another estimate places the number of patients with chronic wounds at 6 million, overall, or nearly 2% of the total U.S. population.[2]

Pressure ulcers occur frequently among hospitalized patients. It has been estimated that about 2.5 million hospitalized patients receive treatment for pressure ulcers each year.[3] Their care is very costly. For instance in 1999, the estimate for the total cost of caring for hospital-acquired pressure ulcers was between $2.2 and $3.6 billion per year.[3] The cost of care for a single hospitalized patient with a pressure ulcer ranged between $5,000 and $40,000.[4–6] The estimated cost for surgical closure of a pressure sore ranged from $75,000 to $90,000. Often, the hospital does not get fully reimbursed for this cost.[1] Hence, the average hospital in the U.S. incurs between $400,000 and $700,000 in direct costs to treat pressure ulcers annually, and a large portion of this cost is not reimbursable.[3,7]

There is empirical evidence that demonstrates a strong association between pressure ulcer and hospital length of stay.[8] Under the prospective payment system, the required care for these patients places hospitals at a significant financial disadvantage, particularly the loss of revenue as a result of the prolonged hospitalization.[1] The problem is all the more acute among the elderly. Indeed, 70% of all pressure ulcers occur among patients who are 70 years of age or older.[8] Additionally, pressure ulcers greatly increase the risk for osteomyelitis of the pelvis and septicemia,[8] and cellulitis.[9] For instance, nearly two thirds, or 65%, of elderly patients hospitalized with hip fractures develop pressure ulcers.[10] Among other investigators, Allman et al. found that pressure ulcers constitute a "significant predictor of both length of hospital stay and total hospital costs,[4,11,12]" increased risk of amputation and death.[3,4,11,12]

Several factors contribute to the high cost of treatment for pressure ulcers. These include nursing time, physician time, surgical procedures—flaps and debridement—and, of course, longer hospitalization for complications. There is also the added cost of expensive devices and products, such as specialty beds, pressure-relieving devices, pharmacotherapy, and rehabilitation. The experience can be painful and disfiguring. In addition to the physical symptoms, afflicted patients may suffer from the sequelae of low self-esteem, embarrassment, and "body image disturbances." Indeed, the problem degrades quality of life and functional performance among patients. This becomes all the more serious when considering that such patients often experience slow recovery because of having comorbidities. Often, they become dependent on a caregiver to change their dressings and to help them with basic activities of daily living. In turn, caregivers have to devote time and energy to care for these patients, who tend to be elderly parents. The burden on caregivers is substantial, and it can disrupt the normal routines of nuclear families.[13]

Since many of these patients require professional help in their home environments, there was a concomitant increase in the demand for homecare services.[14] From the wound care perspective, this increased the demand for home health services. However, it was not a boon for

home health agencies that have to operate under the Prospective Payment System because the increased demand did not generate additional revenue.[15] Nonetheless, the actual increase in the number of homecare patients with acute and chronic wounds resulted in the prominence of the homecare setting for the care of these patients.[16] For instance, between 2000 and 2005, the average number of home health visits per patient was expected to increase from 65 to 82.[17] Yet overall reimbursement has been declining. Dansky et al. reported that home health agencies are currently being reimbursed at levels 2% lower than 1993–1994 levels.[18,19]

Nearly a quarter of home care referrals in the U.S. are for wounds.[20] Homecare agencies complain about the deficit they incur in treating such patients. Although their cost ranges between $8,000 and $30,000 per year, their reimbursement is limited to about $2,500 on a national level.[20]

Nurses who are specialty trained in wound care can reduce the cost of care by applying their knowledge, skill, and efficient use of resources.[20,21] Indeed, it has been demonstrated that effective and timely treatment of chronic wounds is based on high-quality, standardized, "community-based specialty care",[20,22,23] and that chronic wounds heal more rapidly in the home setting when the care is provided by specially trained nurses, as compared to their counterparts.[24] However, less than 0.2% of the registered nurses in the U.S. are wound care certified. This implies that the vast majority of such patients do not receive optimal care in their home environments.[20]

Description of the intervention

The TeleWound program consists of a Web-based transmission of digital photographs and a clinical protocol that enables homebound patients who have chronic pressure ulcers to be monitored remotely by a plastic surgeon who is a specialist in wound care management. These patients have been receiving their normal care from their plastic surgeon when they visit the office. However, care in their homes has been provided by a home health agency. Those participating in the TeleWound program are visited by the TeleWound nurse in their homes. During these visits, the nurse takes a digital photograph of each wound, as shown in Figure 1, and completes a standardized wound assessment form, which captures detailed data such as (but not limited to) wound location, size, stage, drainage, odor, presence of exposed bone, "feel" of bone if exposed, percent necrotic tissue, dressing regime, and products used. There are also two open-ended sections, one where the TeleWound nurse documents her overall assessment, and another section for communication/questions from the nurse to the physician. The information is relayed on a secure Web-based platform to the manager of the program who arranges the complete file for the physician.

The digital camera model chosen was the Nikon CoolPix 4500 model (Nikon, Melville, NY), plus a Nikon CoolLight S-1. The CoolLight is a ring light that attaches directly to the camera. It ensures consistent lighting for all images, because the ambient light situation in the homecare environment is often unpredictable. (Flash is never used because it tends to "wash out" the wound color.)

Digital photography employs an explicit but simple protocol, including specifications as angling the camera "head on" to wound, taking the photo between 10 and 18 inches away from the wound, placing a paper ruler and wound identifier tag in close proximity to the wound, and capturing the wound, tag, and ruler in each

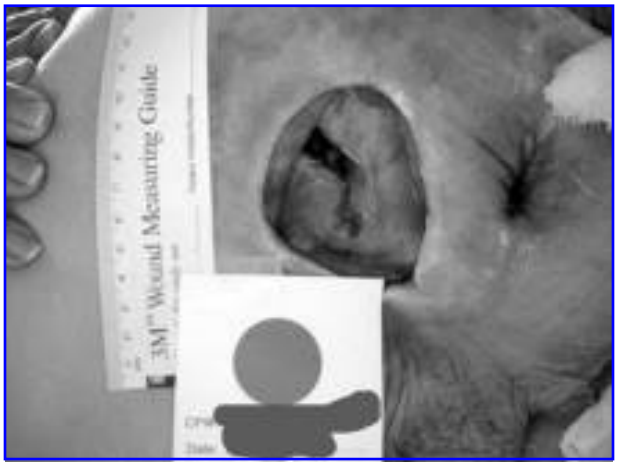

FIG. 1. Digital transmission of TeleWound photograph.

photo. The tag is preprinted with a large red circle. This red circle is the same hue and intensity of healthy wound bed tissue, and is used to compare the color of the actual wound to a standardized color. The nurse also makes sure the wound is centered in the photograph, without shadows, and uses a contrasting background. After executing this task, the nurse reviews the photographs. If they are found inadequate, new photographs are obtained. All photographs and protocols are transmitted over a Virtual Private Network within 24 hours.

In-home TeleWound visits are conducted by the nurse either weekly or biweekly, depending on the stability of the wound. The surgeon reviews the information within 36 hours of receiving it, and makes treatment decisions based on the data, except when alerted to an emergency situation by the nurse or manager. The surgeon determines whether or not a change of order is indicated or whether a clinic visit or surgical debridement should be scheduled. The surgeon also responds to the nurse's questions and comments, which were relayed in the open-ended sections of the wound assessment form.

STUDY DESIGN

The leading hypothesis in this study posits that the TeleWound management program will result in reduced frequency of visits to the ED, reduced hospitalization and length of stay, reduced visit acuity, and improved financial performance. Moreover, it is expected that the longer patients participate in the TeleWound program, the greater the effects.

A quasiexperimental design was chosen as the most feasible approach to test this multipart hypothesis. It consists of an improved nonequivalent control group design, in which the experimental (TeleWound) cases are observed prospectively, whereas the control group is a matched historical group. The improvement over the traditional nonequivalent group design derives from matching cases with comparable controls. The TeleWound group consisted of 19 patients who gave informed consent to participate in the study. Of those who were asked to participate in the study, two refused after the start of the project. Hence, the total pool consisted of 21 patients. In order to ensure the reliability of the analysis, these cases were included in the study only if they participated in the TeleWound program for a minimum of 3 months. Moreover, for analytic purposes, the experimental (TeleWound) group of 19 subjects was further subdivided into "established" patients (those who have participated in the program for 12 months or more from the start of the project) and "nonestablished" patients (those who have participated less than 12 months). The experience of the subset of "established" patients was examined separately because its members were expected to show a larger effect than the group as a whole. The TeleWound group consisted of 11 males and 8 females. The "established" subset among them consisted of 7 males and 4 females.

Nineteen controls were matched by wound type, comorbidities, distance of residence to clinic, and payer mix. These cases were selected from hospital records. All received their wound care from the same surgeon but not necessarily from the same home health agency. Distance from home was calculated by placing home address and the address of the clinic into MapQuest®, which computed mileage for each address. Visit acuity was abstracted from the electronic medical record, where it is systematically coded.

The two groups were not matched by age. However, all subjects of the study are patients of a single provider and receive treatment in the same outpatient clinic as the experimental group. The data for the TeleWound group were collected prospectively for a period of 2 years, whereas the data for the control group were abstracted from the electronic master records for the same period.

The dependent variables: use of service and financial performance

Use of service measures was straightforward. They included number of ED visits, number of outpatient clinic visits, number of inpatient hospitalizations, length of stay, num-

Table 1. Emergency Department Visits by TeleWound and Control Groups

	Total sample				Established patients only			
	No visits	*One or more visits*	*Total*	*Mean*	*No visits*	*One or more visits*	*Total*	*Mean*
TeleWound group	11	8	19	0.84	9	2	11	0.45
Control group	5	14	19	2.05	2	9	11	2.82
	$\chi^2 = 3.89$		$p = 0.049$		$\chi^2 = 8.91$		$p = 0.003$	

ber of outpatient clinic contacts, and level of outpatient visit acuity. This latter variable was abstracted from hospital financial records. A "clinic contact" is defined as any type of contact (phone calls, nursing notes, etc.) with the plastic surgeon or plastic surgery nurse, which was recorded in the electronic medical record. Financial outcome measures examined were based on inpatient and outpatient health system direct and indirect costs. These data covered 2 full calendar years, 2004 and 2005. Factors such as wound healing time were not measured in the study.

DATA ANALYSIS AND FINDINGS

The analysis of the data consisted of comparing the utilization experiences of the two groups—TeleWound (experimental) and control—over a 2-year period. A further assessment is made for the subset of "established patients" in order to test the secondary hypothesis to the effect that experience in the TeleWound program tends to increase the magnitude of the effect. The significance of the difference between the TeleWound and control groups is ascertained by the χ^2 and their contingency coefficients (p values). The value of χ^2 was calculated using the standard formula. Although several of the dependent variables were continuous, we had to collapse the categories because of the small sample size.

ED visits

For the 2 years combined, patients in the TeleWound group made a total of 19 ED visits, whereas the control group made a total of 39 such visits. The averages for the two groups were 0.84 and 2.05, respectively, that is, on average, patients in the TeleWound group made less than 1 visit to the ED over a 2-year period, whereas those in the control group averaged more than 2 visits. This trend is even more dramatic among established patients. Nine of 11 in the TeleWound group did not make any ED visits and only 2 had 1 or more visits, whereas the reverse is true of the control group (data are shown in Table 1).

Number of ED visits: TeleWound patients are much less likely to use the ED than the control group, and the TeleWound group uses the ED less frequently. The TeleWound program intervention is positively related to absence of ED use, and negatively related to number of ED visits. These effects increase the longer pa-

Table 2. Outpatient Clinic Visits by TeleWound and Control Groups

	Total sample				Established patients only			
	Ten or fewer visits	*11 or more visits*	*Total*	*Mean*	*Ten or fewer visits*	*11 or more visits*	*Total*	*Mean*
TeleWound group	8	11	19	11.12	7	4	11	9.36
Control group	10	9	19	10.00	3	8	11	13.09
	$\chi^2 = 0.42$		$p = 0.746$		$\chi^2 = 2.93$		$p = 0.087$	

Table 3. Hospitalizations by TeleWound and Control Groups

	Total sample						*Established patients only*			
	No. Hospitalizations	*1–3 Hospitalizations*	*4–6 Hospitalizations*	*7 or More Hospitalizations*	*Total*	*Mean*	*0–3 Hospitalizations*	*4 or More Hospitalizations*	*Total*	*Mean*
TeleWound group	5	8	6	0	19	2.63	9	2	11	1.91
Control group	1	6	7	5	19	4.89	2	9	11	6.09
		$\chi^2 = 8.03$		$p = 0.045$				$\chi^2 = 8.91$		$p = 0.003$

Table 4. Length of Hospital Stay by TeleWound and Control Groups for Both 2004 and 2005

	Total sample				*Established patients only*			
	5 Days or less	*6 or more days*	*Total*	*Mean*	*6 Days or less*	*7 Days or more*	*Total*	*Mean*
TeleWound group	10	9	19	21.00	7	4	11	12.45
Control group	9	16	19	38.53	1	10	11	48.18
	$\chi^2 = 5.73$		$p = 0.017$		$\chi^2 = 7.07$		$p = 0.008$	

tients participate in the program. The differences between the two groups are statistically significant.

Outpatient visits

The TeleWound group made more outpatient visits than the control group (a total of 211 versus 190, or an average of 11.12 versus 10.0). However, these differences were not statistically significant as measure by the χ^2. Among established patients, the TeleWound group made fewer outpatient visits than did the control group. Again, the differences were not statistically significant. Hence, this part of the hypothesis was not substantiated by the data (Table 2).

Hospitalization

We employed 2 measures of hospitalization in this study: number of hospital admissions and length of stay. For the 2 years, the TeleWound group had a total of 50 admissions, whereas the number for the control group was nearly double (93 admissions). When examined in more detail (as shown in Table 3), no patients in the TeleWound group were admitted more than 6 times, as compared to 5 patients in the control group who were in the same category. The difference between the two groups is statistically significant. The established patients demonstrated this difference even more starkly. The average for the TeleWound group of established patients was nearly 2 admissions (1.91), whereas the average for the control group was more than threefold (6.09).

The same trends were observed with regards to length of stay (data shown in Table 4). The TeleWound group spent a total of 399 days in the hospital over the 2-year period, whereas the control group spent a total of 732 days. Stated differently, the patients in the TeleWound group spent an average of 21 days in the hospital during 2004 and 2005, whereas patients in the control group spent an average of 38.53 days in the hospital. Among established patients the difference was even more substantial. Seven of the 11 established patients in the TeleWound group spent 6 days or less in the hospital, as compared to only 1 in the control group with the same length of stay.

Clinic contacts

The program intervention was not designed to reduce contact between patients and clinicians; it was designed to reduce the cost of car-

Table 5. Outpatient Contacts by TeleWound and Control Groups

	Total sample				*Established patients only*			
	15 Contacts or fewer	*16 Contacts or more*	*Total*	*Mean*	*15 Contacts or fewer*	*16 Contacts or more*	*Total*	*Mean*
TeleWound group	8	11	19	16.11	5	6	11	14.73
Control group	11	8	19	13.63	4	7	11	17.00
	$\chi^2 = 0.95$		$p = 0.330$		$\chi^2 = 0.19$		$p = 0.665$	

Table 6. Outpatient Visit Acuity by TeleWound and Control Groups Medium Acuity Only

	Total sample				Established patients only			
	5 Visits or fewer	*6 Visits or more*	*Total*	*Mean*	*5 Visits or fewer*	*6 Visits or more*	*Total*	*Mean*
TeleWound group	4	13	19	6.21	3	7	11	5.64
Control group	9	5	19	4.53	5	4	11	5.45
	$\chi^2 = 5.24$		$p = 0.022$		$\chi^2 = 0.44$		$p = 0.508$	

ing for complex, chronic wounds. Indeed, all patients with chronic wounds (in both the TeleWound and control groups) were encouraged to contact the clinic when they had a problem or a question, and they were not charged for such contacts. We wanted to ascertain whether the 2 groups differed in terms of this variable. The findings confirmed the similarity of the 2 groups, as shown in Table 5.

Visit acuity

We assessed differences in visits between the TeleWound and control groups at 3 levels: high, medium, and low acuity. No differences between the 2 groups were observed among those having either high- or low-acuity visits. On the other hand, there were significant differences among those having medium-acuity visits. This finding implies that the program had no effect on the intensity of care during outpatient visits when the patients had either serious or small problems. It did make a difference for those in between. However, that effect disappeared among established patients. (Data shown for medium acuity only, Table 6)

Financial outcomes

In order to assess financial outcomes, we examined "all cost data" generated by study patients for calendar years 2004 and 2005, for both groups: TeleWound and control. "All cost data" is defined as any cost related to any and

Table 7. Total Financial Outcomes

n = *19*		*All financial data*				*Wound-related care only*			
	Patient type	*Total direct costs*	*Direct costs per patient*	*Total indirect costs*	*Indirect costs per patient*	*Total direct costs*	*Direct costs per patient*	*Total indirect costs*	*Indirect costs per patient*
Inpatient									
Year 04	TeleWound	433,970	22,841	242,874	12,783	61,506	3,237	34,100	1,795
Year 05	TeleWound	122,011	6,422	64,323	3,385	30,677	1,615	16,299	858
Total		$555,981	$29,262	$307,197	$16,168	$92,183	$4,852	$50,399	$2,653
Year 04	Non-TW	459,809	24,200	272,055	14,319	193,311	10,174	114,757	6,040
Year 05	Non-TW	425,687	22,405	237,289	12,489	106,265	5,593	58,122	3,059
Total		$885,496	$46,605	$509,344	$26,808	$299,576	$15,767	$172,879	$9,099
Outpatient									
Year 04	TeleWound	118,257	6,224	55,052	2,897	26,826	1,412	15,343	808
Year 05	TeleWound	121,752	6,408	52,389	2,757	11,746	618	6,671	351
Total		$240,009	$12,632	$107,441	$5,654	$38,572	$2,030	$22,014	$1,159
Year 04	Non-TW	43,575	2,293	24,959	1,314	18,670	983	11,345	597
Year 05	Non-TW	28,386	1,494	16,863	888	8,818	464	6,416	338
Total		$71,961	$3,787	$41,822	$2,202	$27,488	$1,447	$17,761	$935

all care these patients received at our health system, both inpatient and outpatient, regardless of whether or not the care was wound related. Direct costs are those costs driven by and directly attributable to each individual patient. They are variable in nature, since they are generated by rendering care to that individual, per episode of care. Direct costs are essentially "controllable." On the other hand, indirect costs are those costs spread across all patients, and are fixed in nature.

Data shown in Table 7 reveal that both indirect and direct inpatient costs were considerably less for the TeleWound group as compared to the control group. Inpatient costs also decreased from year 1 to year 2 for the TeleWound group from $22,481 to $6,422, whereas they stayed relatively stable from year to year for the control group, from $24,200 to $22,405. On the other hand, outpatient direct costs for the TeleWound group remained almost the same, $6,224 versus $6,408, and it declined for the control group from $2,293 to $1,494. The reason for the decline among the control group is not clear.

We also examined cost data related to wound management only, including services provided by any department or service unit within the health system. In all likelihood, we were able to account for all costs because all these patients were regular clients of the health system. However, we cannot be certain that no other costs were incurred if other providers were used. These data are also presented in Table 7.

All costs incurred for wound management only declined for both groups. However, the TeleWound group experienced a slightly greater decline. On the inpatient side, the TeleWound group experienced a decline from an average of $3,237 to $1,615, whereas the average for the control group declined from $10,174 to $5,593. The most notable differential exists between the total direct inpatient costs for the TeleWound group versus the control group—the difference is staggering ($92,183 compared to $299,576, respectively). Similar trends of decline are observed for outpatient costs.

If we consider the total inpatient and outpatient costs for the 2 groups, the advantage is still held by the TeleWound group for both types of costs. The TeleWound group incurred an average total direct (inpatient plus outpatient) cost of $6,882, and the control group incurred an average of $17,214. For total indirect (inpatient and outpatient) costs, the TeleWound group incurred an average of $3,811,

Table 8. Financial Outcomes for Established Patients Only

n = 11		*All financial data*				*Wound-related care only*			
	Patient type	*Total direct costs*	*Direct costs per patient*	*Total indirect costs*	*Indirect costs per patient*	*Total direct costs*	*Direct costs per patient*	*Total indirect costs*	*Indirect costs per patient*
Inpatient									
Year 04	TeleWound	198,518	18,047	109,778	9,980	30,003	2,728	16,325	1,484
Year 05	TeleWound	17,291	1,572	9,068	824	16,105	1,464	8,343	758
Total		$215,809	$19,619	$118,846	$10,804	$46,108	$4,192	$24,668	$2,242
Year 04	Non-TW	226,320	20,575	128,731	11,70	110,906	10,082	62,879	5,716
Year 05	Non-TW	385,392	35,036	214,707	19,519	95,181	8,653	52,645	4,786
Total		$611,712	$55,610	$343,438	$31,222	$206,087	$18,735	$115,524	$10,502
Outpatient									
Year 04	TeleWound	50,572	4,597	16,577	1,507	11,814	1,074	7,217	656
Year 05	TeleWound	25,406	2,310	12,685	1,153	6,049	550	3,475	316
Total		$75,978	$6,907	$29,262	$2,660	$17,863	$1,624	$10,692	$972
Year 04	Non-TW	34,035	3,094	19,542	1,777	16,754	1,523	10,220	929
Year 05	Non-TW	20,057	1,823	12,129	1,103	7,179	653	5,368	488
Total		$54,092	$4,917	$31,671	$2,880	$23,933	$2,176	$15,588	$1,417

and the non-TeleWound group incurred an average of $10,034. For both types of costs, the advantage lies with the TeleWound group.

Finally, we examined the financial outcomes for the established patients only. This is the subset of 11 established cases in the TeleWound group who were also matched with the control group. We examined total financial outcomes related to all care received at the health system as well as financial outcomes related to wound management only. It may be recalled that we expected the established patients to show a greater effect from the intervention.

Among established TeleWound patients, the average inpatient direct cost for all care declined from $18,047 in 2004 to $1,572 in 2005, whereas the control group experienced a substantial increase from $20,575 in 2004 to $35,036 in 2005. The decline in average cost of all outpatient care was relatively similar between the TeleWound and control groups (as shown in Table 8). However, overall, the TeleWound group had a substantial advantage over the control group. The comparisons in their total costs for the 2 years combined are as follows: The total average direct cost (inpatient and outpatient) for the TeleWound group was $26,526 and $60,528 for the control group. Average indirect costs were $2,748 for the TeleWound group and $34,101 for the control group.

These differences become even more dramatic when we examine wound management costs only. Average inpatient direct costs for the TeleWound group were $4,192 for both years, whereas the control group incurred an average of $18,735 per patient. Indirect costs were also markedly different: the TeleWound group incurred an average of $2,242 per patient, and the control group incurred an average cost of $10,502.

If we consider the total inpatient and outpatient costs for the 2 groups, a clear advantage is held by the TeleWound group for both types of costs. The TeleWound group incurred an average total direct (inpatient plus outpatient) cost of $5,816, and the control group incurred an average of $20,911. For total indirect (inpatient and outpatient) costs, the TeleWound group incurred an average of $3,215 and the non-TeleWound group incurred an average of $11,919.

CONCLUSION

The urgent needs of our aging population, in particular, nursing home residents, prisoners, and Veterans Hospital patients, provide strong incentives to develop innovative methods to deliver clinically appropriate and cost-effective wound care. Despite the proliferation of wound care centers, often patients with pressure ulcers and associated multiple comorbidities are poorly suited for management at these sites. Hence, we investigated the appropriateness of telemedicine for in-home wound management. Telemedicine is a particularly attractive strategy for those with spinal cord injuries, because their transportation is always difficult, time consuming, and expensive.

The leading hypothesis for this study posited that subjects managed with a combination of traditional wound care plus telemedicine would have superior financial outcomes over subjects managed with a traditional "only see the doctor in person" approach. We utilized a case-controlled study design in which patients in the control group were carefully matched for wound type, comorbidities, distance of residence to clinic, and payer mix. Primary outcome variables included services provided and financial performance. The subjects were followed up between 12 and 24 months. A single provider managed all the outpatient visits and attended all of the telemedicine sessions to evaluate the wounds.

The results of this clinical study are striking and provide strong encouragement that a single provider can affect positive clinical and financial outcomes using a telemedicine wound care program. For example, the telemedicine group had 50% fewer emergency department visits than the control group. Furthermore, the subjects in the telemedicine group averaged less than 1 emergency department visit each, during the 2-year period of the study. This is a particularly important statistic because presentation in an emergency room with a pressure ulcer and fever virtually guarantees hospital admission.

The analysis of the data provides insight into the impact of an emergency visit on hospitalization. In the telemedicine group, hospitalization occurred half as many times as in the control group. Although all subjects in the trial

required hospitalization, the incidence was threefold higher in the control group. The most telling statistic is the length of stay during hospitalization because it is an indicator of acuity of illness and is a significant driver of cost. There were 54% fewer days of hospitalization in the telemedicine group versus the controls. Thus, the data show that telemedicine wound care lowers the admission rate as well as actual length of stay for subjects with pressure ulcers. Clearly, fewer hospital days would increase revenue margins for hospitals using the prospective payment system for pressure ulcers.

Good management of subjects in the trial came at a small price. The paradigm shift from on-site clinic care to remote telemedicine visits required that the telemedicine group be "seen" more frequently than the controls. Although the difference was not statistically significant, it does imply more oversight from the clinician because the telemedicine group was evaluated weekly via digital photography and nursing assessments. This factor led to the success of the TeleWound program as a credible modality to manage pressure ulcers at a lower cost and possibly better health outcomes. Cost savings were even more dramatic on the inpatient side.

The impact factor of this study will be a function of technology use by clinicians who manage wounds. Surgeons are particularly well-suited for this task because they aggressively debride wounds and have short segments of time to devote to reviewing telemedicine photos and nursing assessments. Hospitals will profit immensely from this approach because hospital beds are at a premium, and their goals are to maximize revenue, access, and quality of care. The next step in this process is to integrate the model into daily practice at bellwether medical centers to determine programmatic effectiveness in larger clinical arenas.

REFERENCES

1. Ablaza V, Fisher J. Telemedicine and Wound Care Management. Available from http://www.rubic.com/articles/article2.html; posted 1998. (Last accessed December **2006.**)
2. Available at http://www.criticalcaresystems.com/woundcare/patients/overview.html (Last accessed December **2006.**)
3. Beckrich K, Aronovitch SA. Hospital-acquired pressure ulcers: A comparison of costs in medical vs. surgical patients. *Nurs Econ* **1999;**17:263–271.
4. Allman, RN, Laprade CA, Noel LB, et al. Pressure sores among hospitalized patients. *Ann Intern Med* **1986;**105:337–342.
5. Kerstein M, Gemmen E, van Rijswijk L. Cost and cost effectiveness of venous and pressure ulcer protocols of care. *Dis Manage Health Outcomes* **2001;**9:651–663.
6. Alterescu V. The financial costs of inpatient pressure ulcers to an acute care facility. *Decubitus* **1989;**2:14–23.
7. Whittington K, Patrick M, Roberts J. A national study of pressure ulcer prevalence and incidence in acute care hospitals. *JWCON* **2000;**27(4):209–215.
8. Thomas DR. Pressure ulcers. In: Cassel CK, Cohen HJ, Larson EB, Meier DE, Resnick NM, Rubenstein LZ, Sorenson LB, eds. *Geriatric Medicine* 3rd ed. New York: Springer, **1997:**767–785.
9. Making health care safer: A critical analysis of patient safety practices. Evidence report/technology assessment: Number 43. AHRQ publication no. 01-E058, July **2001.** Rockville, MD: Agency for Healthcare Research and Quality. Available at: http://www.ahrq.gov/clinic/ptsafety/ (Last accessed December **2006.**)
10. Agency for Health Care Policy and Research (AHCPR) Panel for the Prediction and Prevention of Pressure Ulcers in Adults. Pressure ulcers in adults: Prediction and prevention. Clinical practice guideline, number 3, AHCPR publication no. 92-0047. Rockville, MD: Agency for Health Care Policy Research, Public Health Service, U.S. Department of Health and Human Services, May **1992.**
11. Allman RM. Pressure ulcers among the elderly. *N Engl J Med* **1989;**320:850.
12. Ablaza V, Fisher J. Wound care via telemedicine: The wave of the future. Date posted 1999. Available at http://www.rubic.com/articles/article1/html (Last accessed December **2006.**)
13. Berlowitz DR, Wilking SVB. The short-term outcome of pressure sores. *J Am Geriatric Soc* **1990;**38:748–752.
14. Salyer J. Wound management in the home; factors influencing healing. *Home Health Care Nurse* **1988;**6: 24–33.
15. Kinsella A. Internet-based wound care. *Home Care Automation Report* **2002;**7–8.
16. Piper B. Wound prevalence, types and treatment in home care. *Advances in Wound Care* **1999.** Available at http://www.findarticles.com/p/articles/mi_qa3964/is_1999904/ai_n8841992/print (Last accessed December **2006.**)
17. Mauser E. Medicare home health initiative: Current activities and future direction. *Health Care Financing Rev* **1997;**18:275–291.
18. George J. Cuts hit home health hard. *Philadelphia Business J* **1998;**3:42.
19. Dansky K, Palmer L, Shea D, Bowles K. Cost analysis of telehomecare. *Telemed J e-Health* **2001;**7(3): 225–232.
20. Wooton R, Dimmick S, Kvedar J. *Home telehealth: Connecting care within the community.* London: Royal Society of Medicine Press Ltd, **2006.**

21. Kaufman MW. The WOC nurse: Economic, quality of life, and legal benefits. *Dermatol Nurs* **2001;**9:153–159.
22. Bourne V. Community nurses' view of leg ulcer treatment. *Prof Nurse* **1999;**15:21–24.
23. Flanagan N, Rotchell L, Fletcher J. Community nurses', home carers', and patients' perceptions of factors affecting venous leg ulcer recurrence and management of services. *J Nurs Manag* **2001;**9:153–159.
24. Arnold N, Weir D. Retrospective analysis of healing in wounds cared for by ET nurses versus staff nurses in a home setting. *J Wound Ostomy Continence Nurs* **1994;**21:156–160.

Address reprint requests to:
Noura Bashshur, M.H.S.A.
Department of Plastic Surgery
University of Michigan Health System
Domino's Farms
Lobby A, P.O. Box 441
24 Frank Lloyd Wright Drive
Ann Arbor, MI 48106

E-mail: nourab@umich.edu