FEATURE

Multidisciplinary Approaches to the Pressure Ulcer Problem

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Multiple factors affect the specific condition and overall clinical profile of individuals at risk for chronic wounds. The complexity of the pressure ulcer problem lends itself to the application of the National Institute of Health Roadmap Initiative that encourages interdisciplinary research and new organizational models. An overview of research studies relevant to telemedicine and neuromuscular electrical stimulation in the care and prevention of pressure ulcers as well as preliminary results of an innovative multidisciplinary skin care team approach to the primary and tertiary prevention of pressure ulcers are encouraging. The team's pilot study results indicate that patients are satisfied with telehealth provision of care; however, literature and experience also suggest that discrepancies in the inter-rater assessment of wounds using digital photography remain, particularly with regard to wound dimension variables assessed ($P < 0.01$). In another endeavor, the skin care team developed a Longitudinal Analysis with Self-Registration statistical algorithm to assess the effects of electrical stimulation; in a preliminary study, this tool documented improvement in gluteus maximus health and resultant ability to withstand pressure. As the number of groups pursuing multidisciplinary research and care increases, so, too, will the evidence base required to address these common, and complex, chronic wounds.

KEYWORDS: pressure ulcers, spinal cord injury, research, telehealth, electrical stimulation

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The challenge of preventing chronic wounds is due in no small part to multiple factors affecting both the specific condition and overall clinical profile of individuals at risk. Development of a chronic, non-healing wound has a profoundly detrimental impact on the care and rehabilitation of affected individuals.[1,2] The continued high incidence of chronic wounds, including recurrent wounds, demonstrates the need to incorporate research methodologies into wound care programs. New approaches to primary and tertiary prevention such as those presented in this paper remain critically important.

The multifactorial nature of chronic wound care strongly implies that finding a universal panacea is unlikely. But the "continuum of research" — from basic science investigations into mechanisms of tissue damage to clinical trials of new therapies — is promising. Relevant studies should address common underlying principles. First and foremost, researchers always should be mindful that the ultimate goal is to

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improve the care of individuals with or at risk for chronic wounds.

Multidisciplinary teams are key to addressing this complex multifactorial problem. More specifically, scientists and engineers must work closely with physicians, nurses, therapists, and other end users, including patients and caregivers, to ensure the goal of research is to meet clinical needs. Novel solutions can be achieved by addressing clinical issues from the multiple perspectives of researchers with diverse backgrounds, some of whom (such as electrical engineers and polymer scientists) previously may not have been involved in clinically orientated research. Different approaches should be complementary in order to attain the common goal.

This paper reviews published research studies and the pilot study results of programs in one facility that embody a multidisciplinary approach and seek to 1) improve the delivery of clinical care to individuals with chronic wounds using telehealth and 2) prevent pressure ulcer development in high-risk patients by employing neuromuscular electrical stimulation. The focus of this paper is the development of novel approaches and evaluation of their efficacy.

Delivery of Clinical Care: Challenges and New Approaches

Chronic non-healing wounds are a major clinical challenge in the long-term care of many patients with physical impairment. Individuals with spinal cord injury (SCI) have been reported to have a 33% prevalence of pressure ulcers.[3] A multicenter study of pressure ulcer incidence in SCI conducted across the USA Model Spinal Cord Injury System[4] found a significant trend toward increasing pressure ulcer prevalence over recent years (1994 to 2002 versus 1984 to 1993). Among patients with diabetes, the lifetime incidence of chronic ulcers may be as high as 25%.[5]

Chronic wounds cause significant pain and disability for affected individuals. The population at risk for chronic wounds is increasing due to changing population demographics. In addition, costs for many aspects of clinical care are rising at a pace above the rate of inflation. Although information on clinical treatment costs is limited, recently reported overall costs of hospital-acquired pressure ulcers in the US were in excess of $1.3 billion per annum.[6] Patients with chronic wounds often have multiple health problems. The current standard of care for a chronic wound involves extensive clinical attention over extended periods of time. Patients may be followed through frequent outpatient clinic visits or hospital admission for inpatient care may be required, limiting mobility for prolonged periods of time. Securing transportation for repeated outpatient visits may be difficult and time-consuming, particularly if an individual has reduced independent mobility. Patients also may be unable or unwilling to attend inpatient treatment. In these cases, the ability to treat a chronic wound such as a pressure ulcer at home or at a local medical facility is a desirable option. A major goal of tertiary prevention in wound care is to reduce the incidence of recurrent chronic wounds to subsequently reduce the long-term negative impact on quality of life. Novel methods for delivering clinical care have the potential to positively affect the cost of wound care and to improve quality of life for the patient; however, much research is needed in this growing field.

A New Approach: Telehealth

As technological advances help facilitate its development, telecommunications in healthcare has become increasingly widespread over the past decade.[7] Relevant technology has matured but while it has become both readily available and user-friendly, more

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KEY POINTS

- While the importance of providing multidisciplinary care for patients with chronic wounds is frequently discussed, similar approaches to research generally receive less attention.
- In this overview, the authors provide examples and preliminary outcomes of care utilizing the expertise and talents of a wide variety of professionals.
- Complex problems require the multifaceted approach multidisciplinary patient care research teams can offer.

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research is needed in order to establish the most effective applications across the whole medical field.[8] Clinical researchers are investigating telehealth's potential to improve the care and prevention of wounds via increased access for end-users and decreased costs for healthcare systems.

The Veterans Health Administration (VHA) is one of the largest healthcare organizations in the US. It has a well-established, integrated electronic health record system and serves a large, geographically diverse patient population, many of whom have chronic healthcare issues. Specialized clinical centers often serve veterans who require ongoing care and live remote from the medical facility. The VHA has initiated an organization-wide telehealth program under the auspices of the Office of Care Coordination. Components include the care of veterans at home (home telehealth) and inter-facility videoconferencing (clinic telehealth). Either mode of telehealth intervention can be delivered in real-time mode or store-and-forward mode. The impact of these clinical care initiatives in the field of wound care and early intervention are being investigated by SCI units within the VHA. These studies are presented here for the first time.

The VA Healthcare System of Ohio (VISN10) has initiated a program of studies to evaluate both home and clinic telehealth for the specialized care of veterans with SCI. The implementation of wound care and wheelchair consultation telehealth clinics was supported by the VISN10 Emerging Technology program. The clinics include integral research components to evaluate efficacy and user satisfaction. The clinic network was set up using a hub-and-spoke arrangement, with the Cleveland SCI Unit acting as the hub. The central (hub) team is a multidisciplinary group led by a SCI specialist physician; it also includes a nurse, an occupational and/or physical therapist, biomedical engineer, epidemiologist/statistician, and administrative support. The team members at the remote sites are not required to be experts in SCI care and comprise a clinician, nurse, and occupational and/or physical therapist.

Pressure ulcer care is provided by inter-facility teleconsultation from the remote sites to the central team. Both real-time and store-and-forward capabilities are available. The consultation can either be performed as a real-time assessment of the patient's pressure ulcers during videoconference or stored digital images can be reviewed by central team personnel at videoconference following the assessment. The central team makes recommendations for future prevention and treatment that can be implemented at the remote sites without requiring the patient to travel for further appointments.

The VISN10 wheelchair telehealth clinics also address pressure ulcer prevention. The user's seating posture and the wheelchair configuration can be viewed directly during real-time videoconferencing; subsequently, recommendations or wheelchair prescription, pressure-relief method, and postural adjustments are provided.

Preliminary evaluation by questionnaire of end-user satisfaction with this novel approach to clinical care indicates that patients are more satisfied with telehealth than with regular visits because of the reduced need for extended travel. Patients do not report feeling that quality of care was compromised by "seeing" clinicians remotely and they preferred the telehealth conference over local clinic visits for evaluation. The analysis of predefined outcomes measures, such as participant satisfaction and wound appearance, provides both qualitative and quantitative evidence that telehealth clinics represent a positive experience for patients and may decrease costs for healthcare systems.

Home telehealth for wound care also has been investigated by VA Medical Centers (VAMC). A multidisciplinary clinical team at the San Juan, Puerto Rico VAMC provided real-time telehealth interventions to assess need, coordinate care, and provide patient education. The patient population included veterans with SCI who had been diagnosed with moderate to severe pressure ulcers. The outcomes measures of this clinical pilot study were reported approximately 2 years after the team approach was initiated and included multiple clinical variables and healthcare system utilization. Effective wound healing was reported together with a marked decrease in the number of hospital admissions.

Monitoring pressure ulcers and treatment progress is an essential component of any home-based wound care program. Advances in digital technology have

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made high-resolution digital cameras readily available and relatively inexpensive. Mixed results in some studies comparing the reliability of digital photography in wound assessment were attributed to variation in training and experience of the raters, as well as the wide range of wound types included in the analyses.[9]

Pilot study. The Skin Care Research Team (SCRT) at the Cleveland VAMC conducted a pilot study[10] to assess the reliability of digital photography (a store-and forward application of telehealth) for wound evaluation. The objective was to compare the accuracy and reliability of digital images to in-person evaluation. The study protocol was approved by the Institutional Review Board (IRB). Raters with similar experience and training evaluated 31 Stage III and Stage IV pressure ulcers in a group of 15 SCI inpatients. Digital wound images were obtained using a standardized clinical protocol. In-person assessments were completed within 24 hours of digital imaging.

Six wound variables were defined to describe wound dimensions (length and width) and the appearance of the wound bed, wound exudate, and periwound area. Outcomes measures were categorized and Kappa statistics applied to compare in-person and photograph wound assessments. A substantial agreement (Kappa <0.06) between wound bed description and periwound tissue color was found, both between raters and methods. Exudate type and color and periwound tissue description showed fair agreement (Kappa <0.45). Wound dimension variables showed significant differences (P <0.01) for both inter-rater and inter-method comparisons. Results demonstrated a persistent variation between raters despite similar training and experience — most likely, to be a reflection of the subjective nature of wound assessment. Additionally, variations in wound assessment between methods were noted, primarily due to variability in wound dimensions and wound drainage. The impact on clinical care occurring as a result of such observed differences was not assessed in this pilot study and a larger study to confirm the observed results and the influence of variation in wound assessment on pressure ulcer treatment and outcome is indicated.

Digital photos to monitor chronic wounds have the potential to be used to reliably and accurately assist in home-based treatment protocols. Routine digital imaging of wounds could be used effectively both to monitor patient cooperation and to enhance access to care with the potential to improve clinical outcomes but improved wound measurement techniques are needed.

Early Intervention: Pressure Ulcer Prevention using Electrical Stimulation

Early intervention — a primary approach — is the prevention of pressure ulcers before they start to develop. Improving external pressure distribution by using advanced cushions has been a focus of many strategies to reduce pressure ulcer incidence, as have rehabilitation program efforts to educate high-risk patients on the importance of pressure-relief measures. However, several important factors in pressure ulcer development are related to intrinsic changes that place the patient at higher risk. For example, severe muscle atrophy related to disuse reduces effective soft tissue coverage and increases interface pressures over bony prominences. Regional blood flow may be impaired due to decreased vascularization and reduced patency of the remaining vascular supply.[11,12]

Neuromuscular electrical stimulation (NMES) can produce changes in regularly stimulated muscles in response to repeated muscular contractions. These changes may increase the health of the muscle and surrounding soft tissues. Several authors[13-15] have reported on improvements in factors related to tissue health as a side effect of using electrical stimulation for functional applications, such as standing or systemic exercise. Taylor et al[13] found that patients with mid to low thoracic spinal cord lesions who received surface electrical stimulation (SES) for muscle conditioning during training for use of their Odstock functional electrical stimulation (FES) standing system exhibited significant increases in thigh blood flow and quadricep muscle depth, both positive changes in regional tissue health. Similarly, in a clinical pilot study, Scremin et al[14] found significant increases in muscle cross-sectional area in individuals with SCI who followed an exercise regimen incorporating SES with lower extremity cycling.

Few studies have focused specifically on the use of electrical stimulation to improve tissue health. In a feasibility study, Levine et al[15] reported that surface

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stimulation of the gluteus maximus in SCI subjects increased regional blood flow but the effect was small in the unconditioned atrophied muscles assessed.

Current study. The Cleveland VAMC's SCRT is investigating the long-term use of NMES to improve tissue health of people with SCI.[16] The GSTIM system, developed at the Cleveland Functional Electrical Stimulation (FES) Center uses implanted percutaneous electrodes and an external stimulator (NeuroControl Corporation, Cleveland, Ohio). Electrodes are implanted bilaterally in the gluteus maximus to enable side-to-side weight shifting induced by electrically stimulated muscle contraction. The primary hypothesis directing this research was that exercise of paralyzed gluteal muscles using the GSTIM system would improve the intrinsic health of the tissue at the seating interface. The secondary hypothesis was that dynamic weight shifting would vary seated posture and pressure distributions at the seating interface and augment the efficacy of conventional pressure-relief maneuvers. Multiple outcomes measures included regional tissue gas levels, gluteal muscle thickness, and seating interface pressures.

In order to determine the sustained effects of long-term use of the GSTIM system, repeated measurements were taken over a period of several months and years during each individual's participation in the study (from 6 months to 7 years). Seating posture was assessed during quiet sitting (static mode) and application of alternating gluteal NMES (dynamic mode). The investigators found that a valid quantitative method to describe the statistically and clinically significant changes in data from seating interface pressure distributions over time was needed. Another consideration was that the subject needed to sit the same way at each assessment in order for valid comparisons to be made; exactly reproducing the sitting posture with months between laboratory visits was found to be impractical. Therefore, spatial registration of the pressure maps was needed to ensure they were aligned before analysis — ie, the midline and orientation of the pressure maps were aligned in space for all assessments. This allowed seating interface pressure distributions between repeated assessments to be directly compared, even those obtained at long-time intervals. In addition, this study looked for changes in the weight-shifting effects of dynamic stimulation. Temporal registration was required for dynamic mode data sets to make sure that comparisons were synchronous — ie, to ensure that comparisons were made between pressure maps obtained at the same phase of stimulation, such as when right gluteal stimulation is applied.

In order to extract the information required from the massive amount of data obtained, the SCRT worked in collaboration with statistical and imaging experts to develop the Longitudinal Analysis with Self-Registration (LASR) statistical algorithm.[17] The specific objective was to develop a tool that would enable determination of locations of statistically significant pressure reductions over the entire pressure map area without the need for predefinition of areas of interest by the observer. In other words, the LASR tool automatically looks at the whole pressure map and objectively determines differences for all points rather than having the observer subjectively select the few points that may be considered to be in a region of interest, such as the ischia or sacrum. The multistage LASR algorithm includes both spatial and temporal self-registration of pressure maps to allow intra-subject comparison of repeated assessments over time. The LASR output map gives a graphical representation of statistically significant pressure changes across the entire mapped region. Examples of LASR output maps and movies (for dynamic stimulation assessments) can be found at http://stat.case.edu/lasr/.

The LASR tool showed positive changes in pressure distribution following long-term use of the GSTIM system. A recent case study[16] of an individual with chronic SCI found that increased gluteal thickness and tissue gas levels were maintained with routine daily use of the GSTIM system for more than 7 years.

These findings imply that the GSTIM system may provide an adjunctive pressure-relief regimen in high-risk individuals that can reduce the risk of pressure ulcer development, subsequently improving the overall quality of life for users. Further long-term study of gluteal stimulation is required to confirm that the positive effects of regular NMES use can be achieved in individuals without SCI who are at high risk for pressure ulcer development.

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In many clinical programs, interface pressure mapping is increasingly used as an assessment tool in wheelchair and seating clinics. Clients with complex seating needs and those requiring repeated evaluations routinely receive interface pressure assessments as part of their posture and function review. Currently available systems have limited capability for objective comparison of pressure map data sets obtained over time and methods to determine the significance of any observed differences via statistical analysis are non-existent. The LASR tool developed for this pilot clinical research study has the potential to enhance the information retrieved in the broader setting of clinical practice.

The Importance of Multidisciplinary Wound Care Research

As the problems to be addressed become more complex and investigative tools become more sophisticated, the future of scientific research and evidence-based practice increasingly will involve multidisciplinary teams. In clinical research and, more specifically, in the field of wound care research, multidisciplinary teams can optimize the pathway for basic laboratory and pilot clinical studies to effectively translate research into standard clinical practice. In the authors' opinion, these teams and programs enable current treatment techniques and procedures to be validated and novel methods to be explored.

This approach was initiated by the Wound Healing Research Unit (WHRU) at Cardiff University, Wales in 1991. The WHRU has a multidisciplinary research team, led by Keith Harding, MB, MRCGP, FRCS, and serves as an internationally renowned clinical, scientific, and educational wound healing resource. The WHRU facilitates interactions between researchers, clinicians, and commercial entities to improve the care of people with complicated wounds through clinical trials and investigation of multiple aspects of wound healing. Started in 2002, the Program for the Advancement of Chronic Wound Care (PACWC) at the Yale School of Nursing is a commercially sponsored program that focuses on advancing healthcare practices research in chronic wound care. The program investigators, led by Katherine Jones, RN, PhD, FAAN, include nurse-researchers, an epidemiologist, and a biostatistician. The PACWC's mission is to act as a repository for the collection, creation, and dissemination of information on best practices in wound care. Other programs, such as the Comprehensive Wound Center (CWC) at Ohio State University, led by Chandan Sen, PhD, focus on wound therapy research — eg, oxygenation therapy.

Cleveland VAMC SCRT's multidisciplinary team is led by a physician-researcher, Chester H. Ho, MD, and a biomedical engineer, Kath Bogie, DPhil. Team personnel include clinical and engineering staff together with an epidemiologist and statistician. Team members also are affiliated with the VA Centers of Excellence in both Functional Electrical Stimulation (FESC) and Advanced Platform Technology (APTC). These affiliations further foster interdisciplinary collaborations. The SCRT is involved in research studies to investigate novel methods and approaches to the treatment and prevention of chronic wounds.

The efforts of these groups are strongly supported by the NIH Roadmap Initiative[18] that encourages researchers to "move beyond the confines of their own discipline and explore new organizational models for team science." Wound care is well recognized as a major and multifactorial clinical problem that is likely to become increasingly prevalent as populations age. Many fields not traditionally associated with clinical care are currently developing devices, materials, and methodologies that could impact clinical care in the future. The goal of multidisciplinary research teams must be to explore and develop new options and to work together to enable synergistic approaches to improve the overall quality of life for individuals with or at risk for chronic wounds.

Conclusion

The further development of evidence-based medicine, especially in wound care, is likely to be provided by multidisciplinary teams willing to examine, address, and implement multifactorial solutions. One forward-thinking facility utilized an evidence-based approach to wound care by creating a skin care team telehealth as a pathway for wound care. The use of electrical stimulation to prevent pressure ulcers is also being investigated. Both efforts have yielded positive outcomes that will be studied further. While the initial

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focus of this work has been on efficacy, considerations such as cost effectiveness are also important. Expanding use of new models of clinical care and technology to widespread clinical use are further challenges in the continuum of research and require further multidisciplinary team approaches for success.

Advancing technology holds the promise of proliferating improved care techniques and approaches but only by obtaining and publishing the data needed to support anecdotal and hypothetical presumptions will the foundation for best practice be built. - OWM

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ERRATUM

In the article, Walker M, Bowler PG, Cochrane CA. *In vitro* studies to show sequestration of matrix metalloproteinases by silver-containing wound care products. *Ostomy Wound Manage* 2007;53(9):18-25, two tables were inadvertently included. These tables do not relate to the text; they are from another article. The Editors sincerely regret the error.

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