

Human Wound and Its Burden: Updated 2020 Compendium of Estimates

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Significance: Chronic wounds impact the quality of life (QoL) of nearly 2.5% of the total population in the United States and the management of wounds has a significant economic impact on health care. Given the aging population, the continued threat of diabetes and obesity worldwide, and the persistent problem of infection, it is expected that chronic wounds will continue to be a substantial clinical, social, and economic challenge. In 2020, the coronavirus disease (COVID) pandemic dramatically disrupted health care worldwide, including wound care. A chronic nonhealing wound (CNHW) is typically correlated with comorbidities such as diabetes, vascular deficits, hypertension, and chronic kidney disease. These risk factors make persons with CNHW at high risk for severe, sometimes lethal outcomes if infected with severe acute respiratory syndrome coronavirus 2 (pathogen causing COVID-19). The COVID-19 pandemic has impacted several aspects of the wound care continuum, including compliance with wound care visits, prompting alternative approaches (use of telemedicine and creation of videos to help with wound dressing changes among others), and encouraging a do-it-yourself wound dressing protocol and use of homemade remedies/substitutions.

Recent Advances: There is a developing interest in understanding how the social determinants of health impact the QoL and outcomes of wound care patients. Furthermore, addressing wound care in the light of the COVID-19 pandemic has highlighted the importance of telemedicine options in the continuum of care.

Future Directions: The economic, clinical, and social impact of wounds continues to rise and requires appropriate investment and a structured approach to wound care, education, and related research.

Keywords: human wound burden, COVID skin, military wounds, wound economics, wound care education

INTRODUCTION

CHRONIC WOUNDS IMPACT the health care system due to their increasing prevalence and cost. A 2018 retrospective analysis of the Medicare 5% data set for 2014 is currently the only available reviewed data set analyzing all wound categories, including acute and chronic wounds in the Medicare/Medicaid population.

Chronic, nonhealing wounds (CNHW) impact about 8.2 million Medicare beneficiaries.¹ Medicare cost projections for all wounds ranged from \$28.1 to \$96.8 billion, including costs for infection management, among which surgical wounds and diabetic ulcers were the most expensive to treat.¹ Furthermore, outpatient costs (\$9.9–\$35.8 billion) were higher than



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inpatient costs (\$5.0–\$24.3 billion), possibly because of an increase in outpatient wound treatments that are currently provided.¹ Despite these alarming statistics, the investment in research support is not on par with the threat of these debilitating health issues.^{2,3} Diabetic foot ulcers (DFUs) (30.5%), for example, have a comparable 5-year mortality rate to cancer (31%), which has remain unchanged since 2007 and yet funding for studies related to these life-threatening complications remains significantly lower than that for cancer research.⁴ The most common wounds are driven by metabolic disruptions (*e.g.*, diabetes), vascular deficits (*e.g.*, venous or arterial insufficiency), or mechanical impacts (*e.g.*, persistent/localized pressure), making CNHW patients particularly vulnerable to coronavirus disease (COVID)-19 infection. Prepandemic wound care model typically required visits to an outpatient facility (*e.g.*, wound care center), which in response to the pandemic were misclassified as nonessential or limited access. The direct consequence of such changes in health care is the disruption of continuity of wound care in several ways. However, such changes, while negatively impacting wound outcomes, may also have driven the development of a telemedicine-based focus for scheduled visits. In the long term, perhaps this mechanism could facilitate better compliance with treatment.⁵ This review is intended to update the previously published human wound burden review from 2019.⁶

CHRONIC WOUNDS

Wounds that have not progressed through the normal process of healing and are open for more than a month are classified as chronic wounds.⁷ There are varying etiologies of chronic wounds, all of which burden the health care system. Patients suffering from diabetes and obesity are at high risk of developing chronic wounds. Vast majority of people who have a prolonged open wound usually also have other major health conditions. The simultaneous presence of a combination of chronic diseases is called comorbidity. Chronic wounds are often complicated by comorbidities, making it difficult to track chronic wounds as a disease in itself.⁷ Research funding directly addressing the study of chronic wounds is disproportionately low compared to the overall impact of chronic wounds as a health care problem.^{8,9} The national Diabetic Foot Consortium (DFC) (National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK]; FOA: DK17-014; NOT-DK-18-017), aimed at bringing experts across the United States together to improve the care of

DFUs, was established in 2018 with the goal of building an infrastructure to facilitate high-quality clinical research on DFUs. Recent advances driven by the collaborative efforts of the consortium include the establishment of a functional infrastructure, including a data coordinating center, six clinical research units, and two biomarker analysis units. The DFC brings together experts from wound healing, vascular and plastic surgery, podiatry, dermatology, endocrinology, nursing, biostatistics, and social determinants of health (SDOH). This collaborative team developed protocols for the study of diabetic patients with foot ulcers and currently two protocols are actively recruiting patients to test. The first study to be rolled out was trans-epidermal water loss for recurrence prediction with Indiana University serving as a Biomarker Analysis Unit.¹⁰ The use of cellular myelocytomatosis and phosphorylated glucocorticoid receptor for healing prediction led by the University of Miami, is the second study. Other achievements include an Institutional Review Board-approved biorepository and three approved ancillary studies. These activities have continued even in the midst of the pandemic. The next phase of research development includes a plan for expanding the portfolio of validated DFU biomarkers that will impact clinical care and there is an active request for proposals currently open for submissions (RFA-DK-21-001).

Chronic wounds are mostly seen in the elderly population.^{1,11} In the United States, 3% of the population older than 65 years have open wounds. By the year 2060, the U.S. government estimates that the elderly population will be over 77 million,¹² suggesting that chronic wounds will continue to be an increasingly persistent problem in this population. Overall, in the United States ~2% of the total population are estimated to be affected by chronic wounds.¹³ The adverse impact of chronic wounds is felt worldwide.¹⁴

The global advanced wound care market is projected to reach \$18.7 billion by 2027, growing at a Compound Annual Growth Rate (CAGR) of 6.6% over the analysis period 2020–2027.¹⁵ China is projected to reach a market size of \$4 billion by the year 2027 with a CAGR of 10% and Japan and Canada are expected to make noteworthy growths at 3.6% and 5.8%, respectively, over the 2020–2027 period. In the global Antimicrobial Dressings segment, United States, Canada, Japan, China, and Europe are expected to primary drivers of estimated 7.2% CAGR. The combined efforts of these geographic regions are projected to increase the size of this market by \$1.8 billion by the close of the analysis period. In terms of growth, China is ex-

pected to be the leader. In Asia Pacific, Australia, India, and South Korea are predicted to drive an increase to \$2.6 billion by the year 2027.

WOUND CARE IN THE TIME OF COVID

Factors associated with poor prognosis from COVID-19 are similar to those that increase the risk for CNHW, including age (65 years and older) and underlying metabolic and physiological derangements such as chronic obstructive pulmonary disease, hypertension, malignancy, kidney malfunctions, diabetes, and obesity. Recent studies highlighted the risks presented to CHNW patients infected with COVID-19.¹⁶ There was a direct correlation between the presence of comorbidities and risk for admission to an intensive care unit (ICU), need for placement on a ventilator, or death.

Nonhealing wounds, left untreated and improperly managed, can result in significant medical issues, including infection, sepsis, the need for limb amputation, and even death. Importantly, the lack of regular wound care visits to a wound clinic could increase hospitalization rates by 20 times.¹⁷ Data suggest that patients who have regular wound clinic visits have 25% lower 30-day readmission rates and use 30% less acute care services if the wound care is effective. Additional data indicated a 40% decrease in wound center visits in 2020 compared to 2019.⁵ Some obvious consequences suggested by wound healers from the United States include the increased risk for pressure ulcers (PUs) (due to restricted mobility, implementation of proning, and use of medical devices to treat COVID-19-positive individuals resulting in PUs in atypical sites on the body), altered nutritional status that indirectly impacts wound healing progress, and the development of other skin issues (COVID skin) attributed to abnormal inflammatory and coagulatory responses following infection.¹⁸

Driven by the need for alternatives to in-person wound care visits, telemedicine options have exploded into the health care arena. Such visits are technology driven, requiring a virtual connection (phone/video calls or text messages). Frequent virtual visits with a provider could be through telehealth visits (require interactive audio and video communication in real time), virtual check-ins (brief communications using video/image, secure texts/emails, or a patient portal), and e-visits (patient-initiated, nonface-to-face communication through patient portals). Several studies have shown that telemedicine options are a cost-effective way to improve wound care outcomes and

promote patient compliance and satisfaction.¹⁶ The Centers for Medicare and Medicaid Services (CMS) recently updated the list of such services that are reimbursable.¹⁹

Problems associated with these options impact both the patient and provider. Key issues include the following: (1) technical barriers—access to internet (affecting quality, timeliness, and speed of communication), prowess to use computers (particularly in the aged population), (2) proper documentation of services provided and sharing with other providers, (3) privacy and security concerns (in the era of cyberhacking), and (4) the expectation of “unlimited” access to a provider.^{5,20}

The following questions arise: How would the changing practice impact the effectiveness of the treatment protocol? How would it impact the billing protocol—can a person be billed the same for an in-person visit versus a telemedicine visit? Given the prevalence of CNHW in lower socioeconomic demographics, is telemedicine even a practical solution to the problem? How about rural communities with limited to no internet connectivity, how can their treatment needs be met?

PRESSURE ULCERS

Pressure or pressure in combination with shear and/or friction promotes the development of localized ulcers called PUs. PU care is expensive and costs more than \$26.8 billion annually according to a recent study that used a Markov simulation to estimate cost for hospital-acquired staged PUs.^{21,22} Cost of individual patient care ranges from \$20,900 to \$151,700/PU. Apart from hospital costs, additional charge for food, transportation, and maintenance is ~\$43,180/year.²³ The COVID-19 pandemic increased vulnerabilities to PU prompting the National Pressure Injury Advisory Panel (NPIAP) to release resources to assist with responses.²⁴ In keeping with this, the European Pressure Ulcer Advisory Panel (EPUAP) Virtual Meeting held in September 2020 highlighted the link between the pathophysiology of COVID-19 and development of PUs including the impact of treatment modalities (proning and ventilator use) and the role of inflammation in this process.²⁵ The incidence of PU increases with age and is promoted by a lack of skin perfusion, moisture, and nutrition, all of which are factors in the COVID-19-driven increase in incidence of PUs.^{26–28} They are usually preventable, but they can be lethal if proper, timely care is not received.^{24,26,27} The global market for PU care products is expected to reach \$11.23 billion by 2026.²⁹

DIABETES

In 2020, the Centers for Disease Control and Prevention (CDC) updated the estimates of diabetes and its burden in the United States.³⁰ As of 2018, 34.2 million Americans (10.5% of the U.S. population) live with diabetes. Eighty-eight million have prediabetes, which if left untreated often leads to type 2 diabetes (T2D) within 5 years. Diabetes prevalence has been found to increase with age.³⁰ About 4.2% of adults 18–44 years of age, 17.5% of adults 45–64 years of age, and 26.8% of those 65 years of age and older have diabetes.³⁰ Health expenditure for treatment of diabetes was estimated at \$760 billion in 2019.

Globally, there is an interesting observation of an intertwining of pre-existing silent pandemics (diabetes, obesity, etc.) with the raging COVID-19 pandemic, bringing to light the broad disparities within our society particularly related to human health. A Lancet study from the United Kingdom identified that 30% of COVID-19 deaths were in diabetics.³¹ Type 1 diabetes (T1D) patients were at three times the risk for dying and T2D patients were twice as likely to die compared to nondiabetics. A recent article in the *New England Journal of Medicine* highlighted a unique bidirectional relationship between diabetes and COVID-19.³² On one hand, there is a correlation between pre-existing diabetes and severe COVID-19 symptoms in keeping with the CDC's shortlist of risks for severe disease.³³ On the other hand, some patients infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) develop diabetes with severe sequelae, suggesting a complex pathophysiology of COVID-19 in the context of diabetes.

Worldwide, there are an estimated 463 million adults living with diabetes and this number is expected to increase to 700 million by 2045.^{34–37} Low- and middle-income countries account for the highest percentage of adults with diabetes. One in every five adults over 65 years of age has diabetes. Globally, diabetic burden was highest in China (89.5 million) with India (67.8 million), United States (30.7 million), Indonesia (21.0 million), and Mexico (13.1 million) following behind. India had the highest number of diabetes-associated deaths (254,555), followed by China (153,185), Indonesia (97,005), United States (68,558), and Mexico (64,067). These same countries had the highest rates of disabilities associated with diabetes with China at the top of the list. The numbers on wound incidence and fate are not available which reflects a void in the health care system.

By 2026, the global T2D drug market is expected to rise to an estimated \$78 billion.³⁸ In the United

States, the demand for insulin pumps is expected to rise to an 8.5 billion business by 2027, driven by the increasing number of diabetics, government initiatives to reduce cost burden (U.S. market), and technological advances in treatment.³⁹

FOOT ULCERS

An open sore on the foot is called a foot ulcer. It may be shallow, confined only to the surface of the skin. Deep FUs can involve full thickness of the skin, muscle, tendons, and bones.^{40–44} FUs are common in people with diabetes and individuals with compromised blood circulation.⁴³ Despite advanced health care and pharmacotherapy techniques that are widely available, prevalence of FU has not changed in the past two decades.⁴⁵ Fourteen percent to 24% suffer from amputation.⁴⁶ Neuroischemic ulcers were particularly associated with limb amputations.⁴⁷

The systematic review and meta-analysis of the global epidemiology of FUs performed using PubMed, EMBASE, ISI Web of science, and Cochrane database searches remain the largest and most comprehensive analysis of its kind, including more than 800,000 subjects from 33 countries. Annually, the incidence of FU globally is between 9.1 and 26.1 million. FU is more prevalent in North America (13%) compared to Europe (5.1%) with a global average of 6.4%. Males were generally more prone to FU compared to females (3.5%). T2D patients were more likely to develop FUs (6.4% compared to 5.5% in T1D).^{48,49} In the United States, populations such as Latinos, African Americans, and Native Americans are more likely to develop FU compared to other ethnicities.⁵⁰

The global DFU market expects a positive 6.8% CAGR between 2019 and 2026 and the valuation may reach \$11 billion by the end of 2026. Regionally, the United States dominated the global market in 2019 with an estimated revenue of \$2.79 billion due to the continually increasing prevalence of FUs, high health care costs (including cost of products), and newly introduced technologies.⁵¹ It is expected to remain dominant through the forecast period (2024).⁵²

VENOUS ULCERS

Venous ulcers (VUs) are caused by chronic venous insufficiency and have a preponderance for the lower extremity.^{53,54} The United Kingdom leads research on VU and studies by the National Health Service (NHS) identified that 1 in 500 UK residents have VU costing an estimated £400–600 million in health care costs.⁵⁵ In the United States,

an estimated 500,000–600,000 people have venous leg ulcers resulting in a nearly \$1 billion burden on health care.⁵⁴ In the United Kingdom, the burden amounts to £400–600 million. The global treatment market is expected to reach \$4.8 billion in 2026 with a CAGR of 6.4% from 2019 to 2026. Compression therapy is the most common method of treating VU, accounting for nearly 62% of the market share in 2018. Emerging advanced wound dressings are expected to be competitive with compression therapy in this market. Europe leads the VU wound market (\$1 billion) followed by the United States and Asia Pacific. Some factors that contribute to VU development include age, relative mobility, obesity, and other underlying conditions such as deep vein thrombosis. In the United States and Europe, people over 65 years of age are vulnerable to VUs.⁵⁶ The prevalence of the VUs is 1% of the population globally among ages 18–64.⁵⁷

A small and interesting study by a team from Italy indicated that the COVID-19 pandemic had a significant impact on management of wound dressings and compliance with appointments as it related to VU.⁵⁸ As a result, providers tried alternate methods such as simplifying the dressing method and a small group even opted to make videos to help patients do their own dressings. From the patient's perspective, there was a decrease of appointment frequency in 59% of the cases and nearly 61% of VU patients did not maintain any contact with their provider, and some (13%) did not change their dressing at all during the pandemic. In 15.4% of VU patients, the ulcer itself worsened due to lack of compliance.

OVERWEIGHT AND OBESITY

The World Health Organization (WHO) reported in 2018 that globally, 13% of adults 18 years of age and older had obesity. The United States leads with the highest prevalence of obesity (42.4%) followed by Saudi Arabia, Turkey, Egypt, Libya, Iran, Iraq, South Africa, Canada, Mexico, Australia, and most of the countries in South America and Europe.^{59–61} In 2020, a correlation was drawn between countries with high obesity rates and cumulative number of confirmed COVID-19-related deaths per million people. An interesting observation in the COVID context was a difference in the age-related prevalence of COVID-19 in these countries. While Italy and China indicated old age (65+) as a risk factor, the United States showed a different trend toward younger populations.^{62,63} A study by Johns Hopkins on patients admitted to their ICUs with severe COVID linked this trend to prevalence of obesity as a common factor in these patients.⁶⁴

While the presence of underlying comorbidities such as lower cardiorespiratory fitness and diabetes is at significant risk for COVID-19, interestingly, the lack of such comorbidities does not preclude an obese person from being at risk for severe COVID symptoms.⁶⁵ The reason for this could be linked to the obesity-associated chronic inflammatory state that could favor an exaggerated immune response to infection with SARS-CoV2. The virus appears to capitalize on the existing inflammatory state by further unleashing a storm of cytokine responses, thereby effectively evading clearance.^{66,67}

There is a possibility that impaired immunological responses in persons with obesity and diabetes could negatively affect the efficiency of a SARS-CoV-2 vaccine. The knowledge that metabolic processes impact the course of COVID-19 has driven the UK government to initiate a national campaign, to encourage adults to reduce their risk for severe illness by providing options for physical activity, healthier food choices, and other promotional activities.⁶⁸ In the United States, the concept of precision nutrition to improve health has been discussed by Drs. Rodgers and Collins in the National Institute of Health's 2020–2030 Strategic Plan for NIH Nutrition Research.⁶⁹

SOCIAL DETERMINANTS IN CHRONIC WOUND HEALING

The conditions in which people are born, grow, live, work, and age have a recognized impact on their health.⁷⁰ Characteristics such as socioeconomic status (SES) (*e.g.*, income, education, and employment status), physical environment, psychosocial factors (stress, depression, etc.), and social support networks (collectively packaged under the umbrella term “social determinants of health” [SDOH]) interact with the biology of the individual, determining health outcomes such as disease development, wound healing, and life expectancy.⁷¹ SES restricts the freedom of choice. For instance, a person without a job or steady income or low education (high school degree or lower) is less likely to have access to health insurance, adequate housing, gym memberships (or other physical activity outlets), and healthy food options. Food insecurity, defined as the *lack of consistent access to enough food to sustain a healthy lifestyle*, is a key SDOH factor that affects 11% of U.S. households and correlates with chronic diseases such as obesity, diabetes, and by association wound healing.^{72,73} Several lines of evidence have addressed the impact of supporting wound healing with

proper nutritional support. Recently, the impact of nutrition in overall health was recognized by the NIH in their effort to promote the concept of precision nutrition. This effort, detailed in the 2020–2030 Strategic Plan for NIH Nutrition Research, aims to catalyze nutrition research, crosscutting research areas, including minority health, women's health, rigor and reproducibility, data science, systems science, and artificial intelligence.⁶⁹

What is becoming clearer as we delve deeper into a more holistic approach to improving health is that these factors influence functionality at the level of the gene (social genomics), resulting in changes that can be global (epigenetic) or specific to cellular subsets and in some cases, heritable. From the perspective of wound healing, several independent studies have shown how the SES, environment and psychosocial stress, impairs wound healing by increasing pain response, decreasing inflammatory responses, increasing risk for infection, and affecting hormonal responses, among others.^{71,74}

ACUTE WOUNDS

Breach in the integrity of the skin that heals uneventfully with time are considered acute wounds.⁷ Surgical and traumatic wounds, abrasions, or superficial burns are generally considered acute wounds.⁷ Every time the integrity of the cutaneous barrier is compromised, a wound is created. Wound infections complicate recovery from surgery and significantly increase the cost of wound care post-surgery. The development of novel and practical concepts to prevent and treat these wound infections is key to effective wound management.

A variety of acute skin lesions (*e.g.*, exanthematous eruptions, vesicular eruptions, etc.) and also more focal lesions (*e.g.*, painful acral papules, petechiae pernio-like lesions) have been identified in COVID-19 patients.^{75–78} The pathophysiology of these lesions is unclear, but could be attributed to immune and vascular dysregulations. In severe COVID-19 sustained, systemic activation of the alternative and lectin-based complement pathways was observed and could be linked to risks for pulmonary embolism and amputations secondary to arterial thrombosis.⁷⁷ Furthermore, in patients defined as long haulers (signs of COVID-19 persisting >60 days after SARS-CoV2 polymerase chain reaction positivity), there were reports of ongoing dermatological manifestations such as pernio and papulosquamous eruptions.⁷⁹

In 2014, acute wounds resulted in 17.2 million hospital visits, including ambulatory/outpatient and inpatient surgical visits.⁸⁰ The majority

(57.8%) of these visits occurred in hospital-owned outpatient settings, while 42.2% were inpatients.⁸⁰ Outpatient visits were primarily (48.6%) covered by private insurers, while Medicare primarily (43.4%) covered inpatient surgical stays.⁸⁰

INFECTION

Bacteria rapidly colonize in open skin wounds after burn injury^{81–84} or surgical incisions.^{40,85–88} Microorganisms colonizing these wounds are typically the patient's normal flora or may be transferred through contact with contaminated external contact such as water, fomites, or the soiled hands of health care workers.^{86,87} Gram-positive bacteria such as *Staphylococcus aureus* and *Enterococcus* spp. and Gram-negative organisms such as *Pseudomonas aeruginosa*, *Acinetobacter* spp., fungi like *Candida* spp., and *Aspergillus* spp. are all among a list of common pathogens that can cause acute wound infections, and several of them are resistant to antibiotics.^{89–92} The 2019 health care-associated infections data (CDC-National HealthCare Safety Network)⁸⁵ indicated a 7% decrease in the standardized infection ratio. Surgical site infections (SSI) are costly and account for an annual cost of \$3.3 billion and associated with 1 million additional inpatient days annually. From the military perspective, a high priority of the Military Health System (MHS) research enterprise is the prevention and management of military-relevant wound infections. Some key focus areas reported include the following: (1) focus on invasive fungal infections and morbidity in blast injuries, (2) skin and soft tissue infections (SSTI), particularly *S. aureus* and completion of a phase 2 trial of a vaccine candidate, (3) host microbiome studies in SSTI, and (4) multidrug resistance in wound pathogens.⁹³

An important factor in the failure of a sore to heal is the presence of polymicrobial consortia, living cooperatively in highly organized biofilms. The biofilm shields the pathogenic microbes from antimicrobial therapy and the patient's immune response. A key focus in biofilm research is the development of suitable prevention and treatment options that would clear infection. Some newer forays into this avenue include nanotheranostics (using nanoparticles and fibers as a combination diagnostic and therapeutic tool against drug-resistant and biofilm-forming bacteria),⁹⁴ bacteriophages,^{95–97} and electroceuticals^{98–100} as some nonconventional approaches to targeting wound biofilm infections. Biofilm infections have been linked to wound chronicity.^{83,84,101–106} Furthermore, these infections cause defective func-

tional wound closure, where the wound site appears closed, but the repaired skin lacks barrier function, by triggering microRNAs that destabilize junctional proteins that are necessary for establishment of the barrier following closure.^{83,84,100,103} Therefore, the covering of a wound and a lack of discharge may need to include the criterion that the repaired skin must have physiological functionality to be called “closed.” Thus, covering of the wound, a lack of discharge, and restoration of barrier function should be considered criteria for functional wound closure in patients. Ongoing patient-based studies (NCT02577120) are testing the hypothesis that closed wounds that are deficient in barrier function lend themselves to wound recurrence.

SCAR AND FIBROSIS

Scars and associated functional as well as esthetic concerns represent a huge burden on health care.¹⁰⁷ Burn wounds usually leave hypertrophic scars after they have healed. In particular, the face is highly susceptible to excessive scarring, causing functional deficits and psychosocial burdens.¹⁰⁸ The global scar treatment market size is expected to reach around \$32 billion by 2027, expanding at a CAGR of 8.3%. The United States is a primary driver in this market due to investments in research on scar treatment products. Topical products such as creams and lotions are particularly valued, followed by laser treatments and injectable options. Asia Pacific is expected to become rapidly competitive in this market, and in Latin America, the growth rate is expected to be moderate during this forecast period. A new study reviewed promising new strategies such as antiangiogenesis therapy, fat grafting, stem cell therapy, and molecular targets such as cytokines to prevent scarring following wounding.¹⁰⁹

PHYSICIAN EDUCATION

With the development of specialized wound care practices there is an associated need for rigorous clinical training, research, evidence development, and advocacy to improve patient wound outcomes. Currently, formal education for providers is limited to a few courses during pregraduate or postgraduate medical education. Although some training is provided if a physician chooses to work at a wound care center, it is typically not as rigorous as a typical residency or fellowship-based medical education. The American College of Wound Healing and Tissue Repair (ACWHTR) is a primary advocate for specialization in wound care with a patient-centered outcome approach and is working to

create a board-certified specialty in wound management.¹¹⁰ Comprehensive education is critical for the development of wound care management as a discipline in mainstream medicine, particularly given the increasing geriatric population.¹¹¹ The American Board of Wound Management (ABWM) provides a Certified Wound Specialist (CWS[®]) board certification that formally recognizes Masters level knowledge and specialty practice in wound management.¹¹² In Europe, wound care education is similarly lacking, but the European Wound Management Association (EWMA) is working toward establishing a core standard for acceptable wound management education.¹¹³

NURSING EDUCATION, PHYSICAL THERAPY, AND OSTOMY

Traditionally, wound healing has been under the aegis of basic nursing practices,¹¹⁴ such as wound covering management, therapeutic nutrition, mobility, and psychosocial support. Nurses play a crucial role in handling and managing acute wounds and chronic wounds like PUs, bedsores, FUs, and VUs. The Wound Ostomy and Continence Nurses (WOCN) Society is the oldest wound care society that has board certified over 6,000 nurses worldwide.¹¹⁴ They are considered the gold standard for certification in wound nursing and this process requires completion of a rigorous curriculum followed by stringent recertification processes.¹¹⁴ In 2010, the Organization of Wound Care Nurses (OWCN) was established.¹¹⁵ It provides the foundation and training for all the licensed nurses who are practicing in different care settings free of cost. Wound care and ostomy education programs for nurses are increasingly becoming available in an effort to improve nursing service quality.¹¹⁶

Appropriate professional use of multiple wound care disciplines may markedly impact wound care.^{117–119} Physical therapy represents one such major discipline. Trained physical therapists may employ numerous treatment regimens such as wound debridement, modalities, edema management, positioning, orthotic use, and mobility improvement. Occupational therapists may provide edema management, wound debridement, positioning, toileting programs, self-feeding, and wheelchair management as relevant to the need of the patient. Addressing supportive interventions such as physical and occupational therapy and nutrition management are likely to promote the rate of wound healing, thereby lowering the overall costs of wound care. After all, the longer a patient's healing time, the higher the cost to the facility.

Wound, ostomy, and continence nurses, in addition to being educated and trained to provide acute and rehabilitative care, represent an important component of the wound care ecosystem.^{120–122} Ostomies, stomas, acute and chronic wounds, and urinary and fecal incontinence often present severe physical challenges for wound patients. These lead to emotional and social issues that may be addressed by properly trained and educated allied medical professionals. Limitations in well-structured wound care education of providers may be viewed as a significant barrier to uniform evidence-based wound care throughout the country.

PATIENT EDUCATION

Literature addressing patient-centered wound care has mostly focused on quality of life (QoL), pain, adherence, and coping. The key concern from the patient perspective is improved provider recognition of patient concerns in treatment planning and request for personalized approaches. The evolution to shared wound care decision making is what patients are seeking.^{123,124} Engaging patient awareness and involvement in wound management is key to ensuring successful healing outcomes.¹²⁵

COMBAT WOUND CARE

In 2019, the National Academies of Sciences, Engineering, and Medicine, together with the Board on Army Research and Development, convened a workshop to discuss the future of combat trauma care and improving soldier survivability in high-intensity conflicts in 2035.¹²⁶ Some key factors that the military is particularly interested in developing include technologies that can address hemorrhage control in the field, development of shelf-stable whole blood and blood products, infection diagnosis, and treatment and management of pain. There appears to be a strong inclination toward virtual and autonomous systems in combating trauma in diverse terrains, indicating an interest in developing artificial intelligence/robotic medic assistance. In short, the Department of Defense (DoD) is interested in multiuse, portable, scalable wound care solutions that can address bleeding, infection, and pain management supported ideally by automated mechanisms that enhance Warfighter readiness.

The DoD and the U.S. Department of Veterans Affairs (VA) are the two federal government institutions involved in providing health care to the 3.9 million U.S. military members who served in Operation Enduring Freedom and Operation Iraqi Freedom (OEF/OIF), the 17 million veterans from prior periods, and the 1.3 million active personnel and their families.¹²⁷

The DoD covers active service members and the VA provides medical support to eligible retirees. The Tactical Combat Casualty Care (TCCC) is a training system developed by the DoD Defense Health Agency (DHA) Joint Trauma System and uses evidence-based, life-saving techniques and strategies to train personnel to provide quality trauma care on the battlefield.

The Combat Casualty Care Research Program (CCCRP) is a collaborative, multidisciplinary partnership that utilizes clinical and translational research to provide state-of-the-art advanced wound care.¹²⁸ With an effort to maximize restoration of function and QoL in Service Members with combat-related extremity trauma, the VA and DoD have increased their research and clinical care efforts with a focus on regenerative medicine.¹²⁹

CLOSING REMARKS

Based on estimates originating from independent sources, it is clear that wounds and weaknesses in the healthcare infrastructure will continue to be an ongoing problem. The COVID-19 pandemic compounds the insufficient emphasis given to the complex problem of chronic wounds and highlights the need for a holistic approach to solving this problem. Key challenges include a dearth of resources in the domains of education, care, and research, the ability to recruit and retain personnel with an interest in interdisciplinary collaborations, and the vision to address the local and systemic factors driving chronic wound development. The larger wound care community must unite and develop a strategic plan to address the challenges.

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**Abbreviations
and Acronyms**

CAGR = Compound Annual Growth Rate
CDC = Centers for Disease Control
and Prevention
CNHW = chronic nonhealing wound
COVID = coronavirus disease
DFU = diabetic foot ulcers

DoD = Department of Defense
FOA = Funding Opportunity
Announcements
FU = foot ulcers
ICU = intensive care unit
PU = pressure ulcer
QoL = quality of life
RFA = Request for Applications

SARS-CoV2 = severe acute respiratory
syndrome coronavirus 2
SDOH = social determinants of health
SES = socioeconomic status
SSTI = skin and soft tissue infections
T1D = type 1 diabetes
T2D = type 2 diabetes
VA = Veterans Affairs
VU = venous ulcer