Background
Chronic vascular leg ulcers affect approximately 1% of the population and are the primary cause of 70-90% of leg amputations. Ulcers may occur on other regions of the body and cause discomfort and functional limitations. Therapeutic approaches to wound healing may deter such extreme interventions and improve the patient’s quality of life, as well as decrease health care costs. Over the last half of the century, application of electrical current to wounds has demonstrated augmented healing in both animal models and human subjects. High voltage pulsed current applied as a voltage between 100-150 V is used in a wide range of clinical settings. The purpose of this review is to analyze the effect of HVPC on wound healing and the parameters that yielded the most efficacious results.

Outcomes Assessment
All four studies utilized wounds surface area (WSA) to determine the effects of HVPC on wound healing of chronic ulcers. WSA and various analyses of the measure is the primary measure of determining progress in wound healing. Using surface area in studies provides an objective measure of difference among participants but also among each patient throughout the duration of the treatment. The only concern with using WSA is that the method does not account for depth of the wound. This may be improved by using a volumetric measurement, though such a method may be harder to implement.

HVP C Parameters
- Twin-peak monophasic current
  - Voltage: 100-150 V
  - Frequency: 100 pulses per second (pps)
  - Pulse Duration: 50-100 μs
- Treatment Duration and Frequency: 45-60 minute duration, 5-7 times a week.

Study
- **Ahmad, 2008**: Randomized trial to determine the optimal treatment time for HVPC. Study was conducted over 5 weeks. Control group received sham HVPC treatment. 3 groups received the same HVPC treatment at varying treatment lengths. Wound surface area (WSA) was the outcome measured. WSA was recorded pre-intervention, 3 weeks, and 5 weeks after treatment application.
- **Feedar et al, 1991**: Double blind, Multicenter Study - 2 groups: pulsed electrical stimulation, sham electrical stimulation (control)
  - 47 subjects with stage II (1), III (9), and IV (8) chronic dermal ulcer; pressure sores
  - Ages 29-91 (mean 63)
  - 52% male, 48% female
  - 4 week long study
  - Treatment Group: 30 minutes of pulsed cathodal electrical stimulation
    - Twice daily
    - 7 days a week
    - Pulse duration: 12 μs
    - Frequency: 100 Hz
  - Control Group: Received the same setup as the treatment group but the voltage was kept at 0 V.
  - Treatment Group: 44% original size
  - 14% healing rate/week
  - Control Group: 67% original size
  - 8.25% healing rate/week
  - Overall: Decreased wound size - Increased healing rate
- **Houghton et al, 2003**: Pretest-posttest randomized, double blind sham study design. 8 week study - Randomly assigned treatment of sham group.
  - 27 subjects with 42 wounds
  - Similar number of males and females in each group
  - Aged 25-91 (mean 66.3)
  - Recruited via advertisement or outpatient/inpatient clinics
  - Treatment Group: 1 electrode over wound with sterile gauze, other electrode placed 20 cm proximal
  - Pulse duration: 100 μs
  - Peak intensity: 150 V
  - Pulse frequency: 100 Hz
  - Applied for 45 minutes, 3 times a week for 4 weeks
  - Sham Group: Same setup but the machine was deactivated by the manufacturer
  - Decreased wound surface area (WSA) at 4 weeks 44.3% (PSST) scores were statistically similar between the treatment and sham groups at 4 weeks
  - Decrease in photographic wound assessment tool (PWAT) scores at 4 weeks
  - Pressure Sore Staging Tool (PSST): scores were statistically similar between the treatment and sham groups at 4 weeks
- **Polek et al, 2016**: Prospective, Randomized, Double-blinded Clinical Trial
  - Patients were from 2 nursing and care centers
  - 6 weeks
  - Electrical Stimulation (ES) Group: Standard wound care and electrical stimulation
  - Control Group: Standard wound care and sham electrical stimulation
  - 44 patients, 75.5% women, 24.5% male
  - Patients with PUs that did not respond to previous treatment for at least 4 weeks - 25 patients; mean age of 79.38 ± 8.50 years; average age = (60-95); mean wound surface area (WSA) of 10.58 ± 10.57 cm²
  - 24 patients: mean age of 76.33 ± 12.74 years; mean WSA of 9.71 ± 6.70 cm²
  - Both groups received pressure ulcer prevention measures, wound care, and physical treatment
  - ES Group: received cathodal HVPC (154 microseconds; 100 pulses per second; 0.24 x 250 KHz) applied continuously for 50 minutes once a day; 5 times a week
  - Control Group: received sham HVPC
  - ES Group: statistically significant decrease in WSA after 1 week of treatment (35.7% ± 30.5%)
  - At week 6, percentage area reduction was 80.31% ± 20.02% Control Group
  - A decrease of only 17.07% ± 34.15% in WSA
  - At week 6, percentage area reduction was 54.65% ± 42.65% (P=0.046)

Analysis
- Multiple randomized controlled studies have investigated the effect of HVPC on wound healing. Many of these studies are also double-blinded. The literature reviewed generally supports the conclusion that HVPC of 4-6 week duration results in decreased WSA and thus an increase in wound healing that is statistically greater than sham treatment.
- Increased wound healing in the four analyzed studies is further supported by a small group of crossover subjects in the study performed by Feedar et al and bilateral ulcers treated with opposite treatments in the study performed by Houghton et al.
- Only Feedar et al reported any adverse effects. These occurred in only 15% of patients and were primarily described as tingling in the wound. This may be due to the study using the highest frequency (128 pps) of the four studies (100-120 pps).
- Studies by Ahmad and Polek et al had very small age ranges compared to those of Feedar et al and Houghton et al. However, the majority of the studies had similar numbers of males and females enrolled. The greatest concern among the studies is the small sample sizes used, where no study had more than 60 subjects. Small sample sizes have the potential to skew data.

Conclusion
HVP C improves chronic wound healing within 4-6 weeks as demonstrated through reduced wound surface areas. Effective parameters for HVPC have been determined through a number of studies. While HVPC has been demonstrated in multiple studies to be an effective treatment for augmenting chronic ulcer healing, this collection of data would be strengthened by replicating studies with larger sample sizes. Further research should also be done to determine the efficacy of electrical stimulation on wound closure.

References