Advancing healing in large hard-to-heal wounds: the ripple effect of autologous whole blood clot therapy: a case series

Objective: Hard-to-heal (chronic) wounds of the lower extremity, particularly large-area wounds, present significant challenges due to their usually prolonged healing time and complications that might lead to surgical interventions, adding to the high burden on the healthcare system. This study aimed to evaluate the efficacy of autologous whole blood clot (AWBC) therapy in promoting healing in large (>28cm^2), hard-to-heal wounds.
Method: Patients with a mean wound size of 63.4±31.6cm^2 were treated weekly with AWBC therapy. AWBC was created from a small blood sample of the patient and applied weekly onto the wound, covering only part of it (the clot size is 28cm^2, and only one was used). The patients were followed until complete wound closure or satisfactory healing was achieved.
Results: This case series comprised 27 patients (55.5% female, mean age: 69.7±15.8 years). The results showed that 78% of the treated wounds progressed toward healing, with an overall mean percent area reduction of 74% at the final follow-up. AWBC therapy demonstrated a high level of efficacy across all wound types, showing effectiveness even when the clot did not fully cover the wound area.
Conclusion: In this case series AWBC therapy offered a promising solution for large, hard-to-heal wounds by creating a favourable microenvironment that promoted tissue repair. The therapeutic effect extended beyond the area directly covered by the clot, suggesting a ripple effect mediated by bioactive factors from the clot. AWBC therapy represents an innovative and effective treatment option for large, hard-to-heal wounds. While additional studies are needed to optimise protocols and further investigate the underlying mechanisms, these findings demonstrate AWBC therapy's ability to address the limitations of existing wound care strategies.
Declaration of interest: SH is a paid consultant at RedDress Medical, Ponte Vedra Beach, FL, US, the manufacturer of AWBC. The other authors have no conflicts of interest to declare.

autologous whole blood clot • chronic wounds • extracellular matrix • hard-to-heal wounds • large wounds • lower extremity wound • wound • wound care • wound dressing • wound healing

Wound Care

Hard-to-heal (chronic) wounds of the lower extremity continue to be a major challenge worldwide, with high rates of amputations.[1] Hard-to-heal wounds are wounds that fail to progress through the orderly and timely phases of healing, typically remaining unhealed for >4–6 weeks. They are characterised by excessive inflammation, persistent infection, impaired tissue repair, and an overall inability to restore functional integrity.[2] Comorbidities, such as diabetes and vascular disease, contribute to the wound's chronic condition, exhibiting excessive inflammation, persistent infection and the lack of tissue response to the healing process and infection risk.[1,3] Hard-to-heal wounds are a continued burden on healthcare systems, with an average duration of 12–13 months.[1] These wounds can recur at a rate of 60–70% and result in a decrease in the patient's quality of life and an increase in morbidity.[1] Normal healing progression is diminished in hard-to-heal wounds, which fail to proceed through the inflammatory phase, as described by McCarty et al.,[4] disrupting the normal balance between deposition and degradation of the extracellular matrix (ECM) components.[1] Hard-to-heal wounds exhibit high levels of proinflammatory cytokines, proteases such as metalloproteinases (MMPs), reactive oxygen species and senescent cells.[1,4] Therefore, the ECM is a therapeutic target in hard-to-heal wounds, and a crucial factor in the entire wound healing process by enabling cellular adhesion, chemotaxis and migration.[5,6] The ECM provides the wound with a physical infrastructure, but, most importantly, it regulates the activity of other cells in the wound area, such as fibroblasts and endothelial cells, enabling the healing cascade in the wound environment.[6] Lastly, the role of the ECM is crucial for the tissue repair process, providing both moisture and balanced environment.[7]

Large-area wounds of the lower extremity, which cover a significant surface area of the body relative to the anatomical region, pose a significant challenge in wound care due to the limitations of existing treatments. Treatments using cellular and tissue-based products (CTPs) are often designed for smaller wounds due to limitations in source materials for clinical practice.[8] Furthermore, insurance coverage for CTPs in the US is based on the size of the product used, with reimbursement calculated per cm^2. This could lead to clinical challenges in larger wounds due to covering irregular shapes or to poor CTP adherence to the wound bed itself.[9] This

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limitation can significantly increase the economic burden associated with the management of large wounds. Large wounds not only expose patients to a prolonged risk of infection and complications but also require therapeutic coverage that supports the entire wound bed.[10,11] Technologies that can effectively cover extensive wound areas are essential, as they must provide an environment conducive to healing, maintain moisture balance, and facilitate tissue regeneration over a broader surface area.[8] Furthermore, large wounds are often associated with high levels of exudate, making it critical for any applied therapy to have sufficient durability and capacity to manage wound drainage over an extended area.

An autologous whole blood clot (AWBC) is created at the point of care from a small sample of the patient's own peripheral blood. The created clot is round with an area of 28cm^2. The clot can overlap the wound edges as well as cover only part of it, without affecting its therapeutic effect. It is worth noting that the application of multiple clots to a wound can be performed at the discretion of the wound care professional, depending on the specific needs of the wound. The blood clot serves as a protective covering, biological scaffold, and optimal microenvironment for the wound site by creating a biological delivery system that releases growth factors and cytokines, promoting the natural healing process of the wound.[12] In a randomised controlled trial, AWBC treatment in hard-to-heal diabetic foot ulcers (DFUs) was found to be superior to standard of care (SoC), resulting in a ratio of 2.73 in healing DFUs compared to SoC.[13] AWBC efficacy was demonstrated in several observational studies of DFUs, pressure ulcers (PUs), surgical and complex cases, showing high efficacy in reaching complete wound closure by week 12.[14,15]

This case series presents the results of an observational study looking at the effect of AWBC in achieving complete wound closure in large, hard-to-heal wounds.

Method

Ethical approval and patient consent

The study was approved by the Advarra Institutional Review Board (No. CR00519761; 16 January 2024).

All patients provided written informed consent prior to enrolment to have their medical history, wound characteristics and images published.

Data

The data were extracted from a multicentre, observational study using AWBC in the treatment of hard-to-heal wounds. Patient data were collected from a registry database between 1 August 2021, and 15 April 2022 (ClinicalTrials.gov: NCT04699305). The study included patients aged >18 years with wound areas >28cm^2.

Patients

The study included patients from 19 participating sites, in the US, Israel, Turkey and South Africa, including from both the public and private health sectors. The wounds consisted of: surgical wounds (n=8); venous leg ulcers (VLUs) (n=7); DFUs (n=6); trauma wounds (n=3); and PUs (n=3). No inclusion or exclusion criteria were defined for this study. Patients were eligible for enrolment if they presented with a hard-to-heal wound (>28cm^2) that had not responded to SoC treatments.

Wound preparation and AWBC application

The wound bed was prepared by thoroughly debriding the wound, removing any necrotic tissue, cleansing, assessing for bacterial bioburden (wounds free of infection), and maintaining moisture management, prior to AWBC application. The AWBC was created based on the manufacturer's instructions as previously described.[13] In brief, 18ml of blood was withdrawn from the patient into an acid citrate dextrose solution A vacuum tube (RedDress Medical, Israel). The blood was then mixed with calcium gluconate and kaolin powders in a designated coagulation mould and was allowed to clot for five minutes. Once clotted, the AWBC was placed on an area of the wound with the most wound edge available to facilitate adhesion using Steri-strips for irregularly shaped wounds. In cases of distal transmetatarsal amputation wounds or rounded areas where adherence to the conical shape of the wound was challenging, the clot was positioned at the centre of the wound. The Steri-strips were then stretched to the wound edges, creating a gap between the clot and the skin edges. The clot was covered with a non-adherent layer and foam. The wound area that was not covered with the clot was dressed with gauze. Re-application was performed weekly according to the investigator's discretion.

Patient follow-up

Patients were followed up weekly for their wound progression. Wounds that did not achieve >30% reduction in wound size after four applications of AWBC were considered non-responsive and were discontinued. Wounds were followed up until wound closure or until the wound was considered progressed enough to continue with SoC treatment. Substantial healing was defined as a reduction in wound size and depth, and/or display of healing, such as the increase in granulation tissue as determined by the wound specialist, which enabled the transition to SoC treatment. The data were extracted from real-world cases, wounds were not followed to complete closure in most, with follow-up often concluding once sufficient progress was achieved to move to SoC treatment.

Data collection and analysis

Baseline data were collected and extracted from the patient's medical files including the patient's demographics, medical history, wound profile and past treatments, along with measurement and wound images.

Results

The analysis included 27 patients with wounds >28cm^2 at baseline. There were 15 (55.5%) female patients, and

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the mean age was 69.7±15.8 years. The mean wound size at baseline was 63.4±31.6cm^2 (range: 28.1–260cm^2) and 30% of the wounds were of >1 year's duration. Most patients (70%) had multiple comorbidities, including diabetes, which was reported in 14 (52%) patients (Table 1). Most wounds (67%) had been previously treated with other therapies without progress in healing. The wound locations were as follows: at the malleolus and shin for VLUs; forefoot, ankle and plantar areas for DFUs; heel and buttocks for PUs; abdomen, hand, shin and scalp for surgical wounds; and shin and leg for trauma wounds.

Substantial healing was achieved in 20/27 (78%) wounds, with an overall percent area reduction (PAR) of 74% at the final follow-up visit. Moreover, in four weeks, the overall PAR for all wound types was 47%. The AWBC application led to satisfactory healing across all wound types: DFUs 6/6; VLUs 3/7; surgical wounds 7/8; trauma wounds 2/3; and PUs 2/3. The PAR following AWBC treatment was also significant across different wound types, with a 77% reduction observed in DFUs, 47% in VLUs, 89% in surgical wounds, 67% in trauma wounds and 63% in PUs. The mean number of AWBC applications was 7±4.6 (range: 1–20). Most wounds (96%) were treated with only one clot per visit, covering only a portion of the wound (in two cases, two and three clots were applied: in one case, the two clots applied covered most of the wound, while in the second case, the clots were placed at the wound edges, covering only a small portion of a large wound). The healing rates and corresponding PAR for each wound type are presented in Table 2.

Table 1. Patient demographics and wound characteristics (n=27)

Variable	
Age, years, mean±SD	69.7±15.8
Sex, n (%)	
Female	15 (55.5)
Male	12 (45.5)
Multiple comorbidities, n (%)	19 (70.0)
Diabetes, n (%)	14 (52.0)
Wound size at baseline, cm^2, mean±SD (range)	63.4±31.6 (28.1–260)
Wound duration >1 year, n (%)	8 (30)

SD—standard deviation

Case series overview

The cases of three patients with hard-to-heal wounds of varying aetiologies who were treated AWBC therapy after failing to respond to conventional wound care are presented. All patients had multiple comorbidities and presented with large, hard-to-heal wounds (Table 3).

Patient 1

A 61-year-old male patient with a Wagner grade 2 DFU on the right distal foot of two months' duration, had a baseline wound area of 80cm² and a depth of 0.7cm. After 15 weekly applications of AWBC, the wound area was reduced by 94% to 4.83cm², with treatment transitioned to SoC dressings thereafter. The wound showed early signs of granulation by week 1, and 52% and 85% PAR by weeks 4 and 12, respectively (Fig 1).

Patient 2

An 85-year-old female patient with a hard-to-heal surgical abdominal wound (baseline wound area: 36cm², depth: 0.8cm) of one month's duration, which had demonstrated poor response to prior negative pressure therapy. Following four weeks of AWBC treatment (initially with two clots, later one per visit), the wound achieved a 95% PAR. The patient was discharged with continued gauze dressing for final closure (Fig 2).

Patient 3

A 93-year-old female patient with a traumatic shin wound (baseline wound area: 101.68cm²) underwent debridement prior to AWBC application. Initially, two clots were applied to distinct wound areas, followed by additional applications over eight weeks. Rapid granulation and re-epithelialisation were observed, and complete closure was achieved by week 8 (Fig 3).

Discussion

The study has addressed the critical challenge of managing large (>28cm^2), hard-to-heal wounds of the

Table 2. Autologous whole blood clot efficacy in the treatment of large wounds (n=27)

Wound type	Number of cases	Satisfactory healing, n (%)	PAR at 4 weeks, %	Overall PAR, %
Surgical	8	7 (87.5)	62	89
Venous leg ulcer	7	3 (42.9)	28	47
Diabetic foot ulcer	6	6 (100.0)	61	77
Trauma	3	2 (66.7)	50	67
Pressure ulcer	3	2 (66.7)	35	63

PAR—percent area reduction

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Table 3. Case series overview

Patient number	Age, years/ sex	Wound type	Initial size, cm²	Depth, cm	Comorbidities	Number of AWBC applications	% reduction
1	61/M	DFU	80	0.7	Diabetes, peripheral neuropathy, CKD, HTN, gastritis, pancreatitis	15	94
2	85/F	Surgical	36	0.8	Obesity, venous insufficiency, HTN, CHF, CKD, CAD, COPD	4	95
3	93/F	Trauma	101.68	–	HTN, heart failure, OA, CKD, GERD, diverticulosis, kidney failure	8	100

AWBC—autologous whole blood clot; CAD—coronary artery disease; CHF—chronic heart failure; CKD—chronic kidney disese; COPD—chronic obstructive pulmonary disease; DFU—diabetic foot ulcer; F—female; GERD—gastroesophageal reflux disease; HTN—hypertension; M—male; OA—osteoarthritis

lower extremity. Hard-to-heal wounds create an immense healthcare burden, and large wounds pose an even greater challenge when using conventional therapies. Hard-to-heal wounds are often exacerbated by comorbidities such as diabetes and vascular disease, and are associated with prolonged inflammation, persistent infections and a disrupted healing process.[16] They frequently present an altered ECM environment that fails to support the cellular activities necessary for tissue repair, including fibroblast recruitment and granulation tissue formation.[1,4]

The AWBC treatment resulted in a highly satisfactory response rate, albeit in challenging wounds of >28cm² in area and with patient comorbidities. AWBC treatment resulted in 78% of the wounds achieving satisfactory healing and a mean PAR of 74%. The varying response rates across wound types suggests that wound aetiology and patient comorbidities significantly influence the wound response to AWBC application. These differences are expected, as wound types differ substantially in their underlying biology, perfusion characteristics, inflammatory burden and chronicity.[1,3]

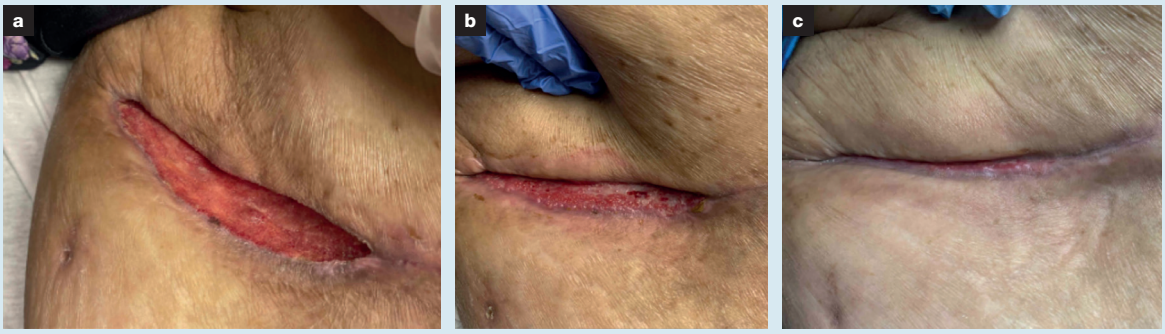
While the findings of this present study do not allow for a definitive conclusion about the efficacy of AWBC treatment for each wound type, given the diverse comorbidities and wound characteristics at enrolment, they do indicate that AWBC treatment benefits all cutaneous wounds, progressing the wound toward healing. Although the treatment efficacy for each wound type is different, AWBC treatment initiates the healing process in all wound types, even in wounds of >1-year's duration. While these results are preliminary, they suggest that not all wounds respond equally to the treatment, indicating that wound aetiology and underlying condition play a pivotal role in healing outcomes. Based on this small cohort of patients and wounds, AWBC treatment appears to be most effective in surgical wounds and DFUs, while VLUs demonstrated a lower healing rate. The primary challenge in treating VLUs is the underlying chronic venous insufficiency, which, due to venous reflux and stasis of deoxygenated blood, can lead to a hypoxic environment and chronic inflammation within the skin.[17] Although AWBC therapy delivers nutrients, cytokines and active cells to the wound, its effectiveness is constrained by limited local VLU physiological mechanisms, decreasing growth factors due to the reduction in proper venous blood circulation.[14] In contrast, the responding wounds with intact arterial and venous blood flow benefit from more robust support for the healing process, allowing

Fig 1. Patient 1: A 61-year-old male patient presented with an 80cm² grade 2 diabetic foot ulcer of two months' duration. He was treated weekly with autologous whole blood clot for 15 consecutive weeks followed by a standard of care treatment for an additional nine weeks. Baseline **(a)**; week 4 **(b)**; week 12 **(c)**; week 15 **(d)**; week 24 **(e)**



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Fig 2. Patient 2: An 85-year-old female patient with a hard-to-heal surgical abdominal wound of 36cm^2 of one month's duration, which had demonstrated poor response to prior negative pressure therapy, was treated with four autologous whole blood clot applications over five weeks. Baseline **(a)**; week 3 **(b)**; week 5 **(c)**



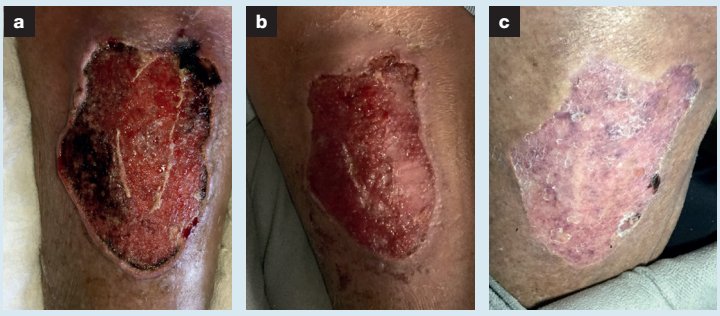
AWBC therapy to be more effective.[13,14,18] While patient comorbidities significantly impact the healing process, AWBC therapy demonstrates the ability to deliver essential healing elements directly to the wound.

The study results indicate that although the wounds were larger than the clot size of 28cm², with the clot covering only 40% of the wound area in 52% of the treated cases, AWBC therapy positively impacted the entire wound area, promoting overall wound progression toward healing.

It is hypothesised that this effect can be attributed to the secretion of growth factors and cytokines from the clot to the wound microenvironment, promoting wound healing across the entire wound area.[12] This observation directly supports the concept that AWBC does not rely solely on physical coverage to exert its therapeutic effect, rather, the clot functions as a biologically active signalling matrix releasing growth factors, cytokines and other mediators that diffuse across the wound bed, influencing cellular behaviour, even in regions not directly covered by the clot.

Moreover, it has been previously suggested that macrophages play a central role in wound healing by facilitating the transition of the wound from the inflammatory stage to tissue repair and regeneration.[19]

Fig 3. Patient 3: A 93-year-old female patient presented with a large traumatic wound on the shin (101.68cm^2) and underwent debridement prior to treatment with autologous whole blood clot applications for eight consecutive weeks until wound closure. Baseline **(a)**; week 2 **(b)**; week 8 **(c)**



During the first phases of wound healing, the macrophages are in their M1, proinflammatory phase and, as the healing progresses, they transition to their M2, anti-inflammatory phase, secreting cytokines and growth factors, such as interleukin (IL)-10 and vascular endothelial growth factor.[19–21] The cytokines contribute to angiogenesis, the formation of new blood vessels essential for nutrient and oxygen delivery to the healing tissue, supporting the remodelling and regeneration of the tissue.[19–21] This natural process is impaired in hard-to-heal wounds when the macrophages are stuck at their M1 phase, unable to transition to their anti-inflammatory phase, releasing inflammatory cytokines and chemokines to the wound environment.

It has been suggested that AWBC creates a supporting environment, releasing factors that affect the macrophages to transition to their M2 phase, which allows the wound to overcome the stagnant inflammatory phase.[12] It is also suggested that this effect of AWBC in part of the wound has a ripple effect on the remote macrophages, and signalling cascades extend to remote regions of the wound, enhancing healing even in areas not directly in contact with the clot.[19] It appears that the release of growth factors and cytokines in one part of the wound initiates a healing process that extends to other areas not directly in contact with the clot.[12] This suggests that infiltration of secreting cells throughout the wound area aids in overcoming the wound's stagnant stage, promoting a more comprehensive healing response in both treated and untreated wound areas.[12]

AWBC therapy shows potential for overcoming the limitations of conventional therapies by creating a favourable microenvironment that supports wound healing through the release of growth factors and cytokines, without the need to cover the entire wound. This therapy not only provides a protective scaffold and promotes cellular activities essential for tissue repair, it also appears to positively impact remote areas of the wound. The secretion of bioactive factors from AWBC seems to initiate a ripple effect, enhancing the wound healing response beyond the immediate area of application.

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Although further studies are needed to fully understand the mechanisms and to optimise treatment protocols, these findings highlight AWBC therapy as a viable, innovative treatment for large wounds. Further controlled, large-scale studies are required to confirm the results of this study. To validate the authors' hypothesis that large wounds can benefit from AWBC treatment alongside SoC procedures, the use of structured application protocols and standardised wound measurement will be essential for improving comparability and strengthening the evidence base. In addition, mechanistic studies are needed to elucidate the biological processes underlying AWBC's effects, including its influence on wound edges and on areas of the wound bed not directly covered by the clot.

Clinical considerations

Although this case series was not designed to establish formal treatment guidelines, the findings offer several practical considerations for clinicians managing large, hard-to-heal wounds. AWBC may be useful for wounds that have not responded to standard therapies. SoC measures, such as offloading or compression, debridement, infection control and moisture management, remain essential components of the treatment. AWBC can be applied even when full wound coverage is not feasible. The results of this study suggest that partial coverage may still promote improvement across the entire wound surface.

Limitations

This study has several limitations. The observational design did not allow for standardisation of cointerventions, such as offloading, compression or debridement. These treatments were applied at the investigators' discretion, introducing variability that may have influenced wound outcomes. In addition, detailed procedural information (e.g., the specific type of offloading or compression device, debridement technique, or cleansing agent) was not collected, limiting the ability to evaluate the contribution of these cointerventions. Wound measurements were performed using each participating site's routine clinical tools, and standardised measurement methods were not collected as part of the registry. Finally, becasue this was a case series of a single arm treatment, without a control group, direct comparisons to SoC or alternative therapies could not be made.

Despite these limitations, the study has several important strengths. As a real-world case series, it includes patients with multiple comorbidities, complex wound aetiologies, and clinical presentations that are often excluded from traditional randomised clinical trials. Furthermore, real-world data allowed for the evaluation of AWBC treatment effectiveness under routine clinical conditions, focusing on actual wound progression rather than protocol-dictated assessments. This provided an understanding of how AWBC performs across a broad spectrum of wound types, severities and care environments.

Conclusions

This study provides real-world evidence supporting the efficacy and clinical benefits of AWBC therapy in treating large, hard-to-heal wounds of various aetiologies. Despite the considerable complexity of the study population, AWBC treatment led to meaningful wound reduction across all wound types. Although the applied AWBC clot covered only a portion of the total wound area due to its size limitation of 28cm², the findings support the hypothesis that AWBC promotes healing through biological signalling and modulation of the wound microenvironment, rather than solely through direct physical coverage. **JWC**

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Reflective questions

- What are the key factors that may contribute to the success or failure of autologous whole blood clot (AWBC) treatment in large wounds?
- What advantages does AWBC therapy offer compared to other wound care products when managing large, hard-to-heal wounds?
- How might patient comorbidities—such as diabetes or vascular disease—affect the clinical effectiveness of AWBC treatment?

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