

Algorithm and Software System for Treatment Application of Platelet-Rich Plasma on Problematic Skin Wounds

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Abstract: Recently a big interest arises to the automated diagnosis and digitalization of clinical data. The purpose of this article is to present treatment algorithm and software system for Problematic Skin Wounds (PSW) by using Platelet-Rich Plasma (PRP), based on the first study on platelet-rich plasma application carried out in Bulgaria. PSW-PRP-Project software system was developed for entering and processing medical data during PRP treatment, visualization of general patient information, treatment trend, as well as a module for training specialists through the created database. For a period of seven years around 100 patients have been treatment at the Department of Orthopaedics and Traumatology, UMBAL KANEV Ruse AD, by applying platelet-rich plasma. The algorithm for the use of platelet-rich plasma for treating problematic skin wounds allows for the proper and accurate treatment of patients with various problematic skin wounds with the purpose of solving the therapeutic problem and their complete recovery. The procedure's course is determined based on assessment on three digital criteria TWS, TAS and TSWD. The algorithms are based on our results, obtained for the first in Bulgaria while treating problematic skin wounds by using platelet-rich plasma and successfully treating 92.78% of patients to full recovery.

Keywords: Problematic skin wounds, platelet rich plasma, functional scoring scales.

1. Introduction

Problematic skin wounds are a serious therapeutic challenge in the world and in Bulgaria, where about 100,000 patients annually have various hard to heal wounds [1, 2]. Multiple comorbidities are a prerequisite for getting such wounds – chronic venous insufficiency covers up to 80% of cases; Diabetes mellitus is a major cause, particularly in respect of lower extremities; as well as decubitus sores [3-5].

There is a variety of non-surgical (conservative) methods and surgical procedures for treatment, and the outcome of their use varies [6, 7]. Unlike the

Platelet-Rich Plasma (PRP) method, they cannot ensure biological treatment (by adding growth factors) and complete tissue regeneration of problematic skin wounds [3, 8, 9]. For accurate initial assessment of a wound and competent subsequent treatment, it is necessary to develop and use clear treatment algorithms enabling uniformity of wound assessment. This will facilitate the work of every practitioner in diagnosing and referring patients to adequate treatment until full recovery thus ensuring their subsequent normal life.

Estimating quality parameters in the treatment of patients using digital quantitative indicators is an effective method of equitable diagnosis and an excludes subjective factor. Evaluation algorithms and criteria embedded in a programmatic environment combine a new approach to building medical systems for analyzing individual medical information in order to preserve human health through an early and timely assessment of its current state of health [10].

The Purpose of this article is to present treatment algorithm and software system PSW-PRP-Project for problematic skin wounds by using platelet-rich plasma based on the first study on platelet-rich plasma application carried out in Bulgaria.

2. Material and methods

For a period of seven years' study was carried out at the Department of Orthopaedics and Traumatology, UMBAL KANEV Ruse AD. Around 100 hospitalized patients with problematic skin wounds were tested and treated with platelet-rich plasma. This representative statistical sample forms the first longitudinal research on treating patients with problematic skin wounds by applying the platelet-rich plasma method in Bulgaria, based on which we have developed treatment and prevention algorithms for treating problematic skin wounds.

Wound assessment is done by the use of scores, introduced by Cancela AM, which attribute certain score points to specific wound parameters:

- Criterion **Total Wound Score (TWS)** stands for total wound parameters—oedema around the wound, erythema around the wound, puss discharge, fibrin, granulation, oedema at the bottom of the wound and ocher oedema;

- Criterion **Total Anatomic Score (TAS)** stands for total anatomic parameters— open bones and tendons, a.dorsalis pedis pulse and a.tibialis posterior pulse;

- Criterion **Total Score of Wound Data (TSWD)** stands for the general wound conditions— size, depth, erosion and period of existence of the wound [11].

The developed treatment algorithm is based on statistical analyses of research results, implemented by the SPSS software (Statistical Package for the Social Sciences) involving three nonparametric tests: Kolmogorov-Smirnov, Mann-Whitney and Wilcoxon to verify the significance of relations between features [12]. Based on the obtained practical results, a software system PSW-PRP-Project was developed, which creates a convenient and effective environment for the processing of patients' medical data, assessment of their current status and visualization of the trend of change of the entered quantitative indicators during treatment using the PRP

method. The software system creates a database and provides a training environment for the training of physicians practicing treatment using the PRP method.

3. Algorithms and software implementation

After conducting experimental studies of platelet-rich plasma application, treatment algorithm that could be applied and used in outpatient and inpatient care have been developed. The platelet-rich plasma method is cost effective and allows for hospital and outpatient practice.

The algorithm for treatment application of platelet-rich plasma on problematic skin wounds shown on Fig. 1 allows for the proper and accurate treatment of patients with various problematic skin wounds in order to resolve the treatment problem and achieve full recovery. The first step of the algorithm is to get acquainted with the patient and their acute skin wound – detailed history has to be taken, local and somatic status has to be assessed. After that, the wound parameters in terms of area and size should be assessed. The following criterion are used: Total Wound Score (TWS), Total Anatomic Score (TAS) and Total Score of Wound Data (TSWD) [11].

The next step is wound processing, as in the onset of treatment, this means surgical debridement, and subsequently cleansing the wound with saline solution. Then follows the preparation of platelet-rich plasma – taking autologous venous blood from the patient, preparing samples for centrifugation, centrifugation and activation of PRP. The subsequent treatment stage is application of PRP to the wound bed and periphery and applying a sterile dressing. The above steps should be repeated at every weekly visit of patient.

Assessment based on the three criteria TWS, TAS and TSWD shall be used to determine the course of the procedure. If the wound score is zero on the three criteria treatment is successful and the problematic skin wound is fully healed. If the wound score is not zero, the scores have to be compared to the previous ones. If scores have decreased PRP treatment is continued to complete healing of the PSW. If no decrease in scores is observed for three months, PSW is not affected by the treatment it should be discontinued and other treatment methods should be sought.

The algorithm of Fig. 1 may be interpreted as network flow problem in the following way:

Let a graph $G(X, U)$ be defined with a set of nodes X and a set of arcs U such that

$$X = \cup_{i \in I} x_i = \cup_{i=1}^n x_i = \{x_1, x_2, \dots, x_n\};$$

$$U = \{x_{ij} \mid (i, j) \in I_0\};$$

where I is the set of indices

$$I = \cup_{i=1}^n i, \quad i = \{1, 2, \dots, n\};$$

$$\text{and } I_0 = \{(i, j) \mid x_i \in X; x_j \in X; x_{ij} \in U\}.$$

Then the following network flow could be defined on the graph $G(X, U)$:

for each $i \in I(x_i \in X)$

$$(1) \quad \sum_{j \in I_i^+} f_{ij} - \sum_{j \in I_i^-} x_{ij} = \begin{cases} 1 & \text{if } x_i = s, \\ 0 & \text{if } x_i \neq s, t, \\ -1 & \text{if } x_i = t, \end{cases}$$

- (2) $f_r - f_z \leq 1$ for each $(r, v) \in P$;
 (3) $f_{ij} \in \{0, 1\}$ for each $(i, j) \in I_0$,

where s is a source and t a consumer of the flow of value 1; P – the set of additional constraints, such that they specify dependences between two separate flow functions f_r and f_z .

It may be put down for the algorithm from Fig. 2:

$$X = \{x_1, x_2, x_3, x_4, x_5, x_6, x_7\},$$

$$U = \{x_{1,2}; x_{2,3}; x_{3,4}; x_{4,7}; x_{3,5}; x_{5,2}; x_{5,6}; x_{6,2}; x_{6,7}\},$$

where the number of vertices is $n = 7$ and the number arcs is $m = 9$, $x_1 = s$, and $x_7 = t$.

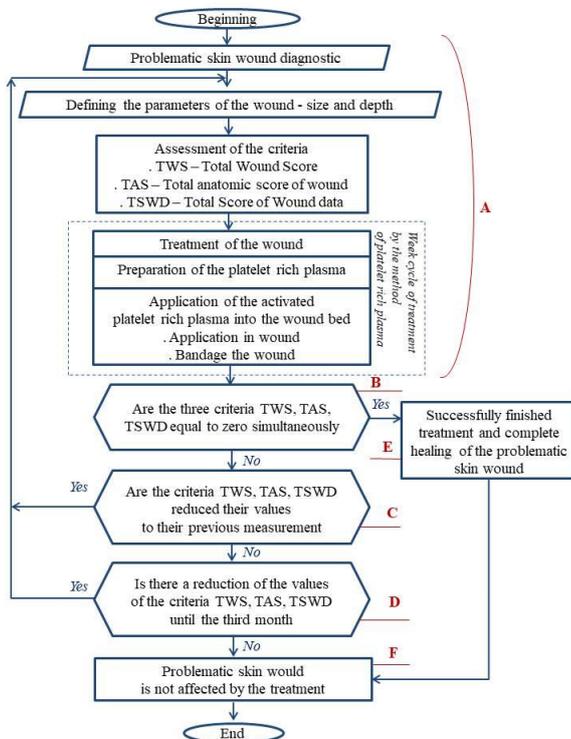


Fig. 1. Algorithm for treatment application of platelet-rich plasma on problematic skin wounds

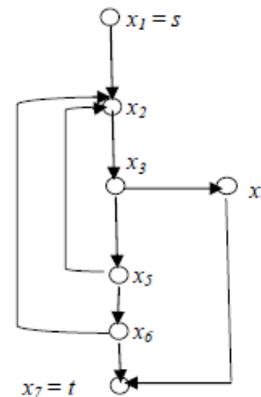


Fig. 2. Network diagram

The graph thus defined is graphically represented in Fig. 2.

In essence the algorithm of Fig. 1, like any deterministic algorithm is a directed graph in the form of verbal instructions. We just make an attempt to formalize it, so that it could be applicable for portable devices and be useful for a wide range of general practitioners.

The arc flow function $f_{1,2}$ corresponds to the initial box “Problematic skin wound Diagnostic” and $f_{2,3}$ – a linear series of sequential instructions unified in the next sub-block A in Fig. 1.

Bloc B considers the alternative “Are the three criteria TWS, TAS, TSWD equal to zero simultaneously”. Block C considers whether the criteria values are reduced compared to the previous measurement, and block D – whether there is a reduction of the criteria after a three-month treatment. Block F means “No effect of the treatment” (Fig. 1).

The following additional constraints exist in the algorithm being considered:

- (4) $f_{3,4} + f_{3,5} \leq 1,$
 (5) $f_{5,6} + f_{5,2} \leq 1,$
 (6) $f_{6,7} + f_{6,2} \leq 1,$

where

$$f_{3,4} = \begin{cases} 1 & \text{if B is true,} \\ 0 & \text{otherwise,} \end{cases}$$

$$f_{5,2} = \begin{cases} 1 & \text{if C is true,} \\ 0 & \text{otherwise,} \end{cases}$$

$$f_{6,2} = \begin{cases} 1 & \text{if D is true,} \\ 0 & \text{otherwise.} \end{cases}$$

The following objective function will be defined:

$$L = \sum_{(i,j) \in I'_0} f_{ij} \rightarrow \max,$$

where $I'_0 = \{(1, 2), (6, 7)\} \subseteq I_0$.

So, the optimization problem for maximization of L subject to constraints from (1) to (6) on the arc flow function may be easily solved by a commercial or even free linear programming solver. In the case being considered the following maximal value of the objective function is obtained

$$L = f_{1,2} + f_{6,7} = 1 + 1 = 2.$$

Software implementation

Database – the system uses a NoSQL database for storing all patients’ data and physicians’ accounts. NoSQL was chosen as it gives flexibility to the records stored in the database. A specific patient can have a special field which no other patient has without altering any other patients, which cannot be implemented with a standard SQL database.

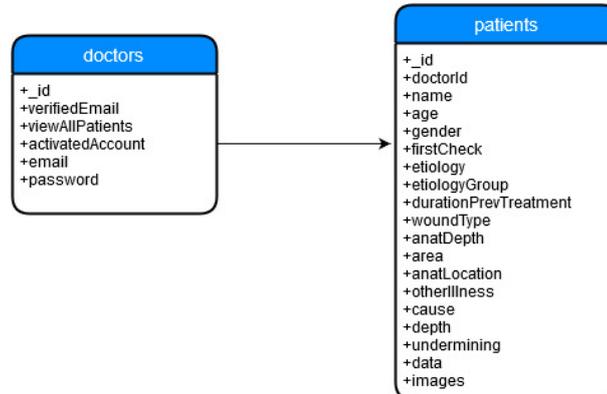


Fig. 3. Entity relationship diagram

In addition to that, the system makes relatively simple queries to the database which on a NoSQL database get executed much faster than a traditional relational database.

User management – an important step in dealing with patient data is the Physician–patient privilege. During the user management system design, that privilege was taken into account. Each physician has a unique number which is included in the patient’s file they being created in system. When a physician is logged into the system and he/she searches for patients, he/she will only see and alter the patients that were created by him/her and does not have access to any patients created by another physician.

When the physicians are in training phase, they have access to a specific number of patients whose personal details such as name, unique number, etc., are hidden in order to protect their privacy. The trainees only have access to medical data related to treatment by the PRP method.

Any guest users only have access to the front page of the system where successfully cured patients' cases will be shown.

The access to the developed system is limited. After initial registration, access is given based on the type of the physician – treating or training.

The system also has a restrictive mode in which when a physician registers, a physician who is already verified or the administrator, must approve them in order to gain access to the system.

4. Results and discussion

The results of the developed PRP-Project software system are presented in Figs 4 and 5. In 2019, the software system was used at UMBAL KANEV Rousse in the Orthopaedics Clinic for processing medical data of patients treated with PRP, evaluating the results of the current and their general condition.

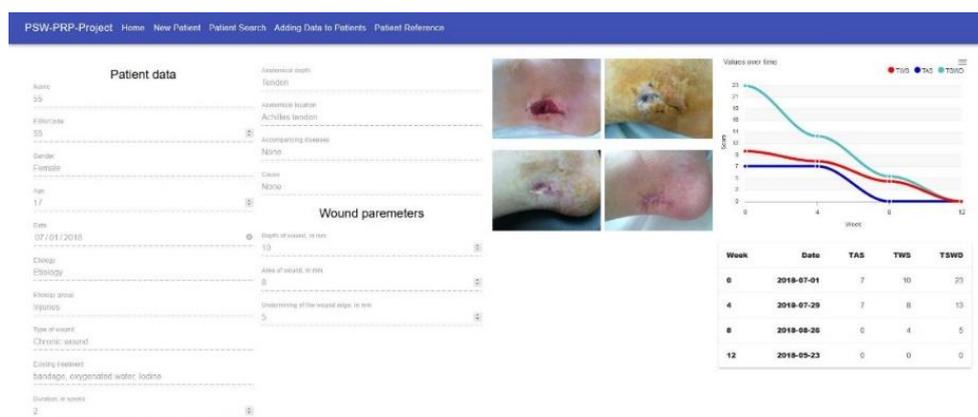


Fig. 4. HMI window for 17 years old woman, successfully treated in 12 weeks

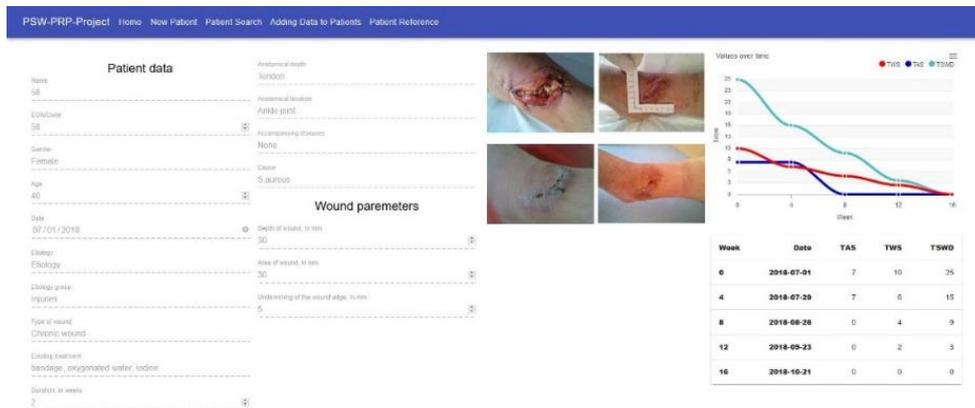


Fig. 5. HMI window for 40 years old woman, successfully treated in 16 weeks

Gender	Age	Etiology	Etiology group	Existing treatment	Duration	Anatomy depth	Anatomy location	Accompanying diseases	Cause	Depth	Area	Undermining
Male	67											
Male	67	Etiology	Trauma	bandage, oxygenated water, iodine	5	Subcutaneous tissue	Achilles tendon	None	S.aureus	3	16	1.5
Male	67	Etiology	Trauma	bandage, oxygenated water, iodine	18	Bone	Heel area	None	None	5	12	1
Male	67	Etiology	Trauma	bandage, oxygenated water, iodine	3	Subcutaneous tissue	Lateral malleolus	Diabetes	S.aureus	5	18	5
Male	67	Etiology	Trauma	bandage, oxygenated water, iodine	2	Fascia	Lower leg	Diabetes	None	8	10	5

Fig. 6. Reference for 67 years old men

The proposed PSW-PRP-Project software system was developed as a web application that makes it available online. The expressed interest in the developed software system also determined the creation of a training regimen through access to the created database of training of physicians practicing PRP treatment (Fig. 6). Each cell in the selection menu has a priority of exclusion OR.

The presented algorithms are really effective and applicable in outpatient and inpatient care because they ensure reliable and effective treatment of patients with problematic skin wounds by applying platelet-rich plasma. The algorithms are based on our results, obtained for the first in Bulgaria while treating problematic skin wounds by using platelet-rich plasma and successfully treating 92.78% of patients to full recovery.

The treatment algorithm presented in Fig. 1 is developed based on studies and analyses and for the first time in Bulgaria we used digitized criteria for assessing problematic skin wounds through all stages of wound healing until complete tissue regeneration. The results obtained allow giving an estimate for the treatment time.

The conducted tests of the algorithm proved that 88.25% of cases of acute potentially problematic skin wounds have been diagnosed at an early stage of wound and the treatment with platelet-rich plasma was successful. The treatment algorithm achieved 85.71% complete healing of problematic wounds. Results obtained have allowed us to conclude that the two algorithms are adequate to the task assigned – successful healing of problematic skin wound in a natural and biologic way.

5. Conclusion

The proposed algorithm for treatment of problematic skin wounds by using platelet-rich plasma is an effective and safe way for decreasing hard to heal complicated skin wounds and ensuring the subsequent normal life of the patients.

Using the proposed TWS, TAS and TSWD criteria for wound assessment allows accurate, prompt and easy evaluation of the entire wound healing process and estimation of specific wound treatment duration by outpatient staff.

The algorithm for therapeutic application of the method in acute, potentially problematic and problematic skin wounds optimizing the quality of treatment is the only one in the world presented in this form and type.

The established software system: (i) Facilitates the generation and tracking of patient-specific data, enables a quick review of his or her therapeutic history in platelet-rich plasma treatment; (ii) Allows comparison of photographic material in different medical cases, as well as references to each indicator at any time through the mobility of the application; (iii) Ability to communicate effectively with other physicians and discuss clinical cases.

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