IMAGING ANALYSIS OF PHYSICAL PARAMETERS IN THE EVOLUTION OF A CHEMICAL BURN CASE OF ABOUT 2% BODY SURFACE AREA - CASE PRESENTATION

GEORGETA BURLACU*,**, CĂTĂLIN CONSTANTIN ARMEANU*****, SIMONA ILEANA ROMANESCU****, MĂDĂLINA RADU***,****, BOGDAN URSU******, DAN MIRCEA ENESCU***,*******

Summary

Burns are one of the most serious skin lesions, chemical burning, in our case, usually destroys all layers of the skin. The deep dermal burns and burns of all thickness require early surgical excision and tegumentary grafting, because in the absence of surgery, their healing extends for more than 3 weeks and produces vicious, keloid or hypertrophic scars with functional and aesthetic sequelae.

Determining the depth of burns is one of the challenges faced by the plastic surgeon. Differentiation is usually done on clinical criteria, and the diagnostic accuracy in these cases is not more than 76% (1).

We hereby present the case of a 72-year-old patient who suffered a chemical (cystostatic substance) burn in the foot level. Monitoring of wound development and treatment efficacy was achieved through photographs taken at each dress change. These were analyzed according to specific physico-mathematical formulas. The development of a diagnostic algorithm based on these formulas indicated the appearance of granulation tissue about 2 days prior to clinical degradation. The granulation tissue is an essential structure for grafting and wound healing. Using the elaborated algorithm we could follow the efficiency of the applied treatment and set the optimum operator moment for grafting, the postoperative results being very good.

Imaging physics (the analysis of the images) can be a valuable tool for medical investigation, both for the proper assessment of the degree of burns (its degree) and for the determination of the effectiveness of the applied treatment and the appearance of the granulation tissue.

***Key words**: chemical burn, granulation tissue, imaging physics, Metlab.*

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Introduction

Burns are the result of tegumentary contact with physical (thermal, electrical) or chemical agents. They are among the most common causes of accidents and cause extreme medical, surgical, psychological and social problems of vital, potentially invalid nature.

Chemical burns are one of the most serious injuries. Most chemical agents produce a clotting necrosis by protein distortion, causing the formation of an escape limiting tissue penetration. The severity of the burn depends on a number of factors, including the agent's pH, concentration, duration of contact time, volume and physical form of the agent.

The eschar formed by contact with the acid prevents the healing process and should therefore be removed - usually surgically - or by chemical or enzymatic deters.

* UMF Carol Davila.
** Emergency Clinical Hospital Bucharest - Emergency Unit - SMURD
*** UMF Carol Davila.
**** Bucharest Emergency Clinical Hospital - plastic surgery.
***** Denton Oncology Center @ Presbyterian HospitalDallas-Medical Physics
****** SC C & T BBG S.r.l- development of data projection solutions, monitoring
******* Clinical Emergency Hospital for Children - Grigore Alexandrescu - plastic surgery and burning

Case presentation

PC *, male patient aged 72 years, diagnosed with: Bronchopulmonary Centriohilar Neoplasm right T4NxM1PUL bilateral, BPOC. Kidney Disease Cr. Std.III. Arteriopathy obliteranta std IVFontaine inferior member bilateral. Post amputation status inferior member left, Essential Hypertension, in the treatment of specialty-PCHt-Docetaxel 80 mg, showing a wound in the left pre-leg. Clinical examination allowed the diagnosis of: Chemical (cytostatic) grade IIB-parcel III, front dorsal left pre-leg, digital films I-IV, about 2% body surface area.

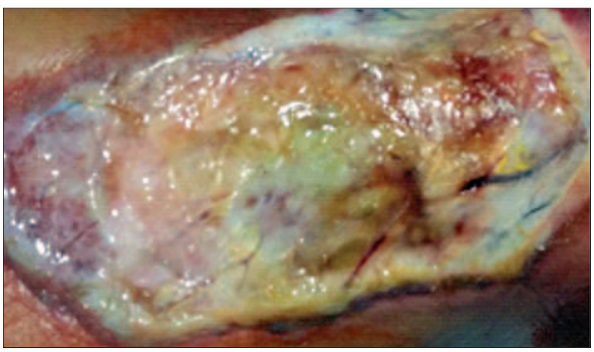


Fig. 1. The initial aspect of the burned wound

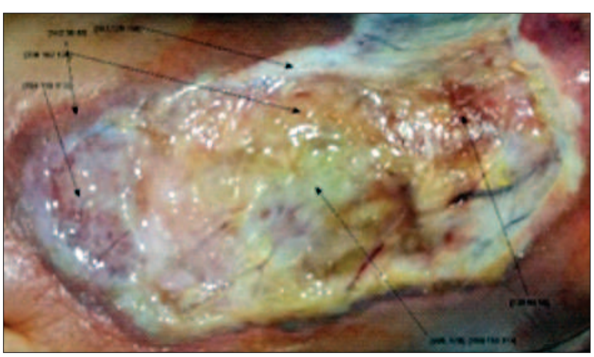


Fig. 2. Digital analysis of the picture

First, was established an abundant lavage with physiological saline (to remove the chemical agent) and then was performed a mechanical debridement of the necrotic tissue from the wound.

Afterwards, Sulfadiazine Silver and Hyaluronic acid were sprayed in a thin layer (spray). To keep wet the wound environment, it was used a hidroactive dress with antiseptic (polyhexamethylene biguanides and Ringer solution).

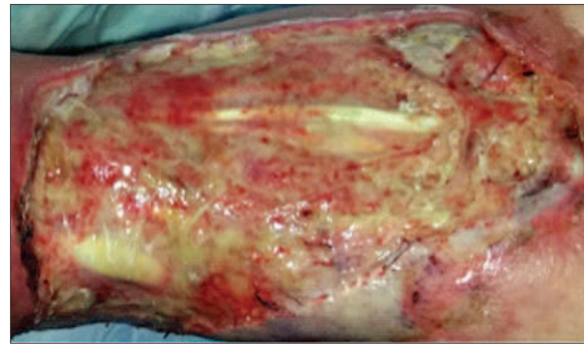


Fig. 3. The wound aspect at the 3rd day

Fig. 4. The wound aspect at the next dress

Starting with the first dress we could see the remission of the inflammatory phenomena and the appearance of the perilesional hyperremic line. The chemical cleaning continued in the following days, and formation of granulation buds was observed.

The dress was changed every 3 days, the biological debridement being done in about 9 days.

On the 10th day there is a complete remission of inflammatory phenomena, with the persistence of necrosis outbreaks, which are being disrupted at the IV-V metatarsalphalangeal joints.

Fig. 5. The wound aspect 10th day

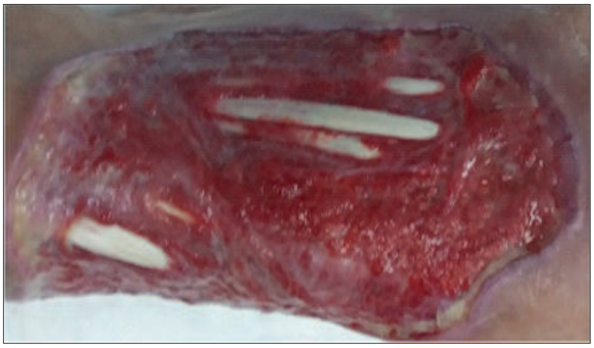


Fig. 6. The appearance of granulation tissue is observed

After the removal of the devitalized tissue and the appearance of the granulation tissue, were used paraffin ointments with 0.5 chlorhexidine acetate, over which was applied hyaluronic acid cream. To absorb excess fluid, a silicone dress was applied which also allowed the patient's discomfort to be diminished.

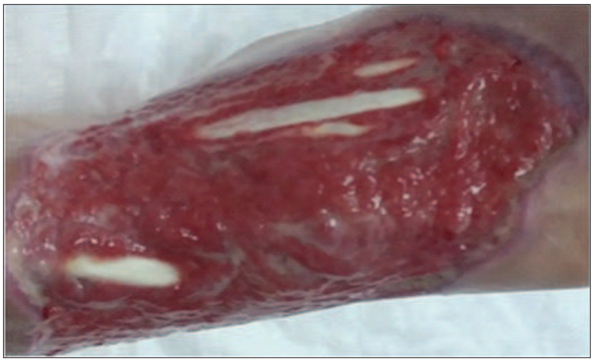


Fig. 7. The wound ready for graft

Fig. 8. The final aspect of the wound (day 29)

At the dress from the 15^{th} day, a granular wound with marginal epithelial buds is found on about 65% of the anterior lower-leg tendon surface and the finger extensor tendon III.

The appearance of granulation tissue allowed at 18 days post-injury, the self-graft. The local evolution was favorable, the graft being viable, 100% attached (integrated). We consider that the obtained postoperative result, both functional and aesthetic, was very good.

Imagistic analysis

General Notions

Matlab (abbreviated from the Matrix Laboratory) is one of the most important programming environments in imaging analysis. A digital image is composed of pixels, each corresponding to a color shade. Digital colors result from the combination of RGB (red, green, blue) and grayscale. Each combination is assigned a numeric value.

This is a program used for the benefit of both humans and animals, with the help of Matlab it was possible to study the behavior of laboratory animals (10). David Meaney, biomedical engineer, uses lab mice to study the pathophysiology and behavioral deficits caused by the traumatic head injuries aided by the program. (10).

The **Matlab** program allows reading an image as a matrix consisting of the numerical values assigned to each pixel. Analyzing the statistical parameters of an image is to track the repetition of some pixels and their neighbors, respectively the corresponding numerical values.

The first calculated parameter is the average. **The arithmetic average** of the numeric values of all the pixels in the image allows the calculation of the other parameters. **The standard deviation** applies to images in which the colors have been changed to grayscale (**Matlab** can recognize 65,000 such tones) and express the variation in gray intensity around the average. **Skewness** (symmetry) analyzes the symmetric distribution of pixel values around the average. **Kurtosis** is the extent to which image pixel values are high above or below average. **The Entropy** of an image is characterized by the repetition of a color in the image. Maximum entropy is when a color does not repeat. **Energy** is the repetition of a pixel pair in the image. The maximum energy is when we have a constant distribution of pixel pairs or when pairs of pixels repeat periodically. **Homogeneity** refers to the approximation of pixel pairs that is repeated in the image.

Statistical parameters are tracked according to a variation, in this case **the time**, respectively the number of days of treatment. The graphical representation of the parameters allows you to notice any change in the texture of the images.

Wound imaging analysis can highlight transitions between the healing phases. Knowing the numeric value of the color that represents the health of a plague, it can be seen that value whenever pixel by pixel is repeated in the image. The **Matlab** program allows graphical representation of the value of the analyzed parameters and the establishment of an evolutionary and therapeutic algorithm.

Statistical analysis of the images

An image or texture I (i, j) with dimensions **m**-with-**n** is a two-dimensional matrix composed of **m** pixels in vertical direction and **n** pixels in horizontal direction (**i** and **j** represent the horizontal and vertical coordinates of the image). The total number of pixels in the image matrix at the gray level is therefore $m * n = N$, $1 \leq i \leq m$, $1 \leq j \leq n$.

The statistical parameters that can be used are:

1. The medium value ì , meaning the medium level of the intensity values of the image or texture I (i, j): Using the appropriate formula, the chart obtained according to the treatment days looks like in the picture 1.

2. The standard **S** irregularity (deviation) of the gray level is defined as the square root of the variation. If the value of the variation is closer to average, the standard deviation is lower (picture 2)

3. The asymmetry is a physical or mathematical characteristic of a system that remains unchanged under the action of a transfer (picture 3).

4. **Kurtosis** is an indicator used to analyze the distribution of a series of data to indicate the degree of flattening or sharpening of a distribution (picture 4).

Next, the second order statistical parameters are calculated from the Cooccurrence matrix of the Gray level (GLCM) of the texture. The Cooccurrence matrix is a probability matrix that measures how many times pair of pixel appears in the image. Thus, it is calculated

5. The **Entropy** is the measure of the disruption of Gray levels in an image. The Entropy of an image is calculated by calculating the probability P of a particular Gray value found in that image(picture 5).

6. The **Energy** measures textural uniformity, i.e. pixel pairs repetitions. The maximum texture or image energy occurs when the Gray level distribution is either constant or periodically uniform (picture 6)

7. The **Homogeneity** measures the degree of approximation of the distribution of values in GLCM. It is a material environment that is defined in relation to at least one physical characteristic (dimension), it does not have an absolute character, that is, it is possible that a environment (system) to be homogeneous with respect to a parameter and that it is heterogeneous with respect to one or more parameters (picture 7).

8. Correlation of images – the correlation coefficient is a metric that expresses the similarity (level of matching) between two signals, so it is very often used to search for patterns (picture 8).

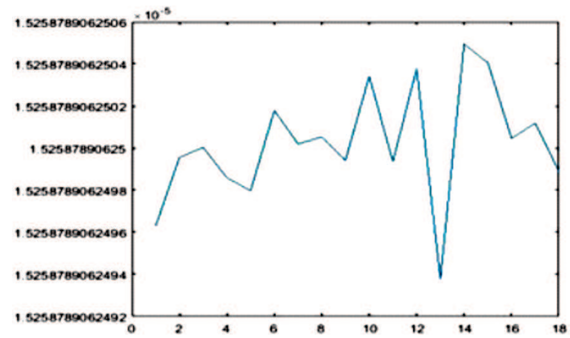
In the above formula, ìx, ìy and óx, óy are the average and the standard deviations of the matrix probability P along the wise row (Px) and on columns (Py), and the correlation does not refer to two different objects, it is a internal pixel correlation.

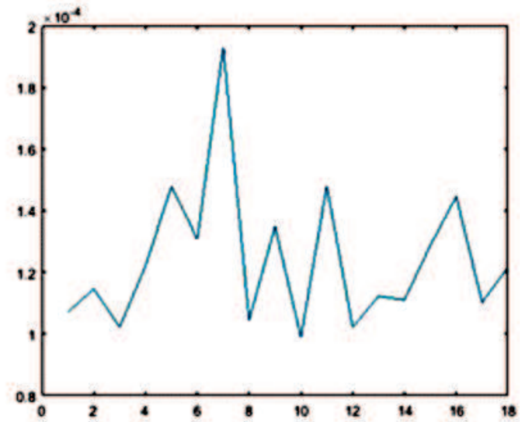
Discussions and Conclusions

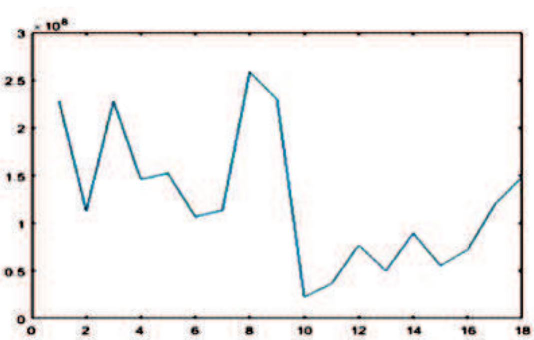
The burns is probably the most severe form of trauma the human being can suffer. There are two distinct steps in the treatment of burns:

- Acute stage where efforts are focused on patient survival and emergency surgical procedures with a functional first-line priority.
- Postoperative stage in which surgical and recovery treatments are required to correct post-injury sequelae, improve aesthetic function and appearance.

Every wound undertakes to healing four phases: haemostasis, inflammation, proliferation and maturation (remodeling). In the local evo-

$$\mu = \frac{1}{N}\sum_{i=1}^{m}\sum_{j=1}^{n} I(i,j)$$	
Calculation formula for the medium value	*Fig. 1. The chart obtained for the medium values*

$$S = \sqrt{\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(I(i,j)-\mu)^2}{N-1}}$$	
Calculation formula for the standard deviation	*Fig. 2. The chart obtained for the standard deviation*

The asymmetry $= \dfrac{\sum_{i=1}^{m}\sum_{j=1}^{n}(I(i,j)-\mu)^3}{(N-1)\times S^3}$	
Calculation formula for asymmetry	*Fig. 3. The chart obtained for asymmetry*

Kurtosis = $\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(I(i,j)-\mu)^4}{(N-1)\times S^4}$

Calculation formula for Kurtosis

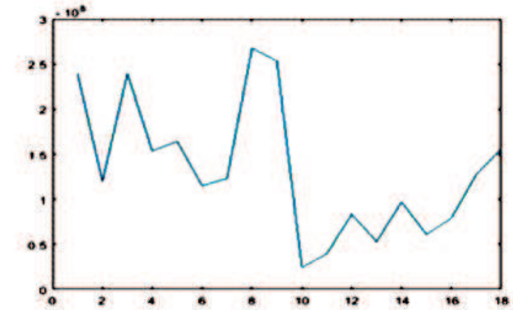


Fig. 4. The chart obtained for Kurtosis

Entropy = $-\sum_{i=1}^{m}\sum_{j=1}^{n}P(i,j)\log P(i\,,j)$

Calculation formula for Entropy

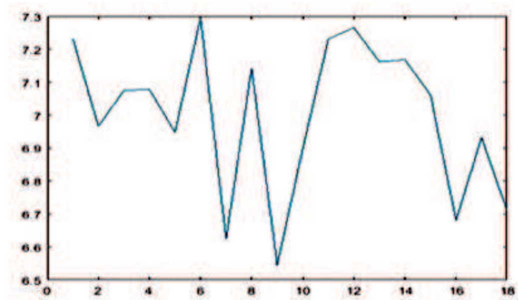


Fig. 5. The chart obtained for Entropy

The Energy = $\sum_{i=1}^{m}\sum_{j=1}^{n}(GLCM(i,j))^2$

Calculation formula for Energy

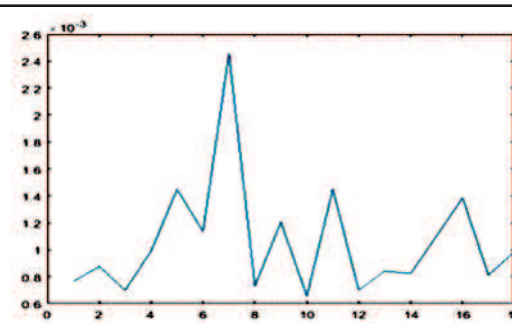


Fig. 6. The chart obtained for Energy

Homogeneity = $\sum_{i=1}^{m}\sum_{j=1}^{n}GLCM(i,j)\frac{1}{1+(i-j)^2}$

Calculation formula for Homogeneity

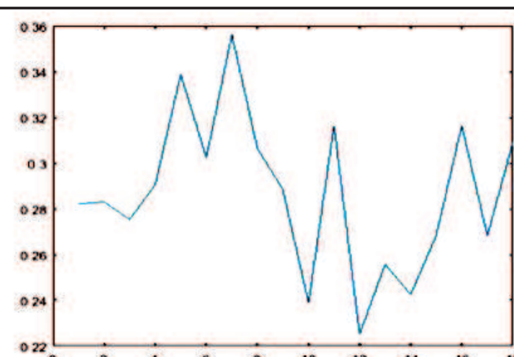


Fig. 7. The chart obtained for Homogeneity

Correlation = $_{=1}^{n}\sum_{j=1}^{n}\frac{\{i\times j\}\times P(i,j)-\{\mu_x\times\mu_y\}}{\sigma_x\times\sigma_y}$

Calculation formula for Correlation

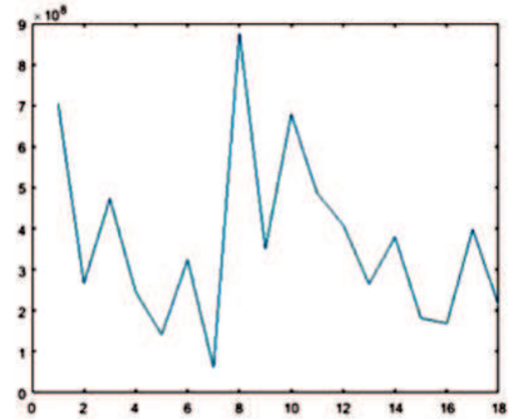


Fig. 8. The chart obtained for Correlation

lution of a burned wound, the main phenomena are the removal of the nonviable tissue, followed by the appearance of granulation tissue (surface suitable for grafting) and finally epithelization. As the healing takes place, the granulation tissue (made up of red buds) is epithelized, covered with lighter tissue. Finally, the scar is formed, which in the case of favorable evolution is close to the color of the skin.

The cutaneous graft applied to a granulation tissue is initially white (pale), nourished by imbibitions. Once with the penetration of blood vessels, the viable graft becomes initially violet (cyanotic), then over time becomes pink, approaching that of the adjacent skin. If the graft is not viable (lost contact with the underlying tissue, it was not properly vascularized etc.), the color differences become more apparent, from the white persistence (lack of vascularization) to the black color of the necrotic tissue.

As a result, the variations in color that can be observed in the burned wound evolve from white to gray or even black of non-viable or necrotic tissue through different pinkish reds with the grain tissue being applied to a color close to that of normal skin.

The depth of the burned wound – the so-called degree of burning – is the determining factor of its healing potential (resulting from deep or adjacent tissues unaffected by the causative agent). The operative or conservative treatment decision (surgery or abstinence) is primarily influenced by degree and type of burn, as they determine local development.

Determining the difference between superficial and deep burns is extremely important from the point of view of therapeutic conduct. It has been established since the last century that the evolution of a burned wound is much better and the healing takes place faster and with less functional and aesthetic sequelae if the burning tissue rapidly escapes in deep burns. Surgery is necessary to reduce local inflammation and allow healthy tissue to ensure that the defect is covered (by providing epithelialization in depth and from the edges of the wound). Differentiation between deep burns (which do not have sufficient vascularization and reserves to allow for healing) and superficial (in which the healing even without outside intervention takes place in about three weeks) is particularly important in order not to lose the essential surgical moment in a deep burning and to avoid unnecessary surgery in a shallow wound.

Therefore, it has long been felt the need for an objective method to determine as accurately as possible the depth of burns. Several devices have been developed that make an estimation of tissue perfusion in the wound, knowing that lower tissue vascularization is usually the result of a deeper burn.

The golden standard in determining the depth of burns is histological evaluation, but this requires biopsy of the wound, and the results are obtained in a minimum of 24–48 hours.

Flowmetria Laser-Doppler and Laser-Doppler monitoring of the tissue perfusion works on the principle of changing the laser beam frequency by reverting the light waves upon contact with the red cells in motion. The change in frequency is proportional to the tissue vascularization. The method has been approved by the FDA and allows the differentiation of superficial blemishes from the 90–99% deep cell. (2)

The Thermal imaging is called in short termography. It is based on the correlation between tissue temperature, tissue vascularization and burning depth. Essentially, the deeper the burn is, the less vascularized it is.

Lawson was the first to use the thermography to assess the depth of burns in dogs in 1961. (9.) In 1966, Mladick used thermal imaging to assess burns in human patients.(8.)

Hacket has demonstrated in a clinical study that thermography correctly evaluates the depth of burns in 90% of cases, while clinical examination succeeds in 67% of cases. %. (1.)

The imaging analysis of a wound enables its evolution, i.e. the monitoring of the removal of necrotic tissues and the appearance of the granulation buds. After photographing with each ointment and using statistical programs (**Matlab**) to determine the color variation of the pixels, it was possible to analyze certain parameters reflecting the distribution of pixels and their changing color.

In the evolution of the wound in our presentation, it was found that:

- The average chart has reached a numerical value that represents the disease state (necrosis) at another numerical value representing the state of health.
- The symmetry of pixel values around the average has evolved from asym-metrical to symmetrical.
- The Kurtosis ranged from acute to moderate values, and in the evolution to health no more acute values occurred.
- The Entropy of a healed wound has become minimal.
- The Energy of the wound increased, becoming the maximum.
- At the same time, Homogeneity became more evident with healing.

In addition to the statistical parameters presented above, the dynamic parameters of an image can also be traced: speed, acceleration and kinetic energy. The speed and acceleration of an image is the difference between the values of two pixels joined. The higher the difference between the values, the higher the speed. The kinetic energy is the change in pixel values between the first image at the beginning of the evolution and the final image.

In our case, the algorithm of imaging analysis has allowed us to evaluate necrotic tissue and the appearance of granulation with more precision. I used the Nikkon camera with special attached lenses, taking pictures of the clinical evolution of each ointment.

Computerized digital imaging analysis has provided the ability to visualize tissue color variations, which are normally not visible to the eye.

Determining more accurately via imaging analysis of areas lacking viability, differentiating them from those with uncertain viability and those that evolve favorably allowed the adaptation of treatment to clinical evolution. The presence of areas with a close proximity to healthy areas, correlated with their distribution and the size of the areas where necrosis persists, was permanently monitored and recorded in the **MatLab** program. The dress were continued until the images showed that homogeneity and wound energy allow a cutaneous grafting.

The implementation of the imaging physical analysis algorithm in the evolution of burns allows, on the one hand, a more accurate appreciation of the depth of the affected structures and the viability of the tissues. By using the statistical program, it is possible to monitor the wound evolution more correctly, which will lead to the establishment of the therapeutic course according to the evolutionary phases.

The image analysis, by image digitization and statistics is a way of studying remote data, is reproducible, computerized, and maximally effective. An important advantage is the possibility of monitoring the development of a wound through the telemedicine system.

Bibliography

1. Hacket MEJ. – The use of thermography in the assessement of burn and blood supply of flaps withe preliminary reports on its use in Dupuytren s contracture and tretement of varicose ulcers.*Br J Plast surg*. 1974:27:311-317.)
2. Jaskill AD, Ramella-Raman JC, Shupp JW, Jordan MH, Jeng JC – Critical review of burn depth assessment techniqnes: part ii. Review of laser Doppler technology. *J Buurn Care Res*. 2010 Jan-Feb; 31(1): 151-7).
3. R. Mutihac, medical imaging, University Publishing House of Bucharest, 2011.
4. S. Curteanu, Initiation in Matlab, Polirom Publishing House, 2008.
5. R. Gonzales, R. Woods, S. Eddins – Digital Image Processing Folosind Matlab, Pearson Education, 2004
6. Chemical Burns – Robert D Cox, MD, 2015 – Medscape
7. Skin Anatomy – Bardia Amirlak, MD, 2015 – Madscape
8. Maldrick R, Georgiade N, Thornr F. – A clinical evolution of use of thermography in determining degree of burn in injury. *Plast Reconstr Surg*. 1966; 38: 512-518.
9. Lawoson RN, Wladek Cb, Webster DR. – Termographic assesment of burns and frost bite. *Can Med Assoc J* 1961;84:1129-113.
10. The Scientist/November 1, 2016. Assessing the Behavior of Lab Animals.

Conflict of interest
NONE DECLARED

Correspondance address: Georgeta Burlacu
UMF Carol Davila Emergency Clinical Hospital Bucharest
e-mail: georgetaflorea77@yahoo.com