Digital Image Analysis for the comparative study of skin erythema after skin closure of surgical wounds

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Abstract: Digital images of clean surgical wounds following suturing were obtained and computer-assisted image analysis was performed. Surgical wounds were sutured by two different kinds of sutures each. A comparative study of the quality of five different suture materials according to the quantity of skin erythema that they caused was carried out. The aim of study was to establish an objective method for quantitative measurement of skin erythema. Our Digital Image Analysis (DIA) software was focused on the necessary transformations of the images obtained, in order to evaluate the superiority of red color value in every pixel using normalized red-green-blue (RGB) values. Each surgical wound was sutured by two different kinds of material in a randomized way using five different materials. Comparison of skin erythema was performed between the pair of suturing materials used in the same surgical wound. Digital images were obtained before, after suturing, right after removal of sutures and a month later. The mean value of normalized red was measured in both halves of the wound in every image obtained. DIA was performed by the software "ΦΩΣ" (PHOS) of digital morphometric analysis which was developed for the purposes of the study. Statistical analysis of the results was performed by the paired Wilcoxon Signed Rank test. The present study shows a non-invasive quantitative method of skin erythema evaluation. The software "ΦΩΣ" calculated the mean values of normalized red in surgical wounds closed by the pairs of sutures AB, AC, AD and AE ($p<0.05$ in 3 out of 4 groups). Skin erythema produced by suture material A is lower than that of the rest four kinds of sutures and was reliably evaluated as the mean value of normalized red by the software "ΦΩΣ". The developed software can, non-invasively, evaluate quantitatively the skin erythema caused in surgical wounds after skin closure.

Key-Words: Skin erythema; Digital Image Analysis; Normalized red; Morphometric; Software "ΦΩΣ";

1 Introduction

The human eye can satisfactorily describe the quality of skin erythema but this does not occur when quantitative evaluation is needed. Several scales have been suggested and used broadly in everyday clinical practice but these are all based on the subjective evaluation of the examiner and cannot really detect the changes in depth of time [5]. There is also possible genetically decreased perception of red color among humans and therefore the results of clinical examination may not be objective [6]. The development of an exact quantitative method for the expression of skin erythema would assist the clinician to evaluate the progression or regression of any skin disease where erythema holds the leading part and is actually the cause of the patient's visit to the doctor. Accordingly, it is possible to evaluate objectively the skin erythema which appears after skin closure of surgical wounds and to determine the suture material which is least irritating to human tissues.

Mattsson et al showed that digital image analysis (DIA) can successfully characterize the changes of erythema after burn injury by the system of normalized color [1], [2]. DIA is a modern and well accepted by the scientific community, computerized method for studying skin lesions. It is widely known that every pixel is characterized according to place (i,j) and color in a picture M (i,j) [3]. The color is defined by three components of luminous density for the basic colors. The values of every component of luminous density in true color range from 0 to 255 (since the human eye can perceive up to 256 different color tones). In the system RGB the basic colors are red (R), green (G) and blue (B). The combination of luminous densities of the three basic colors defines the color of a pixel in a picture. The

number of possible combinations is 256*256*256 = 16,777,216 colors possible to distinguish.

The usage of digital color is effective in the commonly used photographic applications; nevertheless it has to undergo transformation so that it can be perceived by the human eye. This transformation will render the association of basic colors since it is necessary to evaluate the superiority of red color value in every pixel when studying skin erythema [4], [6]. The introduction of normalized color associates the three colors in such a way that one's increment results in the decrement in the other, in opposition to normal color where the above stated does not stand [7]. The transformations needed to be done at the pixels of a digital picture M(i,j) are according the following mathematical equations:

$$Rn(i,j)=255*R(i,j)/(R(i,j)+G(i,j)+B(i,j)) \quad (1)$$

$$Gn(i,j)=255*G(i,j)/(R(i,j)+G(i,j)+B(i,j)) \quad (2)$$

$$Bn(i,j)=255*B(i,j)/(R(i,j)+G(i,j)+B(i,j)) \quad (3)$$

Where R(i,j), G(i,j), B(i,j) the components of luminous density of the basic colors according Young's theory of light for every point M(i,j) of a picture.

Where Rn(i,j), Gn(i,j), Bn(i,j) the normalized color values that objectively attribute the superiority of one color, over the other two, at the same point of the picture.

2 Problem Formulation

The present study focuses on the development of an exact quantitative method for the evaluation of skin erythema which occurs in a clean surgical wound after skin closure with sutures. It is a comparative study on the quality of different kinds of suturing material according to the quantity of skin erythema that they evoke in surgical wounds.

The aim is to define the least reactive to the sutured tissues, material. This reaction is a result of local irritation to the foreign suturing material as well as traumatizing of the tissues at the entry points of the sutures due to the applied tension.

3 Problem Solution

3.1 Material and Methods

In the present study the following suture materials are compared: A) PDS II (polydioxanone, Ethicon), B) Polypropylene (polypropylene blue, Assut sutures), C) Ethilon (Polyamide 6, Ethicon), D) Metallic clips (APPOSE™ ULC Tyco) and E) Vicryl rapid (polyglactin, Ethicon).

Digital photos are taken before, right after skin closure, following suture removal and a month after the operation. These photos are processed in order to evaluate the mean value of normalized red in the region of interest (roi). Digital photos are taken by digital camera Olympus 5060, 5.1 Mpixel analysis without flash, under sufficient white light and focusing in the middle of the surgical incision. The photos are processed under scale and result in the final pictures of 100 pixels/inch analysis.

Each surgical wound is sutured using two different kinds of suturing material. One half of the surgical wound is sutured with one kind of material and the other half with another, using the same number of sutures per side and same distances between sutures. Which half is to be sutured first with which material is chosen randomly. The same surgeon performs all skin closures. Therefore we are able to compare skin erythema caused by one suturing material in comparison to another in the same surgical wound. For comparing five different suturing materials ten pairs of them were used (ab, ac, ad, ae, bc, bd, be, cd, ce, de).

Results are divided into ten groups according to the ten pairs and containing ten cases each. In conclusion, a hundred cases will be primarily studied. Surgical wounds comprise surgical excisions of skin lesions. Wounds with any kind of postoperative complication, such as, hematoma, dehiscence or infection are excluded from the current study.

The patients' data are stored in Access database. For each patient we stored the name, age, sex, type of operation and the mean values of normalized red as a manifestation of skin erythema in the time intervals already mentioned.

The mean value of normalized red is determined in each half of the surgical wound by DIA in every photo. By registering the mean value of normalized red in different time intervals it is possible to evaluate the final result of skin closure as well as the progression or regression of skin erythema.

Digital analysis is performed by the specialized program "ΦΩΣ" (PHOS) of digital morphometric analysis specifically designed for the needs of the study. The software was written in MS Visual Basic 6.0^{tm} and runs in Windows 95, 98, 00, NT, XP. The general procedure for DIA analysis in our software is described: Clinical photographs of the surgical wound right after suture removal were loaded on "PHOS". A mask marks the half of the wound (ROI) with the more extended area of erythema as shown in Fig.1, and transforms the image to RGB form as in Fig.2. Then the mean value of normalized red of

ROI is calculated. The mask is moved to the other half of the wound and procedure is repeated. In this way, mean values of normalized red are obtained for each half of every surgical wound as in Fig.3.
Finally, all data are transferred to SPSS for analysis. Statistical analysis is done by Wilcoxon Signed Rank test. This is a non-parametric test for paired samples. The advantage of this test is that it does not presuppose regular distribution for the studied variables. In the case where the results show small or insignificant differences in the mean values of normalized red, the number of cases will be increased. Since the sample is paired, the number of cases able to establish an existing difference is expected to be relatively low.

3.2 Results

Our clinical impression on the superiority of one suturing material over another was up to now verified for 31 cases studied:

Normalized red mean values for the pairs of sutures comparing suture A with B,C,D and E are included in Table 1.

The statistical analysis was done by Wilcoxon Signed Rank test and the corresponding results are in Table 2 and Table 3.

4 Conclusion

There is a vast variety of skin diseases where the main sign which leads the patient to the physician is skin erythema. In clinical trials up to now and in everyday praxis, the degree of erythema is subjectively measured by naked eye. Several efforts have been made to develop a quantitative way of measuring erythema, some of which are used up to now [4], [5], [6], [7]. The need of developing a user-friendly software that can quantitatively evaluate the redness of a ROI has emerged in conjunction with the fact that red is the superimposing feature of erythema. The software "ΦΩΣ" can transform any digital photograph into a normalized red pattern and process the three basic colors, providing mean values, standard deviation and histograms. In this software it is possible to define a ROI and specifically isolate the erythematous region. In the current study skin erythema which is caused by skin closure of clean surgical wounds has been chosen. Different kinds of suture material were used and expected to produce various degrees of erythema. Indeed, the promising results, up to present, showed the superiority of one material that caused lower mean values of normalized red areas in the halves of the same surgical wounds whose other halves were sutured by three other kinds of sutures.

Fig.1. Mask drawing over the left half of the wound from which sutures have been removed right before being photographed

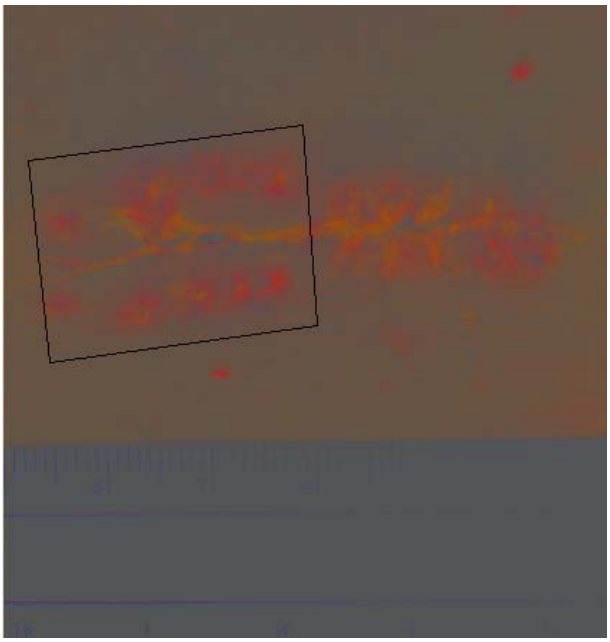

Fig.2. RGB transformation of the digital photograph by the software "ΦΩΣ"

Therefore skin erythema produced in the surgical wounds by suture material A was the least observed compared to the other four kinds of suture material. The very promising results lead to the belief that this

software will be able to objectively evaluate normalized red in the context of skin erythema not only in surgical wounds but also in a variety of skin diseases where erythema plays the leading role.

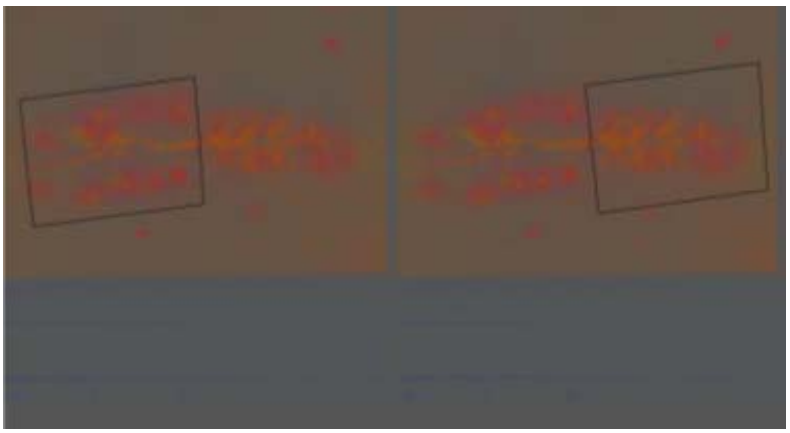

Fig.3. A mask is drawn around the region of interest. Normalized red of ROI is calculated. The mask is moved to the other half of the wound and procedure is repeated. In this way, mean values of normalized red are obtained for each half of every surgical wound

Table 1.
Mean values of normalized red for the pairs of sutures comparing suture A with B, C, D and E

A	B	A	C	A	D	A	E
99.72	99.75	106.29	107.2	99.75	107.8	110.02	110.12
111.73	116.61	102.06	107.58	114.3	116.74	114.95	118.63
98.23	100.86	96.13	96.62	110.87	112.13	106.3	108.17
105.9	107.17	106.25	107.76	104.32	111.46	101.46	103.44
108.1	108.78	105.9	107.17			101.46	107.57
98.17	126.03	107.27	110.82			113.9	114.29
102.64	105.55	104.83	110.24			115.08	115.1
102.41	105.09	108.96	111.09			100.95	103.47
107.29	111.1	104.06	106.9				
105.32	109.95						

Table 2.
Wilcoxon Signed Rank test – Statistics

Test Statistics(c)				
	AB2 - AB1	**AC2 - AC1**	**AD2 - AD1**	**AE2 - AE1**
Z	-2,803(a)	-2,666(a)	-1,826(a)	-2,521(a)
Asymp. Sig. (2-tailed)	,005	,008	,068	,012
a Based on negative ranks.				
b Based on positive ranks.				
c Wilcoxon Signed Ranks Test				

Table 3.
Wilcoxon Signed Rank test – Ranks

Ranks				
		N	**Mean Rank**	**Sum of Ranks**
AB2 - AB1	**Negative Ranks**	0(a)	,00	,00
	Positive Ranks	10(b)	5,50	55,00
	Ties	0(c)		
	Total	10		
AC2 - AC1	**Negative Ranks**	0(d)	,00	,00
	Positive Ranks	9(e)	5,00	45,00
	Ties	0(f)		
	Total	9		
AD2 - AD1	**Negative Ranks**	0(g)	,00	,00
	Positive Ranks	4(h)	2,50	10,00
	Ties	0(i)		
	Total	4		
AE2 - AE1	**Negative Ranks**	0(j)	,00	,00
	Positive Ranks	8(k)	4,50	36,00
	Ties	0(l)		
	Total	8		

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