Analysis of portwine stain disfigurement and pulsed dye laser treatment results
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Citation for published version (APA):

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Color evolution of untreated portwine stains

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Abstract

Darkening of portwine stains with age is a generally accepted but seldom documented hypothesis. In this paper the color evolution of untreated portwine stains was investigated, using objective measurements of the color of both portwine stain and healthy skin of 100 patients with an untreated portwine stain in the head-neck area, whose ages ranged from 0 to 52 yr.

Color was measured with a Minolta chromameter and characterized in the three dimensional L*\(a^*\)\(b^*\) color space. The color parameters, their differences between normal skin and portwine stain, and perceived color difference were plotted as a function of age. Simple linear regression was used to assess changes of the color parameters with age.

The results show darkening of the portwine stain with age based on a significant decrease in lightness (\(L^*_{\text{pw}}\)), a small but significant decrease in redness (\(a^*_{\text{pw}}\)), and a virtually unchanged yellowness (\(b^*_{\text{pw}}\)). In normal skin, lightness (\(L^*_{\text{normal}}\)) decreases slightly but significantly with age.

Yellowness (\(b^*_{\text{normal}}\)) increases significantly with age. Redness (\(a^*_{\text{normal}}\)) increases slightly with age albeit not significantly. The differences between the three color components (\(\Delta L^*, \Delta a^*, \Delta b^*\)) change significantly with age. Surprisingly, the darkening of the portwine stain with age is not reflected by the perceived color difference between portwine stain and normal skin, due to compensating color changes with age in the normal skin.
Introduction

It is generally believed that portwine stains mature with age: "The pink color, characteristic of infancy, gradually darkens to a red shade during young adulthood and to a deep purple during middle age".\(^1\) This, and the nodularity developing with age,\(^2\) is hypothesized to occur according to a process of increasing dermal blood content, predominantly caused by increased size of vessels of the dermal plexus.\(^3\) However, to our best knowledge only very few documented cases can be found in the literature.\(^4\)\(^5\) Systematic studies of color, using objective methods to characterize color and including large numbers of patients, have not been reported so far.

With the lasers now available to treat portwine stains, it would be unethical to deny patients treatment of their lesion. It is therefore impossible to prospectively study color evolution of untreated portwine stains. An alternative approach is to determine portwine stain color of a large group of patients that for some reason did not have their portwine stain treated before.

As part of a clinical study, treating portwine stains in the head/neck region, the color of all portwine stains prior to treatment was measured with a chromameter.\(^6\) In this report our aim was to investigate whether the expected darkening with age was indeed found.

Materials and methods

100 patients with a previously untreated portwine stain in the head/neck region were included (age 0-52 yr, mean 14.7 yr). Color measurements were taken with a Minolta chromameter, type CR-300. Both portwine stain and contralateral healthy skin were measured. Colors were represented by L* a* b* coordinates, where L* denotes lightness, representing the object's reflectance relative to a 100 percent ideal diffuser (on a scale of 0 to 100, in which 0 represents black and 100 white); a* denotes values from green to red (negative values indicate green and
positive values red, and $b^*$ denotes values from blue to yellow (negative
denotes values are from blue to yellow). The color difference between portwine stain and contralateral healthy skin is represented by $\Delta E$, defined as

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2},$$

where $\Delta L^*$, $\Delta a^*$ and $\Delta b^*$ represent the differences in the respective measured $L^*$, $a^*$ and $b^*$ values, calculated as follows:

$$\Delta L^* = L^*_{\text{normal}} - L^*_{\text{portwine}}$$
$$\Delta a^* = a^*_{\text{normal}} - a^*_{\text{portwine}}$$
$$\Delta b^* = b^*_{\text{normal}} - b^*_{\text{portwine}}$$

We used least-squares linear regression analysis to assess changes in color parameters with age. Changes are assumed significant if $p < 0.05$.

Results

The measured values of the color parameters $L^*$, $a^*$ and $b^*$ for both portwine stain and normal skin, and their differences $\Delta L^*$, $\Delta a^*$ and $\Delta b^*$ are shown in Figs. 1-5 as a function of age. In Fig. 4 the color difference $\Delta L^*$ between normal skin and portwine stain, calculated from these parameters, is represented in the wrong way. Regression lines with their associated 95% confidence intervals are shown for each parameter.
Fig. 1: $L^*_{\text{normal}}$, $L^*_{\text{pws}}$ and $\Delta L^*$ versus age.

$L^*_{\text{normal}}$ decreases significantly with age ($p=0.0071$), from $64.7 \pm 1.1$ at age=0 yr to $60.9 \pm 2.2$ at age=52 yr.

$L^*_{\text{pws}}$ also decreases significantly ($p=0.0001$), from $55.1 \pm 1.4$ at age=0 yr to $45.4 \pm 3.0$ at age=52 yr.

$\Delta L^*$ increases significantly ($p=0.0009$), from $9.7 \pm 1.3$ to $15.5 \pm 2.5$. 

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Fig. 2: $a^*$normal, $a^*$pws and $\Delta a^*$ versus age.

The increase with age of $a^*$normal from $12.9 \pm 1.1$ at age=0 yr to $13.8 \pm 2.2$ at age=52 yr is not significant ($p=0.5413$).

The decrease with age of $a^*$pws from $24.2 \pm 1.1$ at age=0 yr to $19.6 \pm 2.3$ at age=52 yr is significant ($p=0.0035$).

$\Delta a^*$ decreases significantly ($p=0.0006$), from $-11.4 \pm 1.1$ to $-5.9 \pm 2.4$. 
The increase with age of $b^*_{\text{normal}}$ is significant ($p=0.0063$), changing from $12.3 \pm 0.7$ at age=0 yr to $15.1 \pm 1.5$ at age=52 yr.

The decrease with age of $b^*_{\text{pws}}$ is not significant ($p=0.1641$), changing from $9.6 \pm 0.9$ at age=0 yr to $8.0 \pm 1.8$ at age=52 yr.

$\Delta b^*$ increases significantly ($p=0.0001$) from $2.7 \pm 0.8$ to $7.1 \pm 1.6$. 

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The increase of $\Delta E$ from $15.2 \pm 1.6$ at age $= 0$ yr to $18.1 \pm 3.1$ at age $= 52$ yr is not significant ($p = 0.1553$).

In portwine stains lightness ($L^*_{pws}$) and redness ($a^*_{pws}$) decrease significantly with age. The decrease in yellowness ($b^*_{pws}$) is not significant. In normal skin lightness ($L^*_{normal}$) decreases slightly but significantly with age. Yellowness ($b^*_{normal}$) increases significantly with age. Redness ($a^*_{normal}$) increases slightly with age albeit not significantly. The differences between the three color components ($\Delta L^*, \Delta a^*, \Delta b^*$) change significantly with age, but the perceived color difference ($\Delta E$)
Discussion

In this paper we describe color measurement values of 100 untreated portwine stains as a function of age. We use this cross section of patients, with ages ranging from 0 to 52, as a model for color evolution of untreated portwine stains. The preferred study design would be to monitor a group of newborn patients with portwine stains over time, without treating their portwine stain. Since such a study protocol would not be approved by any medical ethical committee, our approach is the best alternative. There are however several potential drawbacks, e.g. our population consists of patients applying for treatment, and it is unknown whether their portwine stains are a representative sample of all possible portwine stains. Also, our population does not comprise very dark and/or purple portwine stains, not even in the patients over 40 yr of age. The reason might be that patients with such a portwine stain sought treatment earlier in life, such as tissue grafting, tattooing or argon laser treatment.

Our results show darkening of portwine stains with age based on a decreased lightness \( L^*_{\text{PWS}} \), a small decrease in redness \( a^*_{\text{PWS}} \) and a virtually unchanged yellowness \( b^*_{\text{PWS}} \). This correlates with the histological findings of Barsky et al. and the computations of portwine stain color of Verkruysse et al. Barsky found that older portwine stains contain more dermal blood due to larger vessels than younger portwine stains. Verkruysse calculated that an increased dermal blood content results in a decreased lightness whereas redness and yellowness remain virtually unchanged.

Surprisingly, the darkening of the portwine stains with age is not reflected by the perceived color difference \( \Delta E \) between portwine stain and normal skin, due to compensating color changes with age in the normal skin.
References