Skin cancer screening – better safe than sorry

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Abstract. Skin cancer is the most common type of cancers. In Latvia, on average there are approximately 200 new melanoma and 1300 non-melanoma cancer cases per year. Non-melanoma cancers are: Basal Cell Carcinoma, Squamous Cell Carcinoma and others. It is essential to discover skin cancer at an early stage when it is treatable. For this reason, a reliable, non-invasive and quantitative skin cancer screening method is necessary in order to discover skin cancer as early as possible and to help physicians such as general practitioners and dermatologists assign patients to the best treatment as soon as possible. In this article, the current skin cancer incidence as well as the screening situation in Latvia is described and a non-invasive skin screening method is proposed. The results show that this multispectral imaging method with a parameter p' can distinguish melanoma from melanocytic nevi with sensitivity 75% and specificity 100%. Recommendations on distinguishing henangioma, seborrheic keratosis are described as well.

Key words: skin cancer, melanoma, screening, diagnostics, non-invasive, multispectral, imaging.

1 Introduction

Skin cancer is the most common type of cancers [1]. If diagnosed early, skin cancer is treatable. Unfortunately, majority of the cases are discovered in later stages of cancer, that is why regular screening at primary care level is essential.

According to the World Health Organisation, screening is defined as "the presumptive identification of unrecognized disease in an apparently healthy, asymptomatic population by means of tests, examinations or other procedures that can be applied rapidly and easily to the target population. A screening programme must include all the core components in the screening process from inviting the target population to accessing effective treatment for individuals diagnosed with disease" [2]. Skin cancer screening programs and protocols vary widely depending on the country.

1.1 Skin cancer incidence in Latvia

The healthcare system of Latvia use the classification system ICD-10 Version:2016 for disease classification [3]. The skin cancer types are divided as: C43 Malignant Melanoma (MM) of the skin and its subtypes and C44 that includes: Basal Cell Carcinoma (BCC) and Squamous Cell Carcinoma (SCC) and subtypes.

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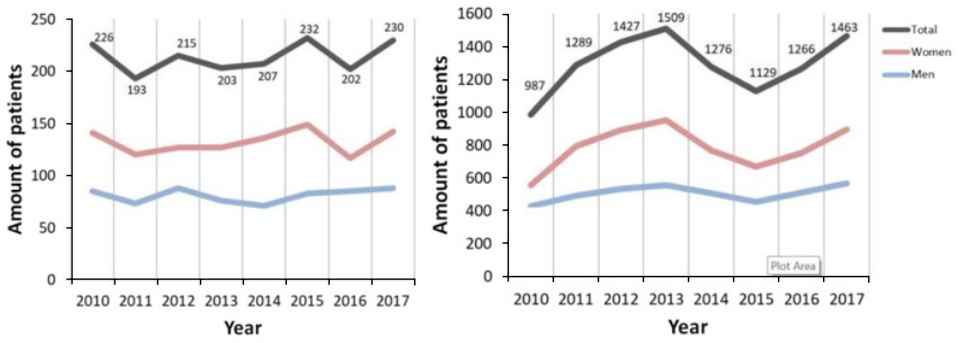

Fig. 1. Skin cancer statistics in Latvia from 2010 till 2017: incidence for Malignant Melanoma (C43) (on the left) and non-melanoma skin cancers (C44) (on the right); the absolute amount of patients with first-time diagnosis [4].

In Latvia, on average there are approximately 200 newly discovered MM (C43) and 1300 non-melanoma cancer (C44) cases per year (see Fig. 1) [4]. At first, the numbers might not seem alarming. However, population of Latvia is less than two million, from which 68% are the urban and 32% is the rural area [5]. The incidence of MM is about 10 cases and for non-melanoma skin cancer about 65 cases per 100 000 people (average in time period from 2010 till 2017, Fig. 1) [4]. The primary healthcare availability, including proper dermatological examination, in rural areas should be improved. That is one of the reasons MM and BCC is diagnosed at late stages.

In the Strategy report of Society Health for 2001–2010 (G. Rozentale et al.) one of the aims was defined as: "The mortality in the population of age group of 65 and younger from visual localisation type of cancers must be decreased by at least 15%". The report shows an increase of the mortality from MM and other skin cancer types from 2001–2009. The mortality trend is increasing, and the defined aim of the Society Health Strategy was not reached. As a conclusion the report states that mortality from MM is 4 times higher compared to other skin cancer types. Also, by discovering the MM at a late stage, the first year mortality is three times higher [6].

So far, there have been government funded cancer prevention programs only for breast, cervical and colorectal cancer in Latvia [7]. For skin cancer prevention in 2018 there was a social campaign organized by The Centre for Disease Prevention and Control (CDPC) of Latvia that included an outreach to the society by providing them with information about the risks of extensive UV exposure, the use of tanning beds, as well as the first visual signs of skin cancer [8].

The actual self-check and skin lesion evaluation is the patient's own responsibility. If there is a concerning mole, there are several options in the existing healthcare system:

1) Patient turns to the family doctor for a consultation and if necessary, gets referred to the dermatologist or dermato-oncologist (can take up to two months of waiting time) of a government paid medical care;
2) Patient can visit the private sector dermatologist (waiting time up to two weeks, but the patient's cost will be approximately 10 times higher);
3) If the suspicious lesion is considered high risk, the patient is under the category of "urgent" and by using the "Green Corridor" the patient shall receive full check-up and diagnosis within several working days, but in the reality that it is not always the case.

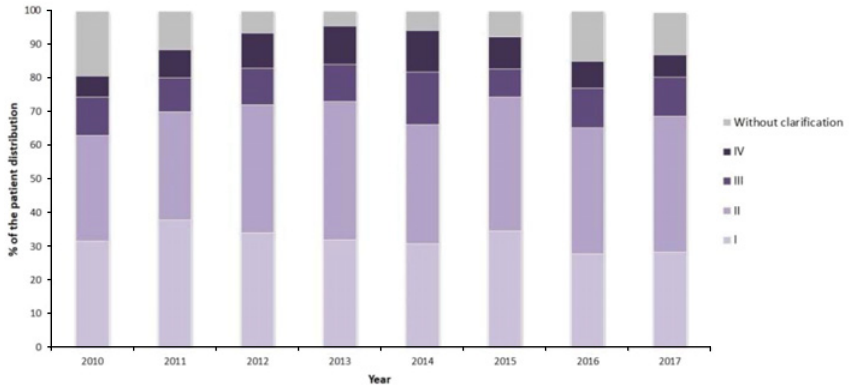

Fig. 2. Distribution of the patients (%) with MM stages I-IV in Latvia 2010–2017 [4].

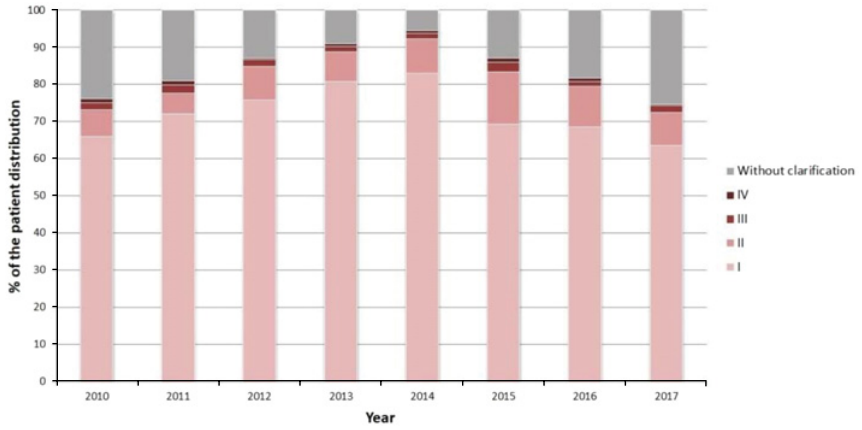

Fig. 3. Distribution of the patients(%) with non-melanoma cancer stages I-IV in Latvia 2010–2017 [4].

The most common cancer type in women in Latvia (time period from year 2006 to 2015) after breast cancer (20%) is skin cancer, from which was melanoma (14%), and in men skin cancer is less common, but still frequent (10%). After successfully treated, the 5-year survival was the highest for skin cancer lesions, including melanoma, 71.3% for men and 77.2% for women, when compared with other types of cancer, for instance: breast, prostate, cervical, stomach, etc. [9].

In Figs. 2 and 3 the distribution of MM (C43) and most common C44 diagnosis which are BCC and SCC as shown. The MM is mostly being discovered at I and II stage, however, there is still a significant number of cases discovered at late stages: III (11,4%) and IV (9.1%), and what is more concerning, more than 10% of the histology diagnosis are "without clarification". For BCC and other C44 cancer types, luckily most are discovered at stages I (72.4%) and II (9.2%). Unfortunately, again diagnosis "without clarification" show in more than 15% of the results [4].

1.2 Current skin screening protocols

According to the National Health Service of the Republic of Latvia, currently there is no specific skin cancer screening programme [10]. The national guidelines state that currently it

is enough with regular visual self-inspection or with regular general practitioner's check-ups for healthy patients or patients with no skin cancer history. It is said that there is not enough evidence yet for necessity of early skin cancer screening at primary healthcare level. In reality, primary care physicians lack knowledge in dermatology, especially in oncology related lesions and they do not perform dermatoscopy, but refer suspicious patients to dermatologists, that makes the diagnosis time very long.

As skin cancer is considered to be easily diagnosed compared with other types of cancers, because it is visual, still there are many cases when cancer is discovered at very late stages, patients do not perform regular self check-ups, family doctors lack experience or training in basic dermatology diagnostics, as well as some dermatologists lack experience with cancerous lesions, since daily they are dealing more with aesthetic issues and procedures. It is essential to make the right diagnosis and choose the appropriate skin lesion removal procedure in order to ensure the best and safest outcome for the patient.

Still, in the government healthcare provided hospitals in Latvia the current diagnosis is mostly performed as a visual examination, with a dermatoscope in the best case, and the preliminary diagnosis is subjective and not quantitative. If a lesion is considered as suspicious, cytology and/or histology is performed.

The care and diagnostics provided in private dermatology clinics is more costly and not always available to the general population due to the comparably much higher price. Equipment such as "FotoFinder" (FotoFinder Systems GmbH) and similar visual quantitative diagnostic tools are only available in some private clinics.

For this reason, a non-invasive multispectral inexpensive imaging system is proposed for skin cancer screening that can be used in daily practice of a general practitioner and dermatologist.

Early skin cancer diagnosis is essential and especially those healthcare specialists that are in close contact with patients for the first time should have a proper training for visual diagnostics of suspicious skin lesions. For now, regarding skin cancer there are recommendations for early detection, but not yet for screening.

In Germany, the project GEKID reports that melanoma incidence has risen from approximately 14 to 18 cases per 100 000 cases since 2007–2008, when the national screening was introduced. The SCREEN project concludes that screening programme is not justified [11]. So far the skin cancer control in a national cancer policy/strategy is effective only in USA [12]. Still, the US Preventive Task Force Recommendations (USPSTF) regarding skin cancer in the report in 2009 state that there is not enough evidence for both: benefits and risks of early cancer diagnostics and screening. Regarding the screening tests is said that: "There is insufficient evidence to assess the balance of benefits and harms of whole-body skin examination by a clinician or patient skin self-examination for the early detection of skin cancer" [13]. As expressed by many dermatologists, skin cancer early detection and screening is still essential. Also, Shawn Allen, MD mentions the confusion and lack of consensus regarding proper guidelines of skin cancer early diagnosis [14].

1.3 Rapid changes in lifestyle and technology

Elevated exposure to the UV radiation is a high risk factor for skin cancer in Caucasian populations [15]. In the past 30 years the beauty standards in the society have changed, and a dark tanned skin is considered a symbol of health and good looks, especially for young women. This cultivated beauty trend inspires tanning bed companies to produce more powerful and effective UV lamps and tanning devices. Luckily, a lot of national health organisations have started to act and make restrictions for artificial UV tanning, especially

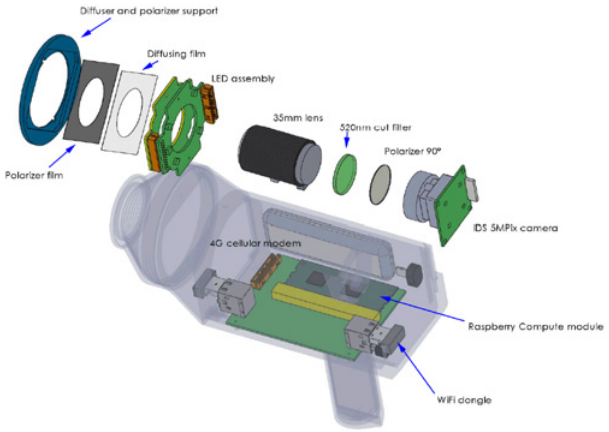

Fig. 4. The components of the screening device. Design courtesy: D.Bliznuks.

for young people, as well as drawing the attention to the harm of extensive tanning at a young age. For instance, in Latvia the use of tanning beds is restricted for children younger than 18 years. This law is becoming effective in 2019 [16]. Before there was no specific restriction regarding tanning beds on a national level.

Nowadays in the digital age, fast information and data exchange is a daily routine. This accounts also for medicine. Digital technologies are available in medicine already in the past two decades. With the era of smart phones now it is very easy to reach the doctor within seconds, and with special mobile applications even exchange images, as well as use numbers of other telemedicine solutions. The field of deep learning image recognition algorithms is developing rapidly as well. The use of picture archiving and communication system (PACS) for radiology images has been well practised in almost every hospital. Now, with the development of the accessibility of good quality imaging devices and smart phones at a reasonable price, the imaging field in dermatology is expanding too.

For those reasons, in cooperation with engineers, physicists, specialists in bio-photonics field and dermatologists, a multispectral non-invasive and portable skin lesion imaging device was created.

2 Material and methods

2.1 Device setup

For the family doctors and dermatologists to use such device for skin cancer screening on suspicious skin lesions, it has to be portable, simple and accurate, and fast to operate. After several years of clinical trials and consistent device improvements a current prototype has been created [17].

The proposed screening device (Fig. 4) consists of multispectral light emitting diode (LED) sources at specific wavelengths: 526 nm, 663 nm, 964 nm for diffuse reflectance (DR) and 405 nm to induce skin auto-fluorescence (AF), as well as a white light LEDs for lesion location and visual archive. The illuminators are arranged in a LED ring. The IDS 5Mix camera is used for image capturing. Afterwards, the captured images are sent to the cloud with the help of a WiFi dongle. The cloud-based image analysis system runs several MatLab

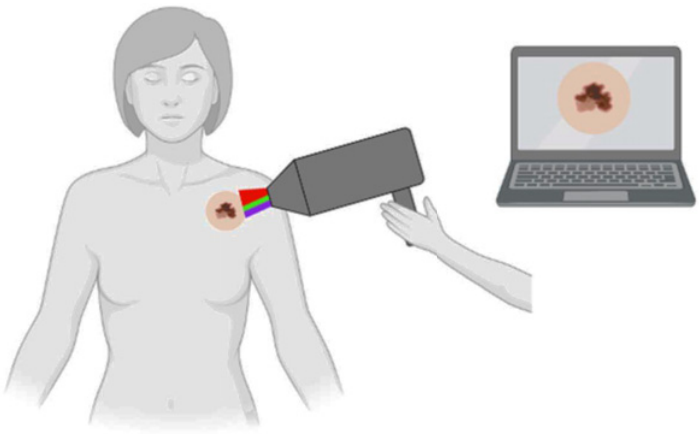

Fig. 5. Measurement set-up and procedure: the doctor captures the image of the patient's suspicious skin lesion with the non-invasive skin screening device that captures it at specific wavelengths. The clinical image is available on the screen, along with the resulting, analysed parameter lesion maps.

scripts according to the created algorithms that calculate specific parameters and create image maps; so that the doctors in just a few minutes after capturing the image could already evaluate the result in the web-based information system (IS) by logging in and viewing each patient's records and visual images of their lesions.

In the Fig. 5 it is demonstrated how the doctor performs the screening of the patient's suspicious lesion on the arm. In the personal computer (PC) web-based solution it is possible to preview the lesion as well as later to view the analysis of the lesion after the examination. The example of an analysed lesion and parameter map is in Fig. 7. The device is wireless, so it is handy to image various parts of the body. The imaging of one lesion after locating it takes around 30 seconds only.

2.2 Parameter p′

For diagnostic purposes and determining whether the pigmented formation is skin melanoma, a p' parameter map [18] is calculated and the image, captured under 405 nm excitation, is analysed. Diffuse reflection images for lesion I and surrounding healthy skin I_{skin} (at 526 nm, 663 nm and 964 nm) are used for calculating parametric p' map:

$$\boldsymbol{p'} = \boldsymbol{lg}\left(\frac{\boldsymbol{I}(526)\cdot\boldsymbol{I}_{skin}(663)\cdot\boldsymbol{I}_{skin}(964)}{\boldsymbol{I}_{skin}(526)\cdot\boldsymbol{I}(663)\cdot\boldsymbol{I}(964)}\right) \tag{1}$$

Images at 526 nm characterize blood absorption, at 663 nm – melanin absorption in skin and at 964 nm – gives us information about deeper layers of the skin. The criterion for skin melanoma is that there is area within the lesion where $p' > 1$.

Since there are cases when seborrheic keratosis provides the same criterion as melanoma, it is possible to distinguish them from melanoma using images under the 405 nm excitation [19]. Seborrheic keratoses present increased intensities within the lesion I_{lesion} in comparison with the surrounding skin I_{skin}:

$$I_{lesion}(405) > I_{skin}(405) \tag{2}$$

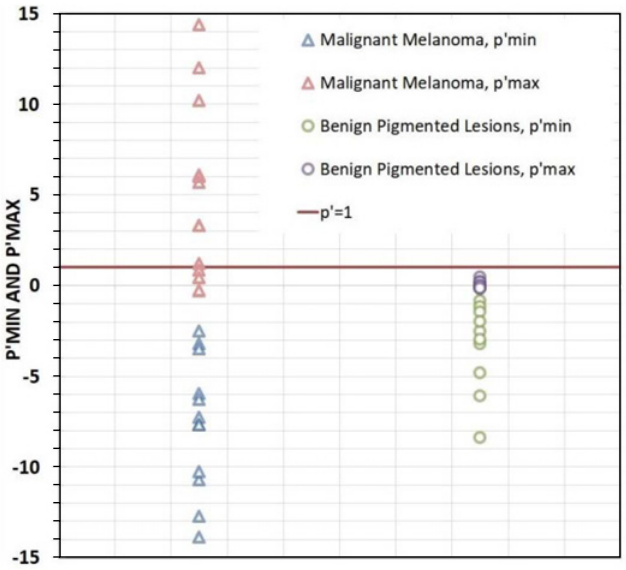

Fig. 6. The evaluation of parameter p' for MM (C43) and benign lesions (D22) maximum and minimum values and the threshold at $p' = 1$.

3 Results and discussion

The parameter p' was calculated for 12 MM (C43) and for randomly selected benign lesions: 10 dysplastic nevi or melanocytic nevi (D22). All lesions were imaged in Oncology Centre of Latvia during regular patient check-ups. The MM in this study were histologically approved, the benign lesions were approved by an experienced dermato-oncologist by using a dermatoscope (DermLite DL4, 3Gen Inc., USA).

In the Fig. 6 the maximal and minimal values of p' parameter are visualised. The standard threshold is set at $p' = 1$ empirically, and usually lesions with a lot of values already at $p' = 0.8$ are considered suspicious. For MM most of the values should be positive and above value 1, in that case, unless it is noise (signals from hair, movement artefacts or image stabilization error), the negative p' values showed no correlation between the diagnoses. For benign lesions (D22) both the p'_{min} and p'_{max} values are below $p' = 1$, showing that the lesion most probably is not melanoma. The calculated sensitivity and specificity for distinguishing MM from melanocytic nevi is respectively 75% and 100%.

In the Fig. 7 the comparison of various skin lesions is shown. As the parameter p' has been created for MM evaluation, it describes mostly the possibility of the lesion to be melanoma. As seen on the 2D distribution for MM the amount of values larger than 1 (red colour) clearly shows the lesion to be melanoma, even though visually in the white and green channel MM and BCC look similar: as dark pigmented lesions with irregular shapes. The Seborrheic Keratosis, as expected, shows greater AF intensity than the surrounding skin. Hemangioma can be distinguished most of the times visually, but also in the p' parameter map the negative values have very high negative peaks due to the vascular signal. The distinguishing method for BCC is still under development, because visually these lesions can be very different in pigmentation and subtypes.

Also, there are cases when the physician can doubt dysplastic nevus for MM. In that case for long term observation this visual evaluation method is useful, because MM have areas

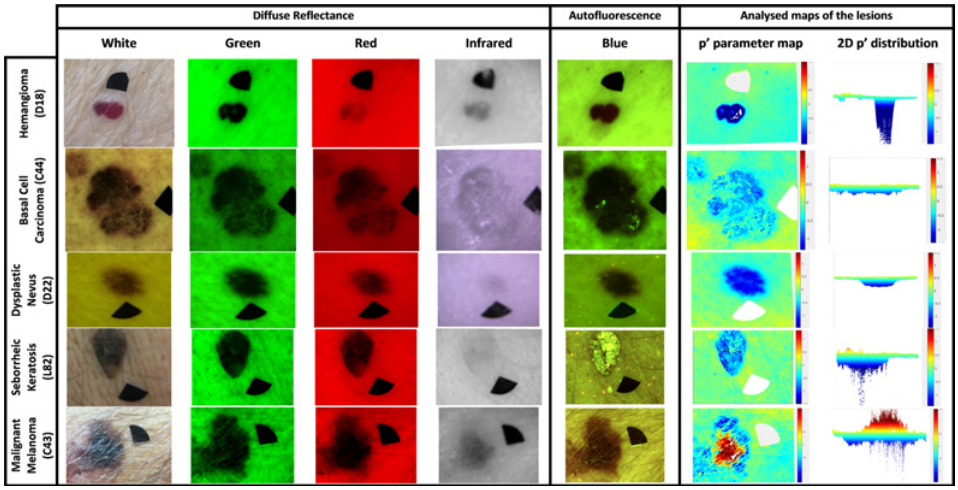

Fig. 7. Possibility to distinguish various lesions: Hemangioma, Basal Cell Carcinoma, Dysplastic Nevus, Seborrheic Keratosis, Malignant Melanoma at various illuminated modes: (from the left): Diffuse reflectance at white light, green (526 nm), red (663 nm), infrared (964 nm); Auto-fluorescence induced by blue (405 nm) light; Analysed image maps: p' parameter map and p' parameter distribution in 2D.

with values $p' > 1$, whereas dysplastic nevus has big amount of values in the negative (blue area values $p' < 0$).

4 Conclusions

The proposed setup and device can be used as a screening tool at a general practitioner's office, as well as an extra help for a dermatologist when deciding on the most appropriate procedure or treatment option depending on the diagnosis and situation. The device has a high accuracy, good visual archive possibility, and this method should be used as a yearly screening tool for new patients and for patients with skin cancer history it could be used as a reference and monitoring tool for cancer recurrence in the post-operative scars. Considering the relatively high skin cancer incidence in Latvia, it is suggested that family doctors draw more attention to their patients and encourage them to attend dermatologists and do self-check-ups regularly.

As the proposed skin screening system is non-invasive, meaning that the preliminary diagnosis can be done without performing unnecessary biopsy in the initial screening stage, also it is easy to use for the physician and the measurement for one lesion takes around 30 seconds, for the patient it is fast and non-painful, so it can be easily implemented in a national oncology early-diagnosis programme to lower the incidence of skin cancer in Latvia and other countries in the world where the population is at high risk for skin cancer.

Along with outreaching to the general public and informing patients about reducing risks of getting skin cancer and changing the lifestyle, there should be extra guidelines and training provided for general practitioners, so that they could screen their patients more efficiently using their experience and various kinds of diagnostic tools.

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has been approved by Ethics Committee; the research has been conducted in accordance with the Declaration of Helsinki, as well as with the Oviedo Convention.

The author of the Fig. 4 is Dmitrijs Bliznuks (Riga Technical University), who has contributed to the mentioned project "Portable Device for Non-contact Early Diagnostics of Skin Cancer".

The Fig. 5 has been created by using free web software BioRender.com.

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