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Infrared Visualization of the Prostate Cancer

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ABSTRACT

BACKGROUND.
Among oncological diseases, prostate cancer is the second leading cause of death in men. Despite the latest diagnostic achievements, there is no precise method for differentiation of clinically significant malignant alterations of the prostate from insignificant changes to avoid undertreatment or overtreatment of such patients.

OBJECTIVES
The present study aimed to (i) identify the dependence of prostate tissue resolution on infrared wavelength, (ii) differentiate malignant tissue from benign prostatic hyperplasia, and (iii) develop diagnostic software for processing the obtained infrared images.

METHODS
The postsurgical biomaterials of the prostate gland were distributed among two groups. Group 1 consisted of 78 samples of prostate cancer tissue obtained after radical prostatectomy, and group 2 consisted of 48 samples of benign prostatic hyperplasia obtained by transvesical prostatic adenomectomy. The infrared images of retained biomaterials were processed by special diagnostic computer software.

RESULTS
The highest resolution of prostate tissue was obtained in the range of 840-860 nm wavelength of the infrared specter. The intensity of the infrared images ranged from 0.039550 to 0.293524 for prostatic cancer, and from 0.3245699 to 0.992317 for normal prostatic tissue.

CONCLUSIONS
Infrared imaging is an effective method of differentiation of prostatic cancer from benign prostatic hyperplasia.

KEYWORDS
Benign prostatic hyperplasia; infrared imaging; prostatic cancer.

BACKGROUND

Prostate cancer is the second leading cause of oncological mortality in men worldwide.[1] The prostate-specific antigen (PSA) and digital rectal examination (DRE) are essential elements of prostate cancer screening work-up, which contribute to a decrease in cancer-specific mortality by early identification of suspicious cases. On the other hand, usage of PSA and DRE may lead to overdiagnosis and lower quality of life (QOL).[2,3]

The issue of unnecessary prostate cancer testing, overdiagnosis, and overtreatment eventually led to changes in prostate cancer guidelines. Since the 2012 update of the US Preventive Services Task Force (USPSTF),[4] a decrease in the diagnosed cases of localized prostate cancer and an increase in the confirmed cases of locally advanced/metastatic disease have been recorded after s significant reduction in PSA testing of the USA population.[5]

5-years after the publication of the USPSTF 2012 recommendations, there has been an increase in prostate cancer "specific mortality" rates in Europe.[6,7,8] Nowadays, prostate cancer is the 3rd leading cause of male mortality across Europe[1,9,10] and 2nd worldwide.[11] Therefore, imaging modalities of the prostate gland, especially multiparametric magnetic resonance imaging (mpMRI), are widely recommended for the diagnosis/monitoring of prostatic cancer. Despite overall pooled 89% sensitivity, mpMRI has only 73% specificity in the case of prostatic cancer.[16]

In the present study, we aimed to use infrared rays as an alternative and inexpensive imaging modality for the diagnosis of prostatic cancer, taking into account the results of the original research of the Institute of Cybernetics of TTU[12] and our previous study.[13,14,15]

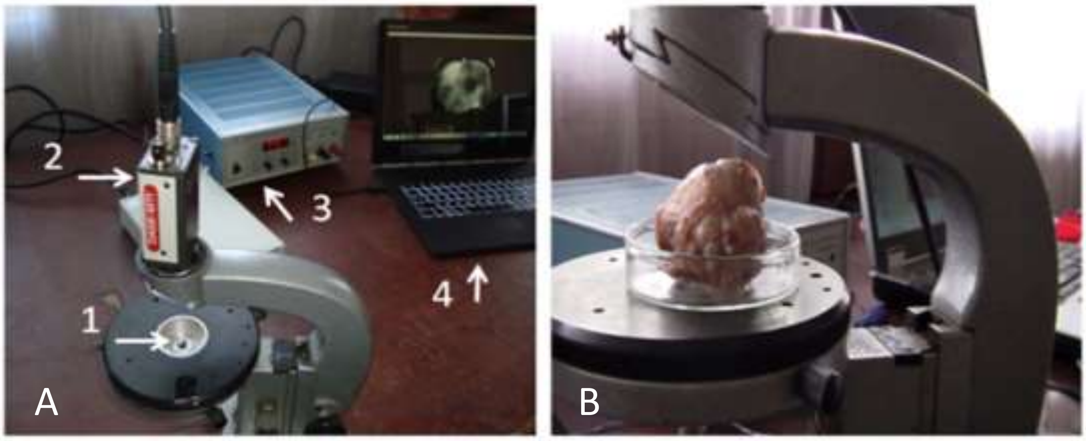
METHODS

126 postsurgical biomaterials of the prostatic gland, examined in the infrared environment, were distributed among two groups:

- Group 1 consisted of 78 samples of prostate cancer tissue obtained by radical prostatectomy, and
- Group 2 consisted of 48 samples of benign prostatic hyperplasia obtained by transvesical prostatic adenomectomy.

The phenomenon of infrared imaging is similar to the conversion of light into nerve impulses in the retina and is as follows: after passing through the postsurgical biomaterial of the prostate gland placed on a clamp and the CCD camera lens, the infrared beam falls on the active matrix and transformed into electronic signals, which converted to the image by special computer software (Fig.1)

FIGURE 1. Experimental unit. A. 1-LED; 2-CCD camera; 3-LED power block; 4-laptop; B. The postsurgical prostate gland biomaterial placed between LED and CCD camera



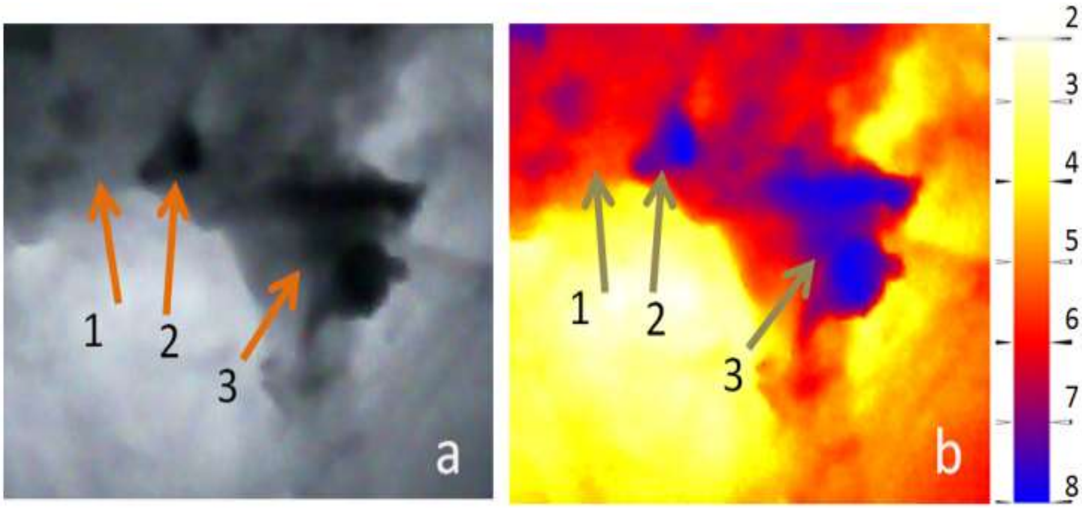
After obtaining an infrared image, the specimen with a marked suspicious malignancy area (if any) proceeded for histomorphological examination.

The computer software with the property of distinguishing 256 different levels of image brightness was used for the automatic detection of prostatic cancer and to avoid the subjective perception of the image brightness.

The zero-brightness level of the image was interpreted as "absolutely dark" with the phenomenon of complete absorption of infrared radiation by the prostate tissue without reaching the CCD camera. Other brightness levels indicated different intensities of infrared radiation captured by the CCD camera after the tissue sample penetrated. The obtained infrared image (in black-and-white and color modes) then was processed by a computer algorithm with the marking of normal and suspicious malignant sites and the assignment of various codes to them (Fig.2). After that, the software automatically evaluated the corresponding intensity of each point of the marked areas and calculated the average intensity values and their ratios.

The confidence intervals (CI) of 90%, 95%, and 99% were calculated by processing all stored data. During the investigation of new, undiagnosed postsurgical biomaterial, the diagnosis was made by automatically calculating the intensity ratio and assessing its compatibility with the stored standardized data (falling in CI 95% was confirmatory). All diagnoses obtained by our innovative method were verified by subsequent histomorphological studies.

FIGURE 2. Prostate cancer fragment in gray (A) and color (B) processing



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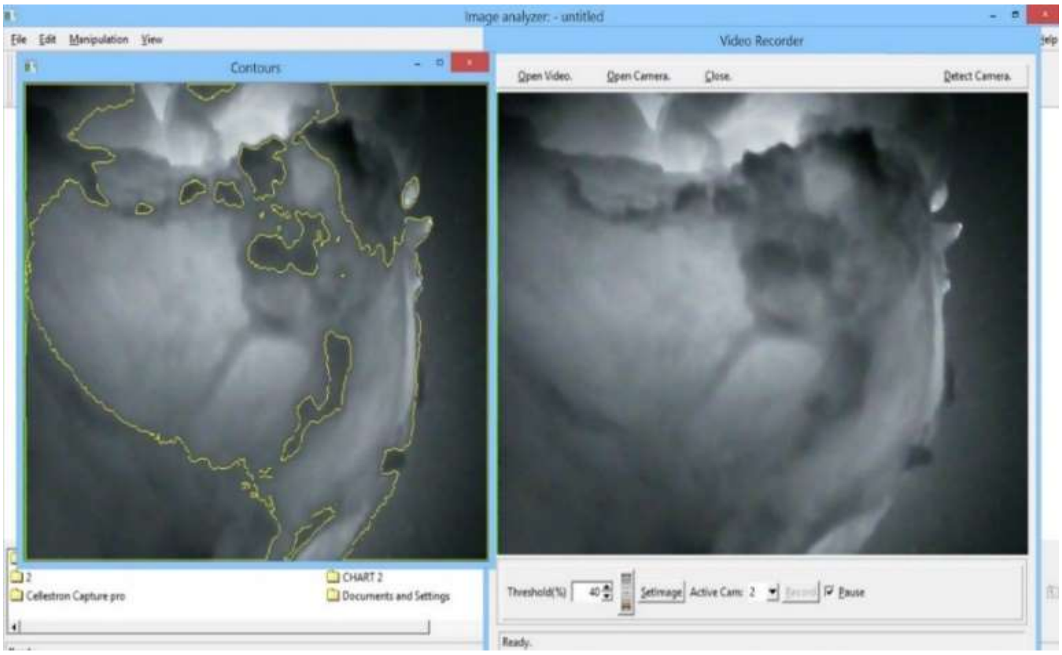
Used software has various functions that allowed us to operate with infrared images in both live and offline modes, and distinguish high optical density areas from lower ones (Fig.3).

The Statistical Package for Social Sciences (SPSS, version 22) software was used for statistical analysis. A Student's t-test was used to compare the difference in the continuous variables between groups. A value of $p<0.05$ was considered to be statistically significant.

FIGURE 3. Program in operation mode. On the right side, the program provides a live image. In the left image, the program separates areas of high optical density from areas of low optical density with boundaries



RESULTS

All 126 postsurgical biomaterials were examined by infrared radiation and assessed according to brightness gradations (from 0 to 256 pixels) using computer software. After that, all samples proceeded to histomorphological study.

The samples were distributed among two groups:

- The first group consisted of 78 prostate cancer (verified by the sum of different Gleason scores on histomorphologic examination) tissues obtained after radical prostatectomy, and the weight of specimens ranged from 32g to 145 g. The intensity of the areas of malignancy ranged from 0.039550 to 0.293524;
- The second group consisted of 48 samples of benign prostatic hyperplasia obtained by transvesical prostatic adenomectomy, with the weight of the prostate gland ranging from 100 g to 270 g. The intensity of the areas of hyperplasia ranged from 0.3245699 to 0.992317. Differences between sample weights and intensities were statistically significant.

DISCUSSION

The findings of the present study indicate the high diagnostic accuracy (verified by histomorphologic investigation) of an infrared imaging method for the differentiation of prostate cancer and benign hyperplasia.

We realize the limitations of our study and the need for further investigations of the sensitivity and specificity of infrared scanning for the diagnosis of prostate cancer.

We believe that the results obtained from our study, together with existing risk calculators, biomarkers, and state-of-the-art technologies, will make a modest contribution to the early and effective diagnosis and optimal management of prostate cancer.

AUTHOR AFFILIATION

The experimental part of the study was conducted based on the Tbilisi State Medical University (TSMU) Departments of Urology1 and Pathology3. The infrared imaging device and software were made by the Institute of Cybernetics of Georgian Technical University (GTU)2.

SUPPLEMENTARY MATERIALS

Supplementary material represents white-light and infrared images of the postsurgical biomaterials (prostate cancer Fig.S1 and benign prostatic hyperplasia Fig.S2).

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