A New Database for Mastology Research with Infrared Image

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Breast cancer has been responsible for several deaths among women around the world. Its causes are unknown, but early diagnosis increases the cure chances of the patient. This paper describes a new infrared image database with additional breast exams and clinical data. We believe that such database will be particularly useful to evaluate the potential contribution of the infrared images to breast disease detection. Furthermore, this paper reviews acquisition protocols in the literature and suggests a new dynamic protocol based on the test results of the reproduced protocols.

Keywords: infrared imaging, acquisition protocols, image database, pattern recognition, information retrieval, breast disease detection, breast cancer, mastology research .

1. INTRODUCTION

Some authors claim that infrared (IR) image may have the potential to detect breast cancer ten years earlier than mammography or any other image-based examination, while other authors claim that it is useless for cancer detection. For instance, regarding specifically two very opposite studies: Kontos, Wilson and Fentiman[1] say that IR images are bad for screening, despite being non-invasive and painless, and they conclude that, because of the low sensitivity for breast cancer, it is not indicated for the primary evaluation of symptomatic patients nor should it be used on a routine basis as a screening test for breast cancer; while Whishart et al.[2] results show that IR image is good for young woman and conclude: The combined sensitivity of IR (acquired by their apparatus) and mammography in women older than 50 years present results with sensitivity of 89%, suggesting this as a potential imaging approach for young age group. Important issues could bridge the gap on more conclusive and objective study for the real viability of the use of IR images on breast cancer screening. Using as an example, acquisition protocols for mammography are very well established and various databases are available even for free. This allows comparing various diagnostic image-based techniques for early detection of non-palpable tumors and even the efficiency of each new feature to be added to the feature vector and how it can modify, even in decimals of percentage, the accuracy of the diagnoses compared to the former techniques. However, regarding the huge number of publications in the subject of IR images where one can find available examinations or an open access

database that turns fair the confrontation of the various methodologies used for this type of examination. How on using so different initial data is possible to promote confirmations for any direction of so diverse claims? One common statement using as diverse data as the number of published works, if it appears, could be, at least, a contradictory event. The objective of this work is promoting an open discussion in this direction, without any commercial or preconceived idea. So, for this purpose, it is present a public database available to every interested researcher, consisting of images acquired without any possible business trends or from permanence desire in the comfort of any current knowledge domain. In addition, the intention is promoting its population for whatever source of possible contributions with the only precaution of maintenance of the same protocol and of course having the consent of the involved patients and physicians. Our goal is promoting the research where the beneficiaries would be those who really want to make an honest research in image processing and patients who may benefit from the study on the technical feasibility of the possible real effects of such tool.

The text is structured as follows. Experimental study was developed to determine the best acquisition protocol for screening, it ends up to the definition of the way this exams are done in Federal Fluminense University Hospital and is presented in next section. Section 3 is related to how the acquisition results are stored and retrieved, and the other clinical data and exams that are available for each patient. Section 4 evaluates if the intentions of this work in promoting the use of IR breast image by describing how it is used in clinical study for screening in Brazil and promoting its usability to the interested community have been achieved.

2. IR IMAGE ACQUISITION PROTOCOL

Considering the inconsistencies among the various protocols used for capturing images, some previous works have been revised and based on them, four protocols have been reproduced, two static and two dynamic, with fourteen volunteers. Analyzing the results we have concluded that dynamic protocols are more efficient to highlight hot regions and vascularization in breast than static protocols. A new dynamic protocol is proposed considering the advantages and disadvantages of the reproduced dynamic protocols.

2.1 Related works

In the examination procedure proposed by Arora et al.[3], the patient is undressed from the waist up and positioned in dedicated equipment set with a chair with mirrors for lateral views, a cooler by using air and a digital infrared camera. The examination lasts 4 minutes per patient and more than 100 images are captured during the stress administration caused by cold (cold air directed to the breasts).

In the protocol used by Kapoor and Prasad[4], the patient is advised to avoid alcohol, caffeine

and nicotine for at least two hours before the test and not to use lotions or creams in the region of the body which will be viewed by the thermal camera. The region of the thorax is cooled by an electric fan during 7 to 10 minutes before capturing images. The room temperature is maintained at approximately 22ºC and darkened during the examination to avoid interference from heat sources.

Another protocol is described by Antonini et al.[5]. In this work the patient is asked to position his hands on his head and remain immobile. From each patient, a total of 5 images are obtained (frontal, right and left semi-oblique and right and left oblique). The distance between the camera and the patient is 0.9 m and the room temperature is maintained at 23°C (±1°C).

In the Kontos' protocol[1], the examination room temperature is maintained stable at approximately 22ºC. In addition, the room has no windows and its openings are muffled avoiding directional airflow to the patient. The room lighting is kept with fluorescent bulbs and it is located remote from the image capture area. The patient is requested to remove the clothes above the waist and rest during 10 to 15 minutes in order to achieve a steady temperature state in equilibrium with the special temperature conditions of the room. Earrings and dress are removed. After, the patient sits on a backless bench positioned at 1 meter from the IR camera, puts his hands at the top of the head and remains immobile. Three images of the patient are obtained: one frontal and two oblique to 45° from a centerline for an optimal exposure of all aspects of the breasts.

Ng and Kee describes a protocol[6] in which the examination environment has temperature between 20ºC and 22ºC and relative humidity of 60%. Heat sources such as sunshine and other electrical devices are reduced to minimum because they affect the environment temperature. The recommendations to patients are: no alcohol drinking, no smoking and no use of drugs that can affect the biological system of the body and result in temperature changes. In addition, the chest region must be free from any ointment or talc kind. Also, 20 minutes before the test the patient is required to abstain from any physical activity in order to reduce the metabolism rate and thereby stabilize the overall temperature of the body. During the examination the patient removes clothing from the top of the body and puts his hands behind the head. Three images are captured, one frontal and two laterals.

The same protocol is described in the Ng et al.[7] and Acharya et al.[8]'s works. The temperature of the examination environment is controlled, 20ºC to 22ºC, with relative humidity of 60% (±5%). The patient is requested to rest at least 15 minutes for adequate cooling to basal metabolic rate, resulting in minimal changes in skin temperature during acquisition. During the rest, the patient wears a loose smock, which does not restrict the air flow. It is assured that the patient is within the period from the 5th to the 12th and 21th day after beginning of the menstrual cycle, because in this period the

vascularization is at basal level with less swelling of the blood vessels.

The images used in the work of Araújo et al.[9] have been captured under a static protocol. The patient rests during 10 minutes, approximately, for acclimatization, in order to stabilize the metabolism before the test. At least 8 images are captured in 8 different positions, however extra images can be captured if needed. The standard positions are: frontal with hands on hips (hands on hips and elbows away from the body); frontal with hands upon the head; only the right breast; only the left breast; outer side of the right breast; outer side of the left breast; inner side of the right breast and inner side of the left breast. The room temperature (between 25ºC and 28ºC) and relative humidity of air are considered parameters and they are inserted in the camera settings during the examination. Furthermore, the air flows are controlled and deviated from the patient.

Koay et al.[10] describes a protocol, which a test is performed in the following week to menstruation or between the 6th and 10th days of the cycle, until the 13th day. The patient is instructed to avoid alcohol, caffeine, lotions for pain and not to smoke for at least two hours before the examination. The region of the breasts is cooled by an electric fan for about 10 minutes before capturing. The room is kept at 22ºC and darkened during the examination. According to the authors, this protocol offered greater temperature contrast between the hot and cold regions of the body.

In Wishart et al.[2], examination is performed with the patient undressed from the waist up and properly positioned in an ergonomic chair with his arms resting on the eye level. A controlled temperature air flow is directed to the breasts for 5 minutes while the infrared camera records a temperature series of the skin surface in 250 images.

Ohashi and Uchida[11, 12] have performed two protocols, one static and another dynamic in an environment with a temperature of 21ºC. The patient remains immobile with hands on his head and images are captured from three directions: frontal, left oblique and right oblique. In the dynamic protocol, the region of the breast is cooled with an electric fan during 2 minutes. After this time, a sequence of images is captured with intervals of 15 seconds between them. A subtraction thermography (examination using IR images) is obtained from this sequence.

2.2 Used protocols for experimentation

The main goal of breast examination using IR image is to detect breast disease based on physiological abnormalities, which can be related to the vascular pattern analysis and in the differences between warmer regions. Thus, it is important to know the best protocol to highlight these elements. Protocols for thermal imaging can be categorized based on the behavior of the body in relation to heat transfer, as static or dynamic[13]. In static acquisitions the body of the patient must to achieve thermal stability inside the acquisition environment. Dynamic

acquisition is used to monitor the skin temperature recovery caused by thermal stress, for example, after cooling the patient[13].

Considering previous works' protocols, four protocols have been reconstructed and tested, two static and two dynamic. The initial purpose was to determine which protocol category, static or dynamic, highlights better hot regions and vascular patterns. The second objective was to determine the best protocol within the elected category.

For evaluating the efficiency of each protocol, we have used thermal images of 14 volunteers, supposedly healthy. Each volunteer has been submitted to all protocols on different days, with the room conditions kept unchanged. Advantages and disadvantages of each protocol have been considered under medical examination criteria. Furthermore, statistical calculations were performed on the images from static and dynamic protocols.

In all reproduced protocols, the initial procedures are equal to each volunteer:

i) check the central temperature by a clinical thermometer;

ii) check whether the volunteer followed the protocol's recommendations which are, by at least two hours before:

a) not to smoke;

b) not to consume caffeine or alcohol;

c) not to practice physical exercises;

d) not to apply any cream or oil type in the region of the breast and armpit.

iii) ask the patient to remove beads, earrings and other accessories which can be viewed in the thermal images and hold the hair with a shower cap; and

iv) ask the patient to remove clothing from the waist up.

In all protocols the volunteer stays with his hands on his head during the whole process.

First static protocol

The volunteer rests for 10 minutes to stabilize the skin temperature of the breasts and armpit. After that, a frontal image is captured.

Second static protocol

Similar procedures of the previous protocol, but in this, the volunteer rests per 15 minutes.

First dynamic protocol

An electric fan is turned on and directed to the volunteer's breasts and armpits per 2 minutes. After this, six images are captured, one each minute.

Second dynamic protocol

Alcohol is applied at the region of the volunteer's breasts and armpits, then an electric fan is turned on and guided to this region by 30 seconds. After this, six images are captured, one each minute.

2.3 Protocol evaluations and discussions

Initially, the region of interest (ROI), the breasts, is segmented in the acquired images. The temperature from each point of the ROI is obtained from the temperature matrix of the camera software (Flir QuickReport 1.2). Then, some parameters of temperature are computed: average, maximum, minimum, standard

deviation and median. The histogram is calculated in order to know the dispersion of this temperature in the ROI. Figure 1 shows a IR image, the manual segmented ROI, and the temperature histogram of the highlighted region[14].

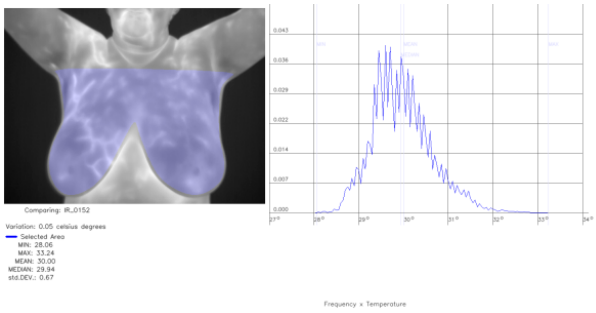

Figure 1: Temperature histogram of the ROI.

Analyzing the volunteer's image data, no differences were noticed between the static protocols. The dynamic protocols presented greater possibilities highlighting vascular patterns and temperature variation among regions than static protocols. Meanwhile, some problems were observed in dynamic protocols, e.g., excessive cooling by using alcohol in some volunteers (Figure 2) and no guarantee of uniformity in the application of alcohol (Figure 3). Also, it was possible to realize that the skin breast of some volunteers cooled much less than other volunteers with the same cooling time with fan (2 minutes or 30 seconds with alcohol).

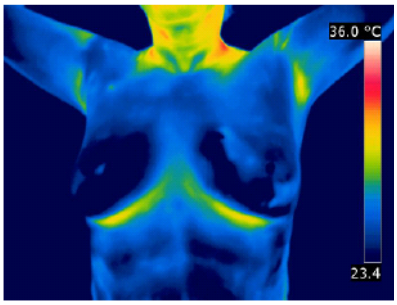

Figure 2: exaggerated cooling.

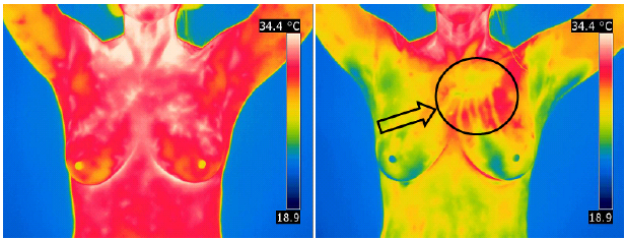

Figure 3: Uniform alcohol application, left image, before the application, right image, after application.

Considering the cited problems, we propose a new dynamic protocol which was performed on the same volunteers of the protocols' tests. The results achieved with the proposed protocol were compared with the dynamic protocols. Figure 4 shows a IR image of the propose protocol.

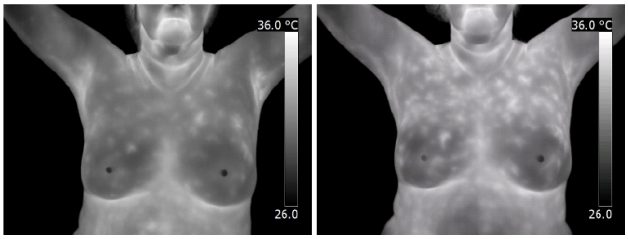

Figure 4: Left image, First Dynamic Protocol, right image, our protocol with hot regions more highlighted.

2.4 New Dynamic IR Acquisition Protocol

We have established a dynamic protocol which differs from previous' works because it uses a common average of temperatures to begin the acquisition. In others word, the thermal stress (refrigeration of the patient by ventilation) will stop once the average of temperatures is achieved. When the mean temperature of the region between the breasts goes down to 30.5ºC or 5 minutes are elapsed, the thermal stress is stopped and the sequential acquisition is started. This was the case that highlighted better the vascular behavior and the

warm regions during tests. Only two, among eleven, voluntaries have achieved maximum time, 5 minutes. The last image of this sequence is the one that best highlights the vascularization and hot regions. The average temperature is monitored by an automatic tool of the camera. Figure 5 shows such region.

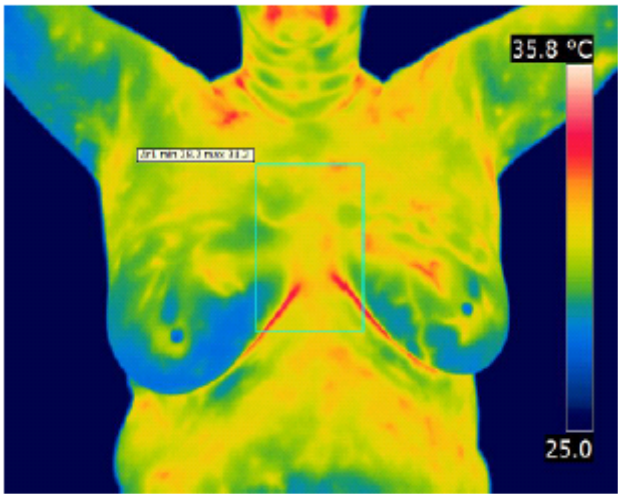

Figure 5: Monitoring the average temperature to begin the sequential acquisition.

2.4.1 Description of the protocol

a. Recommendations to the patient

At least two hours before the examination the patient should avoid: alcohol, caffeine, physical exercises, nicotine and do not apply any cream, oil or deodorant type in the breasts and armpit.

b. Examination room conditions

Room temperature must be maintained between 20ºC and 22ºC, no windows, no openings, no air flow directed to the patient. Only fluorescent bulbs can be used in the room illumination.

c. Preparation of the patient

Inside the examination room, the patient is asked to remove earrings, necklaces or other accessory which can interfere in the thermal image. Patient's body temperature is checked by clinical thermometer and her hair stuck with a coif.

d. Image capture

The thorax area and armpit are cooled by an electric fan until the stopping criterion to be satisfied. After finishing the thermal stress, a 20 image sequence is captured during 5 minutes (while the cold region temperature returns to the balance). The same time interval between each image acquisition is used. Finally, two IR images are captured, one to 90° from the right breast and another to 90º from the left breast.

e. Parameters

The distance from the camera to the patient is one meter and the dynamic acquisition is the one where the patient keeps facing the camera, as Figure 6 shows. The relative humidity of air and room temperature are recorded and inserted as parameters in the camera settings.

f. IR images of the database

Each patient data who was stored in the breast image database has his images acquired by two protocols: the dynamic protocol (mentioned in this section) with capture of 20 image during 5 minutes, and a static protocol, which the patient rests for 10 minutes before five images (one frontal, two laterals of his left at 45º and 90º, and two laterals of his right at 45° and 90°) under the same recommendations and room conditions.

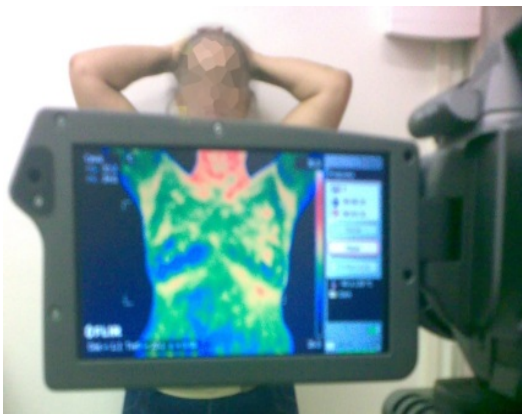

Figure 6: Camera and patient position.

g. Used equipment

The IR images are captured by a FLIR thermal camera, model SC620, which has sensitivity of less than 0.04°C range and capture standard −40°C to 500°C. The IR images present dimension of 640 x 480 pixels.

3. DATABASE FOR MASTOLOGY RESEARCH WITH IR IMAGE

A Database for Mastology Research with Infrared Image – DMR-IR was developed; that is accessible through an online user-friendly interface (*http://visual.ic.uff.br/dmi*) for managing and retrieving information from breast exams and clinical data from volunteer patients. The DMR-IR has been and will be (continuously) fed with IR images of patients with breast cancer and supposedly healthy, for research purposes. Our goal is providing an open access database to the interested community, and represents a valuable resource of data that can be used to compare diverse image analysis techniques.

3.1 Overview of the database

The DMR-IR contains IR images, digitalized mammograms and clinical data obtained from patients of the Hospital Universitário Antônio Pedro (HUAP) of the Federal University Fluminense. The IR images were obtained by the acquisition protocols detailed in previous section. At the time this paper was written there were 141 patients with reports in its. This acquisition and use have been approved by the Ethical Committee of the HUAP and registered at the Brazilian Ministry of Health under number CAAE: 01042812.0.0000.5243. The amount of IR images sums 3534 images, an average of 27 images for patients were obtained, 5 different positions for static protocol (i.e. Front, Right Lateral 45°, Right Lateral 90°, Left Lateral 45° and Left Lateral 90°), see Figure 7. The dynamic protocol produces 20 sequential images in Front position and additionally 2 lateral images (Right Lateral 90°, Left Lateral 90°).

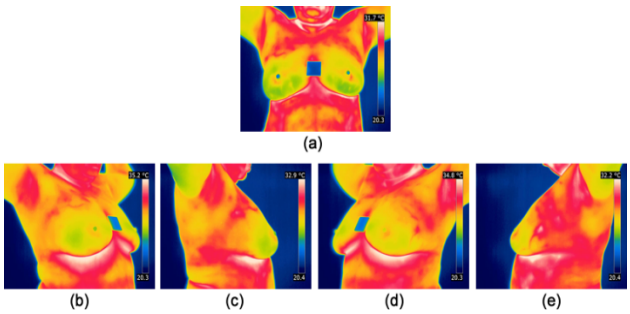

Figure 7: Positions (a) Front, (b) Right Lateral 45°, (c) Right Lateral 90°, (d) Left Lateral 45°, (e) and Left Lateral 90°.

The number of digitalized mammograms reaches 62, each one with their respective four standard views (medio-lateral oblique and cranio caudal for each breast). Ultrasound

images and MRI (magnetic resonance) are also being acquired by the group. The DMR-IR also storages patient information that could be useful for diagnosis, such as: age, race, complaints, symptoms, eating habits, personal and family history, medical history and report.

3.2 Information and Image retrieval

A relational model was used to construct the database and a client-server application for data management. Typical information system retrieval was implemented. A client-side application provides a search dialog that lets users dynamically compose search requests. An application server executes the queries on a data source and returns the results to the client application, where they are shown.

Textual based information is not enough in some cases, especially when user's search requirements are about visual features of the image. To solve this, we have implemented content based image retrieval - CBIR system. Bag of Words (BoW) are used for image representation as local visual feature[15]. The basic idea of BoW is that a set of local image patches is sampled using some key point detector and a vector of visual descriptors is evaluated on each patch independently. Patches created are quantized into a set of visual words which constitute a codebook. After that, an image is described as a histogram-based representation, on which a classifier (such as SVM) is used

Figure 8 shows the CBIR model for retrieving images similar to a user given example (Front positions of IR images were used for experiments). According to Figure 6, after segmentation (detailed in next section) a preprocessing stage is applied over the gray scale image. Firstly, the image must be cropped discarding the background that is outside the boundaries of ROI. After that, morphology operation of erosion is applied in the boundary of the ROI, by using square structuring element of 3x3. Then, a process to smooth the background is performed. Finally a normalization of the contrast is used to enhance the gray scale of the ROI.

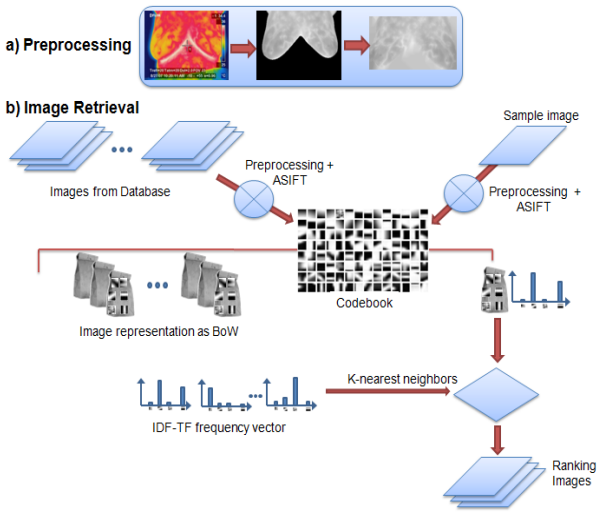

Figure 8: (a) Preprocessing stage, (b) CBIR based in Bag of Words model.

For image retrieval, points of interest have been extracted. A point of interest of an object represents a specific point around which the local image structure is rich in terms of local information content. The Affine-SIFT proposed by Morel and Yu[16] that is fully affine invariant for image comparison is used. 128 elements compose the feature vector per point of interest and each image has 127 average points. These ASIFT features are then clustered with a k-means algorithm using the Euclidean distance.

All information for each patch except its corresponding closest cluster center identifier are discard The clusters represent a codebook and, based on this, each image is represented as a frequency vector, using a TF-IDF weighting technique[17]. Finally a KNN (K-nearest neighbors) approach with cosine measure is performed to retrieve *k* similar images to a sample given by the user.

3.3 Accessing the database

The URL *http://visual.ic.uff.br/dmi* allows user registration and then access to all functionalities of the database cited above. Figure 9 illustrates one of the navigation pages for retrieval of IR images. Images can be downloaded in JPG or BMP format for mammograms; float temperature matrix for IR images. Information about the exam can be downloaded in txt or XML format. In a next version of the database, all these data will be joined in a unique DICOM file per patient.

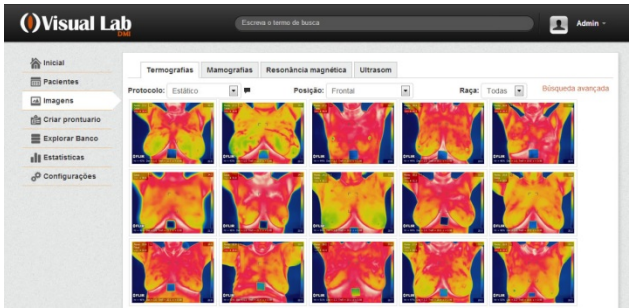

Figure 9: User Interface of DMR-IR database.

4. CONCLUSIONS

IR image acquisition protocols have been reviewed in the literature and a new dynamic protocol has been proposed. Also, a new database for mastology research with IR images has been described. We believe that this study will help to further research in early detection of breast disease such as cancer. Our future work is to develop computational methods to analyze these data, providing information which support to physicians.

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