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Video-Rhino-Hygrometer (VRH)

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Abstract— **Rhinomanometry includes a set of methodologies to diagnose pathological alterations of the nostrils and nasal cavities. Some anatomic variations could cause partial or subtotal obstruction of one or both nostrils, leading to insufficient nasal respiration. Rhinomanometry measures the airflow through one nostril at time, while a pad occludes the other. This method has some drawbacks, such as the alteration of airflow in the not-occluded nostril due to the presence of the pad, the low reproducibility, and a reduced patient comfort. In this paper we propose a new methodologies that, we call Video-Rhino-Hygrometer (VRH)[1], and illustrate specific device to perform it. VRH may be considered as an automatized evolution of the classical Glatzel methods, because it infers information on clinical parameters analysing the image produced by the condense of the breath on a suitable surface. Specifically, VRH uses a web-cam to record these images and, after a suitable processing, it is able to compute a set of clinical features useful to perform diagnosis. Encouraging clinical tests show that the proposed approach provides results comparable with classical rhinomanometry tools without using the pad, obtaining reproducibility results, with an higher comfort for the patient and with a reduced examination time.**

I. INTRODUCTION

Almost the 90 % of the people shows little deviations of the nasal septum that do not lead to an actual modification of the normal respiratory features. But in some people, deviation is so high to cause conspicuous difference in airflow. Such differences should be caused by a partial or a sub-total obstruction of one or even both nostrils [1], [2]. Sometimes, such obstructions get worse because of compensatory hypertrophy of the middle and the lower turbinates. The main symptom is the insufficiency of nasal respiration, which is proportional to the entity of the obstruction [3].

Currently, the most used approach to evaluate the level of a nasal obstruction is the rhinomanometric exam. It measures the permeability of the nasal airways, and analyzes the air resistance by elaborating the out going and incoming flow from both nostril at prescribed level of pressure, selected by the tool. The rhinomanometry is concerned on the theory that the air in a tube moves from the higher to the lower pressure zone due to spressure gradient. The last one is caused by the respiratory strain, which alterates the pressure of back-nasal space, in comparison with the external one. Such a modification provokes an internal and an external airflow, through the nasal cavity. According to the definition of the American Academy of Ophthalmology and Otolaryngology, the rhinomanometric exam is the graphical record of the numeric measurement of the airflow versus the pressure of the nose [4]. In Figure 5 and 7 examples of the output graphs of the rhinomanometric exam are reported.

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The pressure would be analysed in one of the nostril at time, while the patient breaths through the other one. Hence, a pad is put in the nostril which is not under examination to obstruct it. Moreover during the test a transparent face mask, equipped with a linear pneumotacograph, is used. Such a mask is connected to an amplifier with a flow recorder.

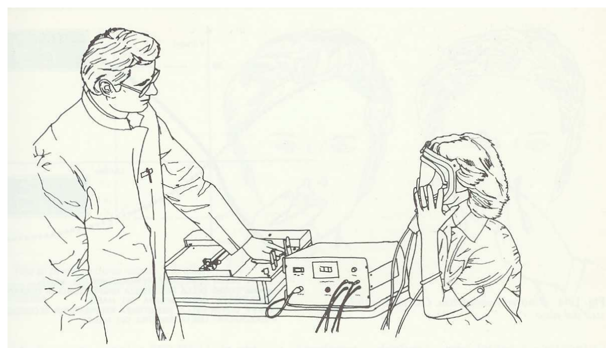

Fig. 1. Typical Rhinomanometer device. Notice the presence of the mask on the face of the patient.

Unfortunately, the rhinomanometric exam has some drawbacks. Firstly, the pad insertion induces a mechanical stress on the nasal cartilage. Such a stress deformes also the not occluded nostril, introducing measurement artifacts. Secondly, the rhinomanometric exam is performed separately for each nostril, thus altering the normal breathing. Thirdly, both the insertion of the pad and the use of a face mask should produce some difficulties to patients that should be not able to complete the examination, especially in the event of very serious pathologies. Fourthly, the results exhibit scarce reproducibility. Indeed, if the examination is repeated just 15 minutes later, the results may differ up to 20 $\div$ 25 %, whereas if it is repeated the day after, the difference may be up to 50 % [5].

In order to overcome these drawbacks we are developing a different methodology based on the automation of the ancient Glatzel method. The main idea of this approach, named Video-Rhino-Hygrometer (VRH), is the use of both a video-camera to record the image impressed by the breath condensing on a suitable surface and quite sophisticated digital processing techniques to extract a set of parameters useful for diagnosis.

Clinical tests have shown that the proposed approach provides results comparable with classical rhinomanometry tools, but with better comfort for the patient, shorter time for the examination, and higher reproducibility of the results (at 15 minutes the differences are less than 10 %).

In the next section we briefly summarize the main idea used to realised VRH and then illustrate the realised prototype. Section III is devoted to illustrate experimental results while some conclusions are collected in the last Section.

II. Video-Rhino-Hygrometer

In 1901 Glatzel shown that some pieces of information on nasal septum deviation may be achieved analysing the image produced by the breath condensing on a surface. Even this is a very attractive test due to its simplicity and patient comfort, it produces only qualitative and non permanent information. These especially because the time persistence of the image is very short and its shape and extension depends on climatic parameters. Some attempts, without any successes, to make more quantities Glatzel method have been proposed in the years using graduated grid on the surface or using hygroscopic material [5].

However the interesting features of the Glatzel methods suggested us to investigate how the capability of modern digital processing techniques might be exploited to realise a methodology able to infer quantities information starting from the analysis of the image produced by the breathing on a surface (or better by the condense of the water vapour presents inside the breath).

To this end, we are developed a VRH device where the breathing image is recorded via a video-camera. This video is automatically processed, frame by frame, in order to extract, once removed any artifacts, a set of quantitative parameters useful for clinical investigation.

A. The device

The proposed device is schematically illustrated in Figure 2 are reproduced in Figure 9. It consists of five main components: a chin rest (1), a metallic plate (2), a video-camera (3), a workstation (4), a set of lights (5). All the components are mounted on a rigid support (6) and the system is completed by a control feedback used to regulate the temperature of the metallic plate at 7° C (not shown in the Figure). The chin rest, besides providing a comfortable support to the patient chin, avoids the contraction of neck muscles. Such a contraction will lead to a reduction of venous blood flow and to a consequent changing of nose air resistance.

The plate on which the patient breathes is steel-made, and its temperature is kept constant at a fixed value (7° C) by using a control feedback. Moreover, in order to consider anatomical differences between patients, the plate has two degree-of-freedoms (dof), which allow vertical and horizontal shifting.

The video-camera is web-cam with 30f/s and a resolution of 640x480 pixels. It is connected to the computer via USB. Moreover it has three dof: vertical, horizontal and rotational around the pitch axis. We choose diffusive lights in order to avoid illumination artifacts on the metallic plate, such as

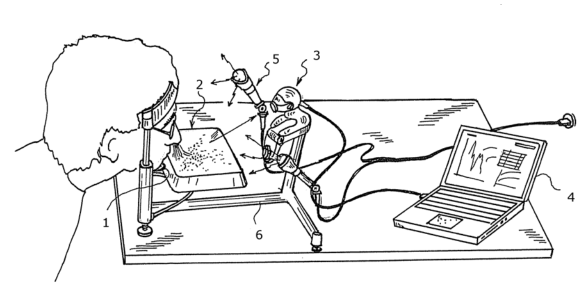

Fig. 2. Schematic representation of the proposed Video-Rhino-Hygrometer (VRH) device.

shadows, which may make both the image processing and analysis phase more difficult. The lights have three dof and have suitable light-diffusers to better arrange the illumination of the plate.

B. VRH examination

At the beginning of the session, the patient puts his/her chin on the suitable rest, the lights are turned on, the camera position is set, and then it starts to register the scene. Then the patient normally breaths on the steel plate for prescribed time (generally for no less then five respiratory acts).

While he/she breaths, due to the low temperature of the plate, there is a condense phenomena on these surface which is recorded via the web-cam. Notice that, optionally, in order to consider only the patient normal breathing, the software may eliminate the first seconds of the patient movie.

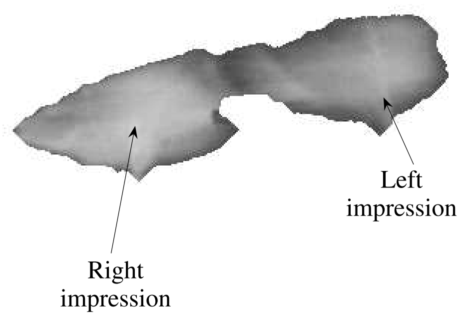

Fig. 3. Example of left and right nostril impressions partially overlapped.

After collecting the patient movie by using the web-cam, as described above, each frame is pre-elaborated to convert the RGB image to grayscale, to improve the contrast and to remove noise. In order to carry over a quantitative evaluation of respiratory flux of each nostril it is important to properly identify both right and left impression on the metallic plate. That task is performed by segmenting the image. Classically, image segmentation is defined as the partitioning of an image into non-overlapping, constituent regions that are homogeneous with respect to some characteristics. Ideally, a segmentation method finds those sets that correspond to distinct structures or regions of interest in the image. It is worth noting that during the breathing, the impressions on the metallic plate could partially overlap (as shown in Figure 3). This observation suggests us to perform the segmentation task of each frame in two steps: (i) first of all, we detect the overall impression area by using an edge detection approach; (ii) then we perform a watershed segmentation to properly split the overlapped impression in the right and left part.

With regard with former step, first-order digital derivatives are used to detect the meaningful discontinuities; as approximation of the 2-D gradient we make use of Sobel mask [6]. Then we perform some morphological operations, such as dilation, erosion, filling and connection analysis, to properly locate the impression area. As results, we obtain an image that contains only the impressions, but in this phase we do not look after impressions overlapping. In the latter step, if the two impressions are overlapped, we split them by using a segmentation approach based on morphological watersheds (see Figure 3). Since the direct application of the watershed segmentation algorithm leads to over segmentation due to noise and other irregularities of the gradient, we make use of markers in a preprocessing stage to bring additional knowledge into the segmentation procedure [7]. At the end of the segmentation process, we are able to identify, for each frame, the impression associated with each nostril. In order to generate normalised values, the gray-level of each impression are scaled via an experimental evaluated 2D look-up-table on the basis of ambient temperature and humidity.

For each frame, the data are processed in order to generate the following parameters:

- impressions extension associated with each nostril;
- averaged ratio of the two extensions;
- spatial location of the centroid of each impression;
- inertia axis associated with each impression (see Figure 4)

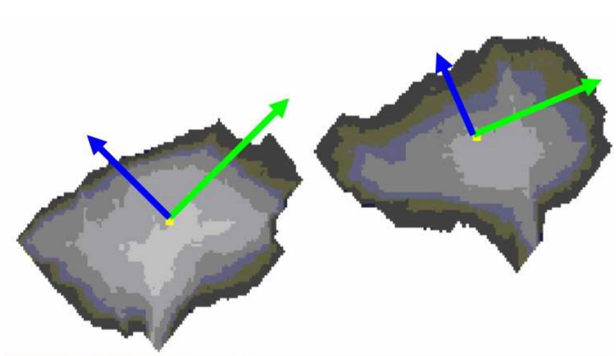

Fig. 4. Centroid location and principle axis orientation and size associated with the impression of each nostrils.

Notice that all the quantities are evaluated weighting the different pixel belonging to the impression via their gray value. Then the time history of all these parameters is collected (see Figure 6 and 8).

In the next section, experimental tests exhibit the usefulness of these parameters in clinical diagnostic. Specifically, the averaged ratio of the extensions associated with each nostril seems to be a good index of nasal septum deviation.

Moreover, it can be regarded that there is good correlation among flows measured via the rhinomanometry and the sizes of each impression evaluated via VRH.

III. Experimental data

To validate the proposed system we performed a series of clinical tests over subjects with different pathologies.

In Figure 9 it is shown a patient performing the VRH test using the developed prototype.

As mentioned before, the results evidence a strong correlation among the ratio of the out going flow (recorded via rhinomanometric exam) and the ratio of the extensions of the impressions (evaluated via VRH). The perceptual difference between the two ratios is smaller than 10 %.

In Figure 5 and 6 we compare the tests of patient A who does not have any pathological situation. In Table III we report comparisons of averaged quantities. Notice that in this case the rhinomanometry estimated a deviation ratio of 1.7, whereas VRH evaluated it as 1.62.

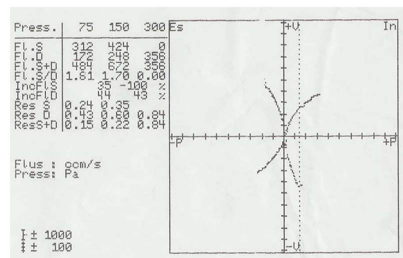

Fig. 5. Rhinomanometric test of patient A.

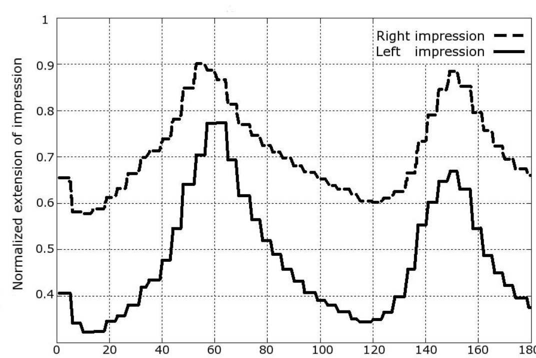

Fig. 6. Time hystories of the size of the left and right nostril impression for patient A, evaluated via VRH.

Figure 7 and 8 report results of a patient B that is affected by an almost-total obstruction of the left nasal cavity. Notice that this situation, as emphasised by both the figures, represents a difficult situation for both the methods.

Notice that patient B has been forced to stop the rhinometric examination because due to obstrcution the in-coming flow was very low, hence he could not breath enough. On the other hand, he easily performed the VRH test which allows

Patient	Rhinomanometry		VRH	
A	L	424	L	2880
	R	248	R	1783
	Δ	1.7	Δ	1.62
B	L	48	L	489
	R	212	R	1645
	Δ	0.22	Δ	0.29

TABLE I

COMPARISON FOR RHINOMANOMETRIC AND VRH TESTS ON TWO PATIENTS (PATIENT B HAS A QUITE COMPLETE OBSTRUCTION OF LEFT NASAL CAVITY). Δ IS THE DEVIATION INDEX AND IT IS THE RATIO BETWEEN LEFT AND RIGHT NOSTRIL PARAMETERS.

concurrent breathing through both nostrils. Quantitative data are collected in Table III. Also in this case, there is a very strong correlation among the deviation index calculated via rhinomanometry examination (equal to 0.22) and that evaluated by VRH (equal to 0.29).

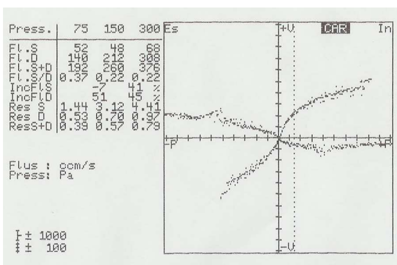

Fig. 7. Rhinomanometric test of patient B. Notice that the graph on the left side is very close to x-axis due to the almost-total obstraction of the coresponding nasal cavity.

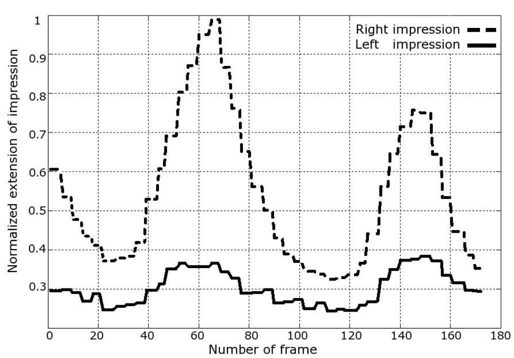

Fig. 8. Time hystories of the size of the left and right nostril impression for patient A evaluated via VRH.

IV. CONCLUSIONS AND FUTURE WORKS

In this paper we have proposed an approach to automate the ancient Glatzel method. The procedure has some interesting features with respect to rynomanometric approach. Specifically it does not alter the normal breathing, it does not modify the airflow in the nostril, it is high comfortable for the patient, it is very quickly (because it performs concurrently the examination of both the nostrils) and, finally, it exhibits good reproducibility. Clinical tests are encouraging: indeed they show results comparable with rhinomanometric tools, overcoming the existing drawbacks.

Future works will be mainly devoted to create a user-friendly fully automatic user-interface and to identify correlation among the different parameters extracted by the VRH with different pathologies.

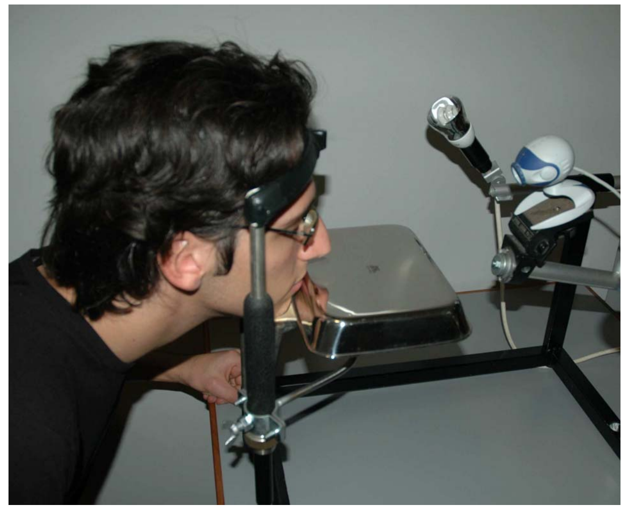

Fig. 9. The Video-RhIno-hygrometer prototype during a test.

V. ACKNOWLEDGEMENT

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