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► **To cite this version:**

Thierry Legou, Aude Lagier, Fabrice Silva, Nathalie Henrich Bernardoni, P. Champsaur, et al.. Test bench for human excised larynx studies. MAVEBA 2015 - 9th International Workshop on Models and Analysis of Vocal Emissions for Biomedical Applications, 9th INTERNATIONAL WORKSHOP, Aug 2015, Florence, Italy. hal-01249201

HAL Id: hal-01249201

<https://hal.science/hal-01249201>

Submitted on 30 Nov 2020

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TEST BENCH FOR HUMAN EXCISED LARYNX STUDIES

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Abstract: Many questions about the physiology of vocal folds vibration, mechanical properties of the vocal folds, impacts of pathologies on the vocal mechanism are investigated in different ways: physical modeling, experiments *in vivo* on animals or in human volunteers or patients, and also on excised larynges (animals or human/autopsic). Many parameters are involved in phonation and quality of the voice such as the source (flow, pressure), the action of laryngeal muscles and glottal configuration, temperature and humidity.

Objectives: In order to independently control these parameters with a biologic model as similar as possible to *in vivo* human conditions, and also to reach a level of reproducibility that permits measurements comparisons, we have developed a dedicated test bench for human excised larynges. Several classic measurements are systematically recorded such as airflow, subglottal pressure, glottograph signal, sound (F0 and intensity), but also contact pressure between vocal folds. A high speed camera is also synchronized for glottis area and motion analysis. The glottal configuration depends on each study, and has been automated to achieve dynamical control, reproducing the action of laryngeal muscles. The humidified airflow is applied to the larynx via an intubation tube introduced in the three last upper rings of the trachea.

Keywords : Larynx, Test Bench, control, measure.

I. INTRODUCTION

Phonation is a complex activity which implies aerodynamic and muscular controls. Humans are able to produce a wide variability of sounds from whispering to shouted voice. The use of excised larynx and on a dedicated test bench permits to decouple these control parameters and therefore understand their individual role. It therefore permits to evaluate the effect of a parameter on phonation for a given configuration. The capacity of measuring and

controlling parameters also offers the possibility to reach a sufficient level of reproducibility to make possible measurements comparisons for a given larynx but also to cope with the intrinsic differences observed between larynges.

II. LARYNX PREPARATION

Larynges are dissected, keeping them intact from the thyroid to the third tracheal ring. The vocal folds adduction was constant, using concomitant arytenoid adduction and membranous vocal folds medialization with Montgomery implants. Subglottal pressure is measured 1 cm under the glottis by a tracheal puncture.

III. TEST BENCH STRUCTURE

The test bench can be divided in six main principal functions (PF). The larynx holder & positioning system (PF1), the airflow apparatus (PF2), the pulling system (PF3), the vocal folds pressure contact module (PF4), the high speed camera (PF5) and the measurement/acquisition unit (PF6).

A. The positioning system. (PF1)

On the bench the larynx lays horizontally, the posterior edges of the thyroid cartilage are in contact with an adaptable holder. Adjusting the space between the two parts of the holder is mandatory in order to identically set the larynx on the bench independently of its size. As the larynx is secured by the strap of the glottograph well tied on its older, the cricoid cartilage is kept free to permit the crico-thyroid tilt (see Fig. 1).



Fig. 1

B. The Airflow apparatus(PF2)

The airflow is generated by a turbine (Werie Rietschle) with a capacity above $10\text{dm}^3/\text{s}$. Before being injected into the larynx, the air goes through a heater/ humidifier (Drager, Aquador). Then, the humidified airflow is applied to the larynx via an intubation tube introduced in the three last upper rings of the trachea. The flow is adjustable manually by a $\frac{1}{4}$ turn valve. To set the desired flow, the operator has a permanent real time monitoring of the airflow actually applied to the larynx.

C. The pulling system(PF3)

In order reproduce the cricothyroid tensor muscle, we have developed a pulling system (Fig. 2) based on a micro linear actuator with a 0.2mm accuracy (Firgelli L12-100) controlled by an Arduino board, an open hardware/open software microcontroller platform. The microcontroller can be controlled on the fly, and its motions are recorded by the measurements unit.

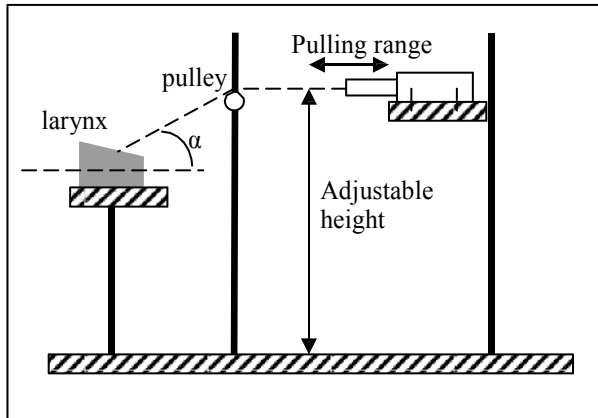


Fig. 2

As the thyroid is secured on the bench, the linear actuator pulls on the cricoids (free to move) via a nylon wire to modulate the cricothyroid tilt. The pulling range (100 mm) of the linear actuator permits to study the impact on phonation of the cricothyroid tilt over its full natural variation range. A dynamic control is possible up to 12mm/s .

The distance between the larynx horizontal axis, the actuator axis and the height of its associated pulley is adjustable giving the possibility to change the pulling angle (α).

D. Pressure/contact unit(PF4)

Vocal folds synchronization is a complex process. Many simulations have taken into account aerodynamic effects and tissues properties that could explain vocal folds motions. The pressure of contact between folds has also been studied to understand its role in the folds synchronization and also to evaluate

its effect on phonotrauma in vocal abuse. To study the pressure of contact, several studies used tiny piezoelectric transducers type 060S from Precision Measurement Company (Michigan, USA). Jack J. Jiang and al used it in exvivo canine larynges experiment [1], and other studies used it in human in vivo measurements [2] and [3].

We selected the available type 105S from the same manufacturer, with stainless-steel diaphragms (visible between vocal folds in Fig. 1.a). The pressure range covered by the sensor is 0-60 psi. The sensor is a part of wheatstone bridge, from which the output voltage is amplified by a differential amplifier. The high gain ($\times 5000$) of two cascaded amplifiers permit the readout of very weak vocal folds pressure signals.

E. High Speed Camera(PF5)

To study vocal folds motions, and to measure the glottis area, we use a high speed camera (Fastcam SA-3, Photron) equipped with a micro-lens (AF Micro-Nikkor 105 mm f/2.8D, Nikon). Films are recorded at 5000fps and the high sensitivity of the camera sensor gives very high contrasted images processed by a homemade Matlab script to measure the open glottis area. To synchronize films and signals recorded by the measurements/acquisition unit, the camera sends a trigger signal at the beginning of each video.

F. The measurements/acquisition unit(PF6)

On the present version of the test bench, all data are acquired using a specialized speech aerodynamic workstation (EVA2) [4]. This unit usually records simultaneously audio, airflow, air pressure, glottograph signal. Table 1 lists the possible measurements variation range for the recorded parameters.

Table 1

Parameter	Range
Airflow	0-2 dm^3/s
	0-10 dm^3/s
Subglottal pressure	0-20 hPa
	0-40 hPa
	0-100 hPa
	0-200 hPa

In addition to these classic parameters, three exogenous signals are also recorded simultaneously. One analog signal which is proportional to the folds pressure. And two digital signals for post synchronization. The first one is sent by the linear actuator that pulls the cricoid and the second one sent by the high speed camera at the beginning of each film sequence. Fig.3 is the sketch of the acquisition system in its environment.

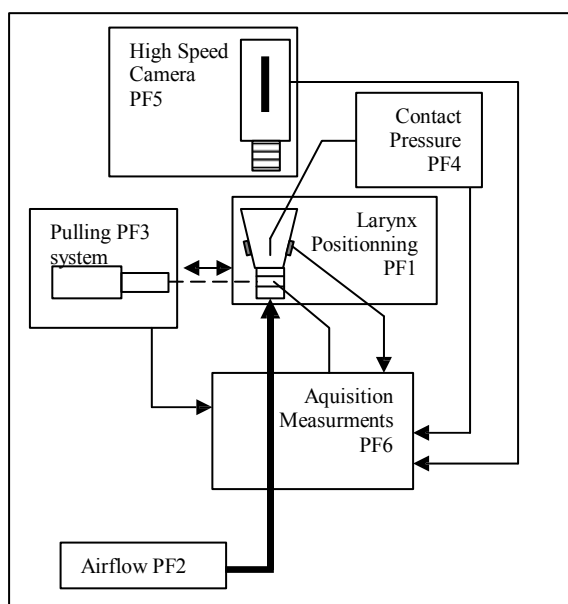


Fig. 3

The sound is recorded by a C420 AKG microphone digitized with a 25000Hz sampling frequency over 16bits. The microphone is set at 15 cm from the larynx, with an angle of 30° from the larynx sagittal axis. Apart from the audio signal, all analog signals (glottograph, subglottal pressure, airflow, pressure of vocal folds contacts) as well as digital ones (puller system and camera trigger signals) are digitized with a sampling frequency of 25kHz over 16 bits.

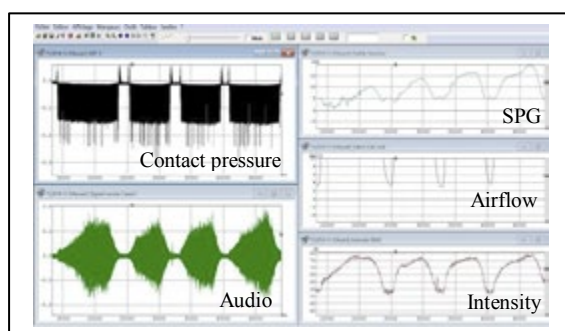


Fig.4

All recorded signals can be displayed simultaneously with a common moving time marker using Phonedit software (see Fig. 4). For quantitative analysis dedicated Matlab scripts are used.

IV. PERSPECTIVES

To remove any human action during tests, the airflow control will be soonly automated.

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