Aerophonoscope assessment of velopharyngeal incompetence: Attempt at classification and therapeutic implications

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Abstract

An aerophonoscope is an instrument which was created in Nantes, enabling aerodynamic evaluation of the velo-pharyngeal sphincter in the usual conditions of speaking and breathing, for people over 3 and a half years old without scaring them. It provides an ultra-sensitive means of detecting nasal air flow, and confirms the variable and inhomogeneous character of nasal air flow, depending on different phonological-linguistical and pathological factors. It enables us to measure the severity of velo-pharyngeal incompetence and to objectify different types of velopharyngeal impairments for children after primary surgery or in a context of speech impairment.

It allows us to guide therapeutic solutions and surgery decisions. Moreover it provides a fun and efficient means of rehabilitation.

Key words: Aerophonoscope; velo-pharyngeal sphincter (VPS); aerodynamic assessment; nasal air flow (NAF); phonotactic links; contaminations; etiologic typology; surgical decisions; visual feed-back for rehabilitation.

L’aérophonoscope AERO-D, inventé à Nantes permet une exploration fonctionnelle de la cinétique vélo-pharyngée, dans les conditions physiologiques de phonation et de ventilation, sans caractère inhibant pour les enfants à partir de l’âge de 3 ans et demi, après chirurgie primaire ou dans un contexte de troubles du langage. Il fournit un moyen ultra-sensible de détection du moindre flux d’air nasal en cas de rhinolalie ouverte, et confirme le caractère variable et inhomogène du flux d’air nasal dépendant de différents facteurs phonologiques-linguistiques et pathologiques. Il nous permet d’évaluer la sévérité des troubles et de découvrir différentes types d’insuffisance vélaire.

Il permet d’orienter au mieux les choix thérapeutiques, les types chirurgicaux et nous donne un moyen ludique et efficace de rééducation, ainsi que d’évaluer l’efficacité des traitements.

Il ouvre de nouvelles perspectives de recherche.

Mots clés : Aérophonoscope, sphincter vélo-pharyngé, exploration fonctionnelle aérodynamique; flux d’air nasal; rapports phono-tactiques ; contaminations; typologie étiologique, décisions chirurgicales , feedback visuel en reeducation.
Introduction

Velopharyngeal incompetence is divided into 2 groups:
+ Closed rhinolalia which excludes the contribution of nasal resonance cavities, and so induces hyponasality, which is not dealt with in our study.

+ Open rhinolalia which, on the contrary, induces hypernasality and has different etiologies.

Mainly, we can differentiate between:
1- major dysmorphic damage (bony and soft cleft palate), treated early with primary surgery, but the incompetence may persist, requiring secondary surgery of the velopharyngeal neosphincter,
2- minor rhinolalia, discovered at the age of about 2 to 5 years old in the context of speech delay, especially with genetic etiology +/- accompanied with hearing, psychological, neuropraxic and cognitive disorders.

The word “rhinolalia” usually means only acoustic and phonetic data, but in this study, we shall use the aggregate term, “velopharyngeal incompetence” from different aspects, for example, aerodynamic, acoustic, phonetic and articulatory ones.

Among the present means, the AERO-D aerophonoscope enables the examination of velopharyngeal dynamic function in physiological conditions of speaking and breathing, without intimidation.

With a cohort of 482 subjects, it enabled us to discover different types of velopharyngeal incompetence and led us to choose the best surgical and rehabilitation treatments, and to assess the effectiveness of these treatments.

It opens up new research perspectives.

I – Method and material

Equipment: The aerophonoscope was created in Nantes in the 1980s, by a speech therapist named Brother Pascal Rineau and Professor Jean Delaire, who was a maxillo-facial surgeon. It can record nasal and oral air flow, by using original sensors in the physiological conditions of speaking and breathing without scaring the child, and is thus easy for children from 3 and a half to 4 years old. It may be used with a laryngeal microphone.

This equipment is composed of 3 sensors connected by a USB port to a computer, on which the AERO RD program has been installed. These sensors have thermistors which are platinum wires, heated to 100°C by an electric current, and cooled by the air expired by the patient: the air flow cools the hot wires according to its speed.
Thus, even minimal nasal air loss can be quickly and reliably detected for a given group of phonemes or syllables and their sequences, according to the physiological conditions of speech.

The mouth sensor is placed at a distance from the lips so as not to prevent them from moving spontaneously, therefore it can only detect a part of the buccal air flow, which is impossible to measure precisely in children.

The nasal air flow sensor matches the shape of nostrils as closely as possible.

It allows a sensitive and objective record of nasal air flow (NAF) and therefore shows 4 physiological facts:

1 - spontaneous nasal ventilation (at rest, in speech or whistling),
2 - the detection of any variations of Nasal Air Flow in speech,
3 - characteristics of closing/opening movements of the velopharyngeal sphincter (VPS) all through the alternate sequences of oral/nasal syllables: their closing competences, their amplitude and stiffness, their speed, their steadiness (according to accelerations, prosody of speech, etc.),
4 - voice-velum coordination, during the pronunciation of voiced or unvoiced consonants. The latter notions are the topic of another study.

These nasal and oral air flows are shown with 2 proceedings:
a) a screen with a child’s face, whose nasal and buccal ports are colored

b) a screen with 2 main lines: an upper one, for the nasal air flow, and a lower one, for the buccal air flow, which is partially detected.

1 - normal curve
No nasal loss for a sentence composed of oral sounds

2 - pathological curve
Nasal loss during the same sentence
Enchainement de sons nasaux et oraux, de plus en plus rapides

Phénomène de contamination entre syllabes nasales et orales

(En phénomène physiologique en deçà d’un seuil de vitesse)

Beginning of contaminations

On this curve we must observe the alternate rise and fall of the nasal flow line, linked with the up and down movements of the velum, linked to the sequences of Nasal syllables/Oral syllables:

- the complete velopharyngeal closing, when the curve joins the base line on /a/.
- the maximal amplitude of velopharyngeal opening during the ascendant peaks on the nasal syllable /non/
- the variations of the speed of these movements: - high declivity = nasal flow acceleration
  - minor declivity = nasal flow deceleration.

These 2 syllables (a/non) are very contrasted, according to nasality feature.

NB NB. On the right of the curve, the sphincter inertia does not allow the complete closing between two nasal syllables. The aerophonescope confirms notice a physiological co-articulation of oral/nasal syllables, beyond a given speech rate level (beyond three syllables per second here): the base line is not reached for the pronunciation of /a/ in the case of healthy subject.
II- A reminder of velopharyngeal sphincter physiology in phonation

The velopharyngeal (VP) sphincter is a muscle of articulation, which plays a very important part in speaking, giving phonemes their oral or nasal character for the voice tone.

The phonological opposition between “oral sounds” and “nasal sounds” is achieved through velar elevation and pharyngeal muscle constriction (for oral sounds) as opposed to velar lowering and pharyngeal muscle release (for nasal sounds) [1].

The main muscle of the soft palate is the levator palatini muscle (LP) whose movements (contrary to expectations) are very fast [3], even if there is some velar inertia in the transitions between oral and nasal sounds. And this inertia explains different acoustic phenomena (variations of formants, phenomena of anticipation and spreading of the nasality [4]. It remains active in speaking.

In pathologic situations, velar incompetence is characterized by:

1-On an aero-dynamic level: the nasal air flow is related to different factors:
   + of course, to the VPS impedance, its ability to close, in other words, its role in “resistance” against nasal flow [7,8 Warren].
   + this is correlated to the intra-oral pressure, and so to the buccal orifice and to the labialization or not of the oral or nasal vowels (9).
   + to the recoil of the tongue [10],
   + to the buccal orifice (11 Amelot); for healthy individuals, there is an opposition between the oral open and closed vowels: the latter require a small buccal orifice correlated to a higher intra-oral pressure, inducing a greater oral air flow than for the open vowels. We can observe the same fact for pathological individuals with cleft malformation.

   The fact that excessive “nasal loss” sometimes exists with means of compensation means (narrowing of nostrils, laryngeal and pharyngeal constrictions).

2- On an acoustic level, the feature of nasality of the sounds /an/on/in/un/ is characterized by the addition of counter-formants and by changes of frequency, intensity and bandwidth (in particular for formants F1 and F2) in comparison with the oral vowels /a/o/e/eu/ [2]. In pathological situations, the excessive nasal resonance is called hypernasality with or without additional noises (nasal blow and ronchi). Sometimes both hypo- and hypernasality are noticed.

Three important phenomena about velo-pharyngeal physiology must be noted:

1) Velar inertia:
   There is a slowness in transitions between nasal and oral sounds which are explained by the following fact: nasal vowels have 2 segments: the first segment has no NAF, then in the second one, the nasal air flow appears; these vowels are produced and perceived as diphthongs (9,14, Montagu, 2004; Ohala 95, cited by A.Amelot).

   During the pronunciation of nasal sounds, there is a moment of maximum opening of the soft palate, where we have a good perception of nasality, especially for the nasal vowel /on/, which is prioritized in our assessment tests.

2) the striking phenomenon of Coarticulation
   + For healthy individuals, most of the time there is a coarticulation of nasal and oral phonemes: a nasal air flow for the oral vowels exists to varying degrees in every language, as Durand described (16) in 1954. In other words, a tolerable physiological margin exists for oral sounds. This small level of opening of the velopharyngeal sphincter induces a nasality in different ways for different vowels (quantified exactly at 0.4 cm² for /ü/; 1.6 cm² for /a/) [17].

   The feature of nasality is not reducible to the binary description (oral sound = tight sphincter, nasal sound = permeable sphincter, as defined by Chomsky (1968). The question may be asked about the minimal oral/nasal connection to modify /o/ to /on /, and /a / to /an/.
Thus, there are different levels of activation of the LP (levator palatini) according to each phoneme. Usually, the following order is found, beginning with the phonemes which facilitate the closing of VPS (the most “resistant” to hypernasality) to the least facilitating ones (the least resistant).

For Vaissière and Basset Karling (17, 18): nasal vowels < nasal consonants < opened vowels < closed vowels < plosives < /t/ /l/ < /s/ [12]

For Clements: Vowels < liquids < unvoiced fricatives and voiced plosives < unvoiced plosives.

Starka (21) describes nearly the same.

A different order will be observed in this study in pathologic situations, mainly in dysmorphic disorders.

3- the striking phenomenon of Contamination may be considered as an exaggeration of the phenomenon of nasal coarticulation, varying in audibility in different languages: French requires a high phonological opposition between oral and nasal sounds.

This contamination may occur before the production of nasal phonemes (anticipation nasality) or after the production of nasal sounds (spreading nasality) (11). For instance, in the words “donc”, the first and the last phonemes are nasalized.

It also depends on different factors: speed of speech, accents of intensity, prosody (melodic rise for interrogative and exclamatory formulations, and melodic descent for affirmative formulations, etc.) which are important to assess.

These phonotactic facts are part of the notion of “phonetic context” (24-26).

Fig 6: Physiological contamination according to rate acceleration of the sequence /a/non/: For this healthy person, we observe the fact in the right part of the curve: the base line is not reached during the /a/ productions, beyond 3 syllables /sec.

Fig. 7 Pathological (dysmophy) contaminations according to different syllables (/do /jo/): the curve does not reach the base line for single /do/ and then goes away in the sequence /mon/do/ and more in the following sequence /mon/Jojo.
N.B. We know the particular case of singing voice:
- the singing formant is produced mostly by raising the soft palate (Levator palatini and Tensor palatini) and by the enlargement of the naso- and oropharynges [14].
- furthermore, the high-pitched notes induce a spacing of harmonics and formants, which modify the spectrum and the perception of all oral and nasal sounds [15] which are not easily recognized.

III – Aim of our work

Aerophonoscopic assessment, focused on the dynamic movements of the pathological VP sphincter, has been conceived in a surgical perspective for the best correction possible of the considerable nasal air flow (NAF), peculiar to the residuals of cleft palates, and all sorts of velar incompetence; and to restore the best kinetic capacities, in order to realize good phonological opposition between nasal and oral sounds.

Surgery and rehabilitation by speech therapists have to consider all the factors of velopharangeal incompetence.

The quality of closed/open movements of the velopharyngeal sphincter depends on many factors, which explain the variability of articulatory, aerodynamic and acoustic data. These data are not linear in healthy people nor are they in pathological ones.

These factors are ranked according to their importance:

1- Anatomical factors:
- the degree of lack of closing, which depends on the length of the soft palate and the width of the nasopharynx.
- flexibility of tissues (surgical clefts, velar retraction after tonsillectomy, etc.)
The increase of nasal air flow (NAF) rate depends on the pressure gradient between oral and nasal cavities which vary according to each phoneme and syllable

2- Dynamic factors:
The opening amplitude, the speed of closing/opening movements, the presence of phonotactic contaminations. These phonotactic contamination depend on several things: the motor characteristics of each phoneme and syllable, melokinetic praxis capacities, stiffness, tongue recoil; means of compensation of speech disorders (for example lingual, pharyngeal, laryngeal muscle synkinesis by full contraction of the Deep Facial Muscular Chain (Delaire 75).

3 – Linguistic factors: Requirements of the language and phonatory behavior, for healthy or pathological people:
- a nasal coarticulation, that is to say, a tiny connection between oral and nasal cavities by a slight velopharyngeal incompetence, audible to varying degrees, and variable in different languages; it is very slight in French [5].
- the proportion of nasal sounds alternating with oral sounds, which is one of the characteristics of continuous speech, of “phonological chain” (Jackobson). It exists with varying regularity and is different in every language.
- prosodic variations: strength of stress accents (of tone and of intensity), characteristic for each language - speed rate and acceleration of an individual’s speech (“tempo”) induces a decrease of movement speed and so an increase of the phenomenon of contamination:
All these factors must be examined to assess the severity of the VP incompetence. If these tests are not made, this leads to a wrong assessment (“false negative”).

4 – Neuromuscular factors:
+ flabby paralysis, organic hypotonia, myasthenia; dystonia linked or not with genetic disease;
- functional hypotonia by the absence of auditory feedback, cognitive deficiency, immaturity.
“Verbal Dyspraxia” (“childhood apraxia of speech”) or Kinesthetic Afferent Dyspraxia, involving more elaborated cognitive linguistic processes [7 Dewey]. [8].
The 3 latter factors are assessed, in particular, with the specific so-called “sensitization” tests during the examination using an aerophonescope.
IV – Examination protocol

The examination by aerophonoscope contains different tests:

A - Examination of nasal ventilation in sitting or sleeping positions.

At rest, we observe the spontaneous inspiration and expiration. This permits to detect the varying degrees of obstruction of the nasopharyngeal system and its consequences in the situation of SAS (Sleep Apneic Syndrome) and the situations of tongue protraction, with the impact on swallowing and malocclusions.

1) Tests of passive movements: the oral breath increases the intra-oral pressure, leading to the passive rise of the velum.

1- during continuous oral breath, NAF detection is in proportion to the extent of velopharyngeal incompetence,
2- during pulsed oral breath, NAF detection is determined by the stiffness of the velum due to scarring, for example, or by the speed of its elevation.

2- Tests of active movements

During the tests of production of oral/ nasal sounds, according to our protocol, we shall indicate for convenience the “nasal syllables” - the syllables containing at least one final nasal vowel, a satisfactory condition to show contamination; with the preference for the nasal vowel /on/, which gives greater perception of nasality than the nasal vowels /an/ and /in/ [10].

It assesses the severity of nasal air losses by the pronunciation of all isolated closed vowels (i/ou/ u/eu/ê) and open ones (a/o/ è/), and the consonants. Each oral consonant is tested with an open and then a closed vowel (pataka then pitiki, for example; va/za/ja/ and /vi/zi/ji/), or in amusing sentences.

First of all, it shows the abilities of complete closing of the velopharyngeal sphincter for the whole spectrum of phonemes and for the tests with increasing levels of difficulty from the easiest vowels: a, /o/ open /o/ closed; /ê/, to less easy ones: /i/ ou /u/, then eu /ê/; from the easiest syllables (pataka) to less easy ones (viziji).

In pathological cases, the more the amplitude of closing/opening decreases, the greater the nasal air flow.
In this diagram, for twelve seconds, we observe:
- the absence of nasal air flow by the absence of a curve (except for the beginning of the syntagm)
- the excess of nasal flow: it appears in peaks, related to each syllable (with a moderate strengthening at the end of the curve).

More specifically, we have to examine the whole phoneme list:

1- from easy, facilitating vowels and consonants (/a/ /e/ /o/, and unvoiced plosives /p/t/k (/pataka/ potoka/), within some amusing words or phrases such as “toi t’es cap”, “a cup o(f) tea”, etc.

2- to less easy vowels and consonants (i/u/ou/é) and voiced consonants /b/d/g/ and /v/z/j/, related to closed vowels (/bidgui,/ viziji/) within words or phrases like “bigoudi”, “the begge(r)”, “j’é vu zizou”.

3- and the intermediate phonemes inside syllables (“(elle)/se /fa/cha;” / “dès/ba/gues/” ).

NB : the liquids /l/r/ and the half vowel /ill/ (within “« l’o/re/ille” » haven’t any range of severity

So, we objectified different phenomena of dissociations:
- dissociation between the syllables with vowels of anterior articulation (vowels /i/o/u) and the syllables with the vowels of posterior articulation (open vowels à /é/o).
- dissociation be tween voiced and unvoiced consonants (/p/t/k/ and /b/d/g, for example).
D- Sensitization tests show the true severity of velar incompetence within continuous speech, according to the specificity of the language and the prosody (accents, intonations and rhythm of speech, in particular).

The tests allow to reveal one or several neurological components. Indeed, their purpose is to objectify the mechanisms of the VP sphincter muscles:

1) -their steadiness by the study of basic tonus with a continuous sound:
2) -their _tonus of action_, which can be weakened in a given dysmorphic syndrome with the tests of effort, line scan (hypertonic movements), etc.

These tests also assess the stiffness of musculo-aponevrotic structures.

3) -their _speed of action_ and flexibility, by the test of accelerated pace, during the succession of nasal/oral syllables.

Thus: **their muscular potential and not only the level of nasal air loss.**

1) **Steadiness** of velopharyngeal muscles (basic tonus) by the test of **holding on the nasal vowel /on/**, or a distorted vowel (/i/, /u/).

- either there is a loss,
- or an unsteadiness: it evokes a _neurological disorder_ (dystonia, coordination or praxis disorders).

![Fig 10: a case of velar steady tone](image)

**Steadiness on the vowel /i/** // **Increasing of velar closing with “phonetic” effort**

On this diagram we objectify: a steady line by holding on /iii/ with constant loss and the improvement by means of staccato (repeated and stronger /i/.) (cf.infra )

![Fig 11: a case of unsteady tonus](image)

Here, the basic tone is very unsteady when **holding on an /i/**
2) **Tonus of action** (and stiffness) which is assessed with the effort test
- accents of intensity: we ask them to make the staccato /hi/ /hi/ /hi/ /hu/ /hu/
  Figs. 10 and 12;

  + if there is improvement or normalization: it suggests a functional incompetence
  + if there is no improvement: it would indicate either isolated or additional **neurological** disorder
    (hypotonia), or **scar** stiffness
  + if continuous closing: it is **hypertonia**.

- pitch accents: we ask them to do a glissando towards shrill sounds.

**Fig 12**

**Effort test with energetic repetition of the phoneme /u/and /i/, stronger and stronger (after 2 inspirations).**

**3 ) Tonus of action also with the Speed of up and down alternative** movements of the VP sphincter, with the test of successive **sequences of Nasal Syllables/Oral syllables** (NS/OS) testing its melokinetic praxias, once a second, then in the rhythm of the French language, then more rapidly, if possible.

The phonemes are called “facilitating” phonemes because they favour the active and passive movements of the rise of the velum and the closing of the velopharyngeal sphincter.

The oral syllables contain all the consonants of spoken French; they are repeated so as to make them almost mute.

We must observe:

+ the different degrees of amplitude of the curve, in proportion with the air flow and the width of the nasal port

+ the speed of these opening/closing movements is assessed by the degree of declivity of the curves. We may observe a slowness of the curve, which indicates a slowness of the VPS closing (cf Fig 14).

**+ the presence of contaminations** (by prolongation of velopharyngeal incontinence) of nasal syllables, containing at least one final nasal vowel, on the following oral syllables (bon /ya/ bon /ya/). The increase of nasality for **oral syllables in** the following sequences:

  a) -from the most contrasting:
  For the alternation of oral and nasal vowels a/an ; /a /on ; /o/on.
  For the alternation of Nasal syllables NS / Oral Syllables OS, within French locutions:
  Mon/papa ; mon/papa ; tata-/on ;caca/mion ; baba/llon ; baba/ton ; dodo/nons ; gogo/mons ; sasavon ;
  chocho/mons ; faifai/sons ; vovo/yons, nouzaizai/mons ; gégé/nant ; lala/vons ; Rara/mons . ;
  or for young children : mon/coco, mon/babar, mon/bobo, mon /dodo, mon/garsgars, mon /foufou, mon/ seau-seau , mon/cha-chat, mon /jojo,

  b) -to the less contrasting ones, for the alternation of NS/OS containing more difficult vowels
(i/u/ou): “pipi/ment, titi/lłons, qui/quirn; Bubu/vons, didi/nons, Guigui/don ; fifi/lłons, sisi/mon, chichi/gnon ; vivi /són, juju/ment ; riri/ons, lili /sóns, you an(d) me

**Fig [13]** Physiological contamination during sequences of Nasal Syllables/Oral syllables. (NS/OS), faster and faster, up to 3 syllables per second, in a healthy subject.

Beginning of contaminations

On these curves showing the **melokinetic praxis** in the alternation of Nasal syllables/ Oral syllables, we can observe:

1- On the right of the curve we can see the phenomenon of assimilation during the acceleration of air flow - physiological contamination of oral syllables on the nasal syllables beyond a certain speech rate (beyond three syllables a second here): the base line is not reached for the pronunciation of /a/.

   The sphincter inertia does not allow the whole closing between two nasal syllables. The aerophonoscope confirms the inhomogeneous character of nasal flow within one-sixth of a second in the usual conditions of speaking (for a healthy subject).

2 - Here, the curve of deflection remains rapid, proving a good action tone, contrary to the following case, where we observe the slowness of rise of the velum during the pronunciation of /a/.

**Fig. 14** Slow velar rise, when pronouncing /a/ (in the sequence /a/non/a/non/)

Fig 15: in the following case of dysmorphic disorder, the curve does not reach the base line for the syllable /do/ and the sequence /mon/do/ at the same distance (no contamination) and then gets away with the sequence /mon/jo/jo/ (contamination)
Fig [16] Presence or absence of contamination during sequences of nasal/oral syllables.

Increase of contamination from /gê/ to /nan/, in a case of hypotonia

4) The poor steadiness of their base or action tonus is determined by a dystonic or dyspraxic component

(5) Inconstance dans le cas d’une dyspraxie verbale
In this case of Verbal dyspraxia ("childhood apraxia of speech"), we notice that the first three sequences “/a/mon” are regular, but the following ones are inconstant slowly and speeding up.

At the end of the examination, we propose 4 levels of severity for velopharyngeal incompetence:

1- minor severity:  
   a) no Nasal loss for oral breath  
   b) light nasal loss for articulation  
   c) improvement with accents, normal speed, no contaminations

2- medium severity  
   a) Nasal Loss with pulsated oral breath  
   b) moderate nasal loss + in articulation  
   c) slight improvement with accents, normal speed and contaminations+

3 – high severity:  
   a) Nasal Loss with continuous and pulsated oral breath  
   b) significant nasal loss++ for articulation  
   c) no improvement with articulation efforts, light slowness of velar rising  
      a lot of contaminations ++

4 - major severity:  
   a) +b) Nasal Loss with blows and in articulation ++  
   c) idem

**Examination protocol**

**I - Passive movement tests:** with oral expiration: continuous and pulsated blow  
In order to assess the soft palate scar stiffness: oral expiration increases intra-oral pressure leading to passive rise of the velum.

**II - Active movement tests:** to assess the closing capacities according to the different types of vowels and syllables  
- from the more facilitating ones: open vowels /a/è/o/ associated with /p/t/k/ in words or little syntagms (“t’es pas cap”, “talk up”).  
- to the less facilitating ones: closed vowel associated with /v/z/j/ (“jévu zizou”) “these vigil(s)”.  

**III - Sensitization tests:** to assess the muscular efficiency, more than pure scar stiffness  
   + above all, with the alternative up and down soft palate movements --and pharyngeal constriction--, to assess the speed of the up and down movements and the inter-syllable contaminations between nasal syllables and oral ones, (oh /non, ah /non) (with repeated syllable including an /o/ vowel which has a medium resistance against hyper nasalisation) “mon/dodo; mon /bobo/; mon jojo/” in order to test the consonant more than the vowel.  
   + Basic tone: observe the NAF steadiness while holding on a nasal vowel or a distorted oral one (/i/, /u/ ++  
   + Tonus of action : by means of effort exercises:  
      - scansion (staccato ho! ho! he !) ; crescendos, glissandos with the velar gesture of « coperto » (by mobilization of the muscular cervical chain) - and slow rhythm, then at the rhythm of French, then faster and faster.

**V – RESULTS**

**A) Cohort** of 652 individuals

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<tr>
<th>Children: 605</th>
<th>Mean age = 8,3 years old</th>
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<td>between 3,5 and 19 years old</td>
<td>Mean age = 8,3 years old</td>
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<tr>
<th>Adults: 47</th>
<th>Mean age = 44 years old</th>
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<td>between 20 and 84 years old</td>
<td>Mean age = 44 years old</td>
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We examined 3 sorts of pathologies:

- **Pure dysmorphic disorders:** 348

   + major ones before or after the primary surgery, regardless of the type of cleft (bilateral or unilateral bony palate cleft, soft palate cleft);
   - Bilateral cleft: 33  
   - Unilateral cleft: 110  
   - Soft palate cleft: 79
+ Minor ones have a velopharyngeal disproportion with a short velum and/or large pharyngeal cavity (“Prçva” syndrome); with or without posterior medial slot, with or without split uvula or submucous cleft; sometimes revealed by tonsillectomy and adenoidectomy: 126

b) Pure neurological disorders: 84
1 - “major ones”: 38 Flaccid deficit, spastic or flaccid-spasmodic deficit
2 - “minor ones”: 39 Hypotonia and dyspraxia, with or without soft neurological syndromes.
   Among them: 12 cases of “Verbal Dyspraxia” called “childhood apraxia of speech” (because of bad programming of phonetic sequences, and linguistic ones (8,19),
3 – specific dystonia: 7

c) Pure dysfunctional disorders: 27 (deafness, mental retardation, cultural or parental mimic, psychological immaturity, antalgic attitude post tonsillectomy) called “mislearning” disorders, because these vela are potentially
   - because of “wanting troubles”: psychological immaturity, antalgic attitude (post tonsillectomy)
   - because of “knowing troubles”: deafness, mental retardation, culture or parental mimism

d) Mixed types: 193
   Mainly by the association of a dysmorphic disorder and a neurological one, related very often to a genetic etiology:
   - Bilateral and unilateral cleft palate: 38
   - Cleft soft palates: 84
   Among them: 11 Pierre Robin sequences + 41 22q 11 syndromes
   (and Neuro-fibromatosis I; 2 Oral-facial-digital, Franceschetti, Van der Wood syndromes
   - Velo-pharyngeal disproportion (“Prçva” syndrome) 71 , including 9 genetic syndromes (Touraine, Stickler, Cornelia de Lange, Prader-Willy, Franceschetti, K lippeil- Feil and Recklinghausen syndromes )
   Among these mixed types : 21 Verbal dyspraxia.

B) An aerodynamic typology
Using an aerophonoscope we objectified the three dynamic types of velopharyngeal sphincter kinetic disorders, correlated with three etiologic frames:
   Each pure disorder is characterized by the following criteria:
and giving the rehabilitation to be more difficult than was initially

doctoral

ventilation

velar

or and/or

according to the

reconstruct

with a

dystonia.

- speech therapy for 4 months

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suggest

these factors may evolve independently of each other during the child’s development, causing

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Thus,

- If there are significant contaminations, in less contrasting alternation of Nasal Syllables /Oral Syllables, it

may suggest a structural disorder or fairly intense neurological disorder: surgical solution of filling,

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- If there are moderate contaminations, it often suggests functional incompetence: solution by means of

speech therapy for 4 months and monitoring of the outcome.

- If there are fluctuating contaminations, it may indicate neurological disorders (dyspraxia, hypermetria,

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The neurological components fall within genetic syndromes, combining a dysmorphic component

with a neurological one (often with a pejorative prognosis). This neurological component requires specific

reconstructive types of surgery (for instance: sphincteroplasty, pharyngoplasty, muscular transposition, etc.

according to the action tonus).

Many children have these mixed types including different correlated disorders:

1) either by co-morbidity, within genetic syndromes which add dysmorphic damage to

neurological disorders++ (“soft neurological syndrome with dyspraxic disorder, hypotonia)

and/or deafness of perception,

2) or by associated factors which are linked to etiology:

velar stiffness by a hypertrophic process (adenoids or tonsils) added to a deafness of transmission; buccal

ventilation, swallowing disorders, dental malocclusion, psychological immaturity and dyspraxia disorders.

These factors may each evolve independently of each other during the child’s development, causing

Table 1: The 3 types of velo-pharyngeal dynamic function

<table>
<thead>
<tr>
<th>Types of Disorders</th>
<th>Passive movement (with buccal flow)</th>
<th>Active movements (articulation of oral syllables)</th>
<th>Basic Tonus (holding on a nasal vowel)</th>
<th>Effort test (hypertonic movements)</th>
<th>Sequences (Nasal syllables/Oral syllables)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Dysmorphic Disorders (348)</td>
<td>Various nasal loss according to rigidity and the size of the gap</td>
<td>Either a great Nasal loss (26%) Or 2 sorts of dissociations: 1-Dissociation (61%) between + open vowels /a/u/e/ less distorted than + closed vowels /a/u/ 2-Dissociation (43%) between: + unvoiced plosives /p/t/k/ less distorted than + voiced consonants</td>
<td>Steady Nasal loss (95%)</td>
<td>Nasal loss improvement (63%) according to the size of the gap and the rigidity</td>
<td>most often Decrease of closing/opening movement amplitude</td>
</tr>
<tr>
<td>2- Dysfunctional disorders (27)</td>
<td>Dissociation (66%) between: - Plosive consonants /p/t/k/ more tonic than - Fricative consonants</td>
<td>NAD</td>
<td>Steady Nasal loss (100%)</td>
<td>Nasal loss Improvement (100%)</td>
<td>Fluctuating amplitude according to attention</td>
</tr>
<tr>
<td>3- Neurological disorders (84)</td>
<td>Different nasal loss observed according to the etiology (Cf. Table 3)</td>
<td>Often unsteady (76%) in the event of Dystonia/dyspraxia</td>
<td>Small improvement In the event of hypotonia</td>
<td>Slowness (closing or opening delay (53%) in the event of hypotonia or hypertonia)</td>
<td></td>
</tr>
<tr>
<td>4- Mixed disorders (93)</td>
<td></td>
<td>Unsteady (42%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thus,

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These factors may each evolve independently of each other during the child’s development, causing

rehabilitation to be more difficult than was initially estimated.

and giving the velum variable dynamic possibilities.
Velopharyngeal dysfunction is related to ventilation, Eustachian tube, swallowing and occlusion dysfunctions, as well as maxillofacial development, which increase the severity or the slowness of the rehabilitation. A velopharyngeal disorder requires all these functions to be tested.

During the child’s development, one functional abnormality may involve one or several structural pathologies, just as one structural pathology may lead to one or several functional disorders.

We can find, for example:
- most often, dyslalia (articulation disorders): naso-velar air loss leads to the decrease of intra-oral pressure, which gives a lesser gradient of pressure for labial (/p/b), dento-labial (/f/v) and dento-lingual (s,z,t/d/) sphincters,
- velopharyngeal dysmorphia may induce a tubal dysfunction with deafness, which itself maintains articulation disorders,
- nasal hypoventilation, inducing lingual protrusion and malocclusion [1],
- primary or mixed swallowing, involving upper maxillary dysmorphia, which itself maintains articulatory disorders [1],
- an excessive NAF may induce laryngeal constrictions and thus dysphonia.

These correlated pathologies develop in connection with the others, inducing improvements or worsening, sometimes beyond surgery or rehabilitative treatments of the cleft palate.

So, speech therapy may be an illusion, because of the importance of one factor or another, and on the contrary, it may improve one or several factors at some points of development.

For example, some factors (hearing or psychological ones) will disappear around the age of 2-4 years old, or later up to 6 years, on an average, under the influence of their own medical, surgical or rehabilitation treatments. And it “purifies” the dynamic aerophonoscopic type. Their evolution is difficult to realize, and so the surgical choice is delicate.

N.B. Concerning the neurological disorders, they can present some combinations of syndromes, for instance dyspraxia and dystonia syndromes, flaccid deficit and ataxic dystonia, dyspraxia and hypotonia.
Differential diagnosis of neurological disorders

This table is linked with the dynamic criteria of dysarthria and dysphonia, described by Darley and Aronson [20]

Table 3

<table>
<thead>
<tr>
<th>Differential diagnosis of <em>velo-pharyngeal</em> neurological disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>A- Dyspraxia (12) (and apraxia)</td>
</tr>
<tr>
<td>Various aperta rhinolalia</td>
</tr>
<tr>
<td>B + Flabby deficit (18) and Hypotonia (27)</td>
</tr>
<tr>
<td>1- Pseudo-Bulbar and bulbar Sd. 2 - du Deuto-neurone (unilat)</td>
</tr>
<tr>
<td>+ Spastic deficit (20) Of the Proto-neurone(supra bulb) (ministroke, dégénérative impairment ...)</td>
</tr>
<tr>
<td>C - Dystonia (7)</td>
</tr>
<tr>
<td>1- extrapyramidal</td>
</tr>
<tr>
<td>2- ataxic including 2 Syndrome 22q11</td>
</tr>
</tbody>
</table>

Among mixed types, and pure neurological disorders, we may notice the very original phonetic and phonological criteria of “Verbal Dyspraxia” or “Childhood apraxia of speech”, which are infrequent. They are caused by a bad programming of phonetic sequences.

In this population of 46 children, who present this “verbal dyspraxia”, with dysmorphic disorders (34) or not (12), we found these different peculiar characteristics:

- Random substitutions of one vowel for another, and substitution of a vowel for a consonant as well = 100%
  + and thus, amongst them, random and fluctuating inter-syllable contaminations between nasal vowels and oral ones = 54%. These random substitutions lead to very quick sequences of rhinolalia sometimes open, sometimes closed, sometimes absent.

- Vowel imprecisions +/- blurred consonants = 78%
  + and thus, among them, oral vowels with a fluctuating and small nasal loss.

- Reduction of syllable sequences in words over 2 or 3 syllables. That involves an increase of nasality contaminations within these words = 43%

- Dissociation between a bad automatic expression and a good effort one = 63%

- An unsteady basic tonus = 54%
  Slowness of the rise of the velum = 32%
C) Contributions of the aerphonoscope for therapeutic decisions

This classification by aerodynamic type contributes to guide the secondary surgery and also to justify the interest or not of speech therapy, because it shows the velopharyngeal movements, whatever the residual gap: their amplitude (correlated to softness or tonicity)- their speed – their flexibility.

It is important, before making any therapeutic, surgical and rehabilitation decisions, to assess the severity and type of VP incompetence. With the following criteria:
- the overall quality of intelligibility at the rhythm of the language [5]
- the aerodynamic velopharyngeal type, assessed by the tests of active and passive movements and sensitization more than the level of nasal air flow.

The surgical correction of these parameters is enabled by the range of different surgeries and the choice for a given type, and by the surgical calendar developed in our Cleft Palate Center [21],[22]

Altogether, we propose the following decisions for secondary surgery:

1- If it is a purely functional disorder:
   Only indication of Nasal Losses (in particular by the tests of effort) and/or lipofilling,
   then a reassessment of Nasal Losses (in particular by effort tests);

2- If it is a purely dysmorphic disorder:
   a) with a gap: lengthening surgery: by plasty and/or muscular transfer (Sommerlad intravelar veloplasty [23] and/or lipofilling,
   then a reassessment of residual Nasal Losses (in particular by effort tests);
   b) with stiffness: softening surgery: muscular transfer ++ and Z or Y plasty, with intense rehabilitation, then a reassessment of range of movement (in particular with softness tests of sequences of oral and nasal sounds at the rhythm of the language);
   c) with stiffness: surgery corresponding to the two previous ones.

3- If it is a purely neurological disorder:
   a) with hypotonia: often associated with dyspraxia: muscle transfer surgery and then rehabilitation, then a reassessment (by the tests of effort, of softness, of speed).
   b) with flaccid deficiency: reconstructive surgery by pharyngoplasty of Orticochea sphincteroplasty or pharyngeal flap, but the latter has fewer functional results.

These two sorts of surgery may involve a Sleep Apneic Syndrome (SAS), sooner or later, and the sphincteroplasty may be reduced according to evolution and rehabilitation.

Then reassessment of gap and residual tonus.

4- If it is a mixed type: with two or three components, the choice is more difficult:
   a)- dysmorphic moderate type with a predominant functional component: supervision alter etiological treatment or speech therapy (ENT, psychological care), then reassessment of nasal losses by assessment of the amplitude of closing/opening, and test of effort, then § 2;
   b)- dysmorphic moderate type with a predominant neurological component: (syndromic, e.g. 22q11): surgery of §3;
   c) severe dysmorphic type with neurological or dysfunctional component: surgery of §2.

From a rehabilitation point of view: The aerphonoscope provides a fun and efficient means of rehabilitation, it enables a visual feed-back of nasal flow, oral flow, laryngeal vibrations, and makes the rehabilitation of all these movements amusing, in particular the velar movements, the rehabilitation of which is considered to be difficult.

It significantly facilitates the control of:
- movements of velar closing/opening (nasal sounds versus oral sounds);
- start-up control of vocal vibrations (voiced consonants versus unvoiced ones) and indirectly the kinesthetic sensations of the glottic sphincter in synergy with that of the velopharyngeal sphincter;
- the mixing of these two neuromuscular controls.

**D) A classification of the vowels and syllables in pathological situations**, according to their facilitating power to close the VPS (or their “resistance” against hyper-nasality)

Using the aerophonoscope, we recorded different dissociations, according to their voicing, opening features; plosive or fricative modality; we noticed:
- concerning the vowels: open vowels are more facilitating than the closed ones.
- concerning the consonants:
  + the unvoiced plosives /p/t/k are more facilitating than the voiced ones/b/d/g/
  therefore, the syllables /pataka/ are more facilitating than /pitiki/ and /badaga/
  + The unvoiced fricatives /l/s/ch/ are more facilitating than the voiced ones (/v/z/j/)

Thus: the voicing feature influences the nasality feature
+ the liquid /l/r/ and the /ill/, do not have any rules.

**Table 4**  
**Classification of phonemes in cases of dysmorphic disorders**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Phonemes</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Vowels</td>
<td>/a/e/o/</td>
<td>/i/u/</td>
</tr>
<tr>
<td>Closed Vowels</td>
<td></td>
<td>/a/</td>
</tr>
</tbody>
</table>

**Consonants**
- Unvoiced plosives /p/t/k/ more facilitating than voiced plosives /b/d/g/ therefore /pataka/ < /bitiki/  
- Unvoiced fricatives /l/s/ch/ more facilitating than voiced fricatives /v/z/j/ therefore /fsa/cha/ < /vizi/ji/  
- Liquids /l/r/ and semi consonants /r/ on their own /lara/ya/ < /iri/yi/

Several types of dissociation

Altogether, we may rank this order from more facilitating phonemes to the less facilitating ones:
open vowels < unvoiced plosives < unvoiced fricatives < voiced plosives < voiced fricatives < closed vowels < nasal consonants <nasal vowels.)

These data more or less explain the lack of correlation between anatomic and aerodynamic data:
The aerophonoscope examinations prove the variability of the nasal air flow – nearly within a 6th of a second,– according to: each phoneme or syllable type; and the phonotactic links between nasal and oral sounds.

**VI - Discussion and working hypothesis**

**A- The aerophonoscopic assessment of the pathologic velopharyngeal sphincter movements** was conceived above all to choose the best surgical solution and the best ways of rehabilitation in order to correct:
- the excessive nasal air flow because of the lack of complete closing
- its kinetic behavior and its muscular potential: their incorrect muscle orientation, and so their lack of tone; their stiffness, their speed and their steadiness.

Thus, we focused especially on:
1) aerodynamic data of nasal air flow for oral sounds and not on the proportion (ratio) between nasal and oral airflows, (“nasalance”)
2) **assessment of contaminations of the nasality feature** especially on the oral sounds among nasal sounds in the “phonological chain” of speech (Jackobson). In the French language ++ continuous speech is characterized by frequent alternations between oral and nasal sounds. These contaminations conduce mainly to the severity of the pathology.

**B – Velopharyngeal incompetence: an acoustic or aerodynamic disorder?**

According to Amelot [9] we know, for healthy individuals, that aerodynamic data (air flow speed and pressure) for the vowels are more correlated with the acoustic signal (78% of cases), than with the anatomic or articulatory data (42 % of cases), in particular because of velar inertia. Feng (2004) demonstrated that the importance of nasality is not linked with the nasal airflow

1- **from an acoustic point of view**, open rhinolalias are caused by the participation of a nasal resonance cavity beyond a tolerable physiological margin of nasality, for each oral vowel and each oral syllable according to:
   - The amplitude movement and the defect of closing
   - The slowness of closing
   - The acceleration of the speech rate -- which depends on our “melokinetic praxis” (Luria )

2- **from an aerodynamic point of view**, the excessive opening induces an abnormal flow (cm3/sec) which is correlated to:
   - The diameter width of the opening of the velopharyngeal sphincter (cm2).
   - The air speed which is linked with the strength and pressure inside the mouth (Newton/Pascal) and so the sphincter resistance according to individual oral sounds, which facilitate sphincter closing to varying degrees. That is why these oral sounds are called more or less “resistant” to hyper nasality or “facilitating phonemes” for VP closure.

Moreover, we know that the acoustic spectrum of the nasal vowels, in healthy individuals, is modified when there is air flow variation, i.e. the closing/opening speed variations lead to the **phonological oppositions** between nasal and oral vowels (A. Amelot).

Indeed, the nasal air flow fluctuates continuously; the more the diameter decreases, the more the air speed increases during the VPS opening.

Beyond Bernouilli’s law, the more significant assessment is the following: to show acceleration/deceleration during these dynamic movements. Now, the aerophonoscopy sensors have **rightly** thermistors which detect the lesser air flow variations, caused by such dynamic movements.

In others words, the severity of a velopharyngeal incompetence is highly measured by the speed variations of these closing/opening movements, during **the alternation between the nasal syllable** (« mon » and the less facilitating syllables (/bi/di/gui/vi/zi/ji/).

Thus, acceleration (a) depends on 3 differentials of flow (dq), diameter width (dw) and time (dt)

\[
a (cm/sec^2) = \frac{dq}{dw} \cdot \frac{1}{dt} = \frac{flow\ differential\ (cm/sec)}{width\ differential\ (cm^2)} \cdot \frac{1}{time\ differential\ (sec.)}
\]

**C – The phenomenon of contamination** betrays also the severity. It results from different factors: the lack of acceleration and some linguistic factors. It is easy to detect by means of the so-called “sensitization” tests. It depends on
- the speed of succession of nasal and oral sounds (“prêve ton peigne à Clément”, “a/non; mon/chat; mon/papa; mon/dada, etc.) and it increases in a very significant way, with the slightest acceleration of the speech rate,
- the proportion of nasal sounds compared to oral ones, in the words (“phonological context” [25] or in the sentences,
- the predominance of facilitating or non-facilitating oral phonemes in the phonological chain,
- the prosodic variations and inherent accents of the language (here - French).

But we have to pay attention to the fact that there is a tolerable physiological margin of nasal air loss, assessed especially for some vowels and syllables, those we described in pathology as less “facilitating”: closed vowels /i/, /u/ and the syllables /bi/di/gui/ and /vi/zi/ji/.
This phenomenon of contamination was studied here only at the rhythm of 3 to 4 syllables per second and a regular alternation of nasal and oral syllables in the proportion of 1 for 1. Our perspective is to study the other proportions we find in the French phonological chain.

NB: The evaluation of severity of the VP incompetence by Mme Borel-Maisonny concerns only an acoustic point of view with 2 phenomena (existence of hypernasality and 3 levels of articulatory disorder) which are mostly not correlated between them.

**D - What is the limit of speed of speech**, leading to tolerable contaminations between nasal and oral syllables in pathological or healthy individuals?

Our hypothesis is three to six per second, for healthy French-speaking adults, with this proportion of 1 for 1.

**E- Surgical decisions**

Before surgery, we have to consider:
- The severity of hypernasality and inelegant nasal noise.
- The alteration of the muscles’ mechanisms, whatever the extent of nasal loss: amplitude and stiffness; speed or slowness ++ of closing/opening movements, unsteadiness of tone, irregularity, inconstancy and difficulties of programming sequences.

Among them, the **main dynamic parameter to restore is the speed** of VP movements in order to give the best phonological opposition of nasal /oral sounds, **whatever the extent of the VP gap**.

This ambition is possible thanks to a wide range of surgical procedures offered at our Center.

+ In case of Neurological Rhinolalia

Often, the surgery only partially corrects the articulation disorders and the rhinolalia, but it allows better aerodynamic conditions for rehabilitation:
- Even a partial decrease of nasal air loss indirectly leads to:
  - increase the intra-oral pressure
  - a better tone of dento-labial (/l/v/) or dento-lingual (/l/d/s/z) articulation points and a better kinesthetic feed-back to work on them;
  - increase the oral air reserve, allowing prolongations of syllable sequences and thus the slowdown of speech rate.

**F - The measure of nasal airflow during speech**

The aerophonoscope allows only a semi-quantitative assessment of nasal air flow, expressed as a percentage at 80, 60, 50, 30, 20 and 10 percent, compared to a maximal air flow objectified by nasal breath at the beginning of the examination, considered as the flow of 100 percent for the speaker.

**G- For healthy individuals**, Amelot describes the **opposition between voiced, and unvoiced** consonants: these voiced consonants are more resistant: they require less oral pressure and may lead to a slight nasal air flow.

But this notion, with an aerophonoscope is not verified **in pathological individuals** with hypoplastic or scarred soft palate: the voiced consonants, even if they require less oral pressure, are produced with a lesser resistance of the velopharyngeal sphincter, involving, in contrast, a greater nasal air flow.

A particular fact from the experiment: the major velar leakage may lead to compensatory movements of pharyngeal constriction, for oral vowels as for nasal ones, in particular the vowels /an/ or the syllable /man/ in French.

**H- We know that each type of velar disorder may lead to dysphonia**. The voice is sometimes distorted to such an extent that the hypernasality is not heard, and gradually reveals itself during voice rehabilitation. Here, we can say that the feature of pathologic nasality influences the feature of voicing.
Conclusions

The assessment protocol via the aerophonoscope allows us to observe directly the permeability, and indirectly the tone and movements, of the velopharyngeal sphincter and it conduces highly to the etiological diagnosis of open rhinolalias, and thus to guide surgical decisions.

A- An ultra-sensitive and objective test

The aerophonoscope provides an ultra-sensitive means of nasal air flow detection and an assessment tool of the kinetics of the VPS, revealing the characteristics of its movements: its closing capacities, its speed, acceleration/deceleration, steadiness, sequence programming, more than the measurement of its opening.

The aerophonoscope confirms the variable and inhomogeneous character of nasal flow in the usual conditions of speech, especially with the striking phenomena of nasal co-articulation and of contamination, which are characteristic of normal or pathological speech, whereas the perceptive assessments remain subjective.

This kinetic allows a tolerable physiological margin of nasal air loss, assessed especially for some vowels and syllables, those we discovered in pathology as less “facilitating”, or less “resistant” to hypernasality (closed vowels /i/, /u/ and the syllables /bi/di/gui/ and /vi/z[i]/j[i]-)

It provides a means of comparative assessment based on reproducible tests before and after treatment.

B- Assessment of the severity of velopharyngeal incompetence.

There is no linear correlation between the extent of nasal loss and the extent of the acoustic trouble (hypernasality)[24]. One of the explanations of that dissociation is given to us by the aerophonoscope.

The severity of an open rhinolalia is not so dependent on the extent of pathological air flow, (correlated to the magnitude of the velopharyngeal gap) as it is on the slowness of the closing/opening of the velopharyngeal sphincter during the alternation of oral and nasal sounds, which determine the phonological opposition between oral and nasal sounds, and thus the fact of an excessive co-articulation (contaminations of the nasality feature).

It allows a qualitative assessment objectifying the dynamics of the closing/opening movements of the velopharyngeal sphincter according to the speed of speech, the phonetic context, during the production of facilitating or non-facilitating oral phonemes and phonetic sequences.

C- It allows to determine three aerodynamic types (dysmorphic, neurological and dysfunctional disorders) by scanning French language-specific phonemes and syllables and in the tests of “sensitization”. These 3 types can be associated (mixed types), for example, in a lot of genetic syndromes.

Each type may guide to choose the best surgical proceeding which could reduce the VP gap and give the best amplitude, speed and steady muscular tone.

Otherwise, the severity of the intelligibility depends on several factors which are linked to etiology and so the treatment of this poly-pathological damage has to be multidisciplinary.

It contributes of course to determine the interest of speech therapy, because it detects the dynamic parameters of velopharyngeal movements, whatever their gap: their speed, their amplitude, and sequence programming.

Furthermore, it provides an amusing and efficient means of rehabilitation.

+ + +

Examination Protocol
Examination protocol of the velo-pharyngeal sphincter function

<table>
<thead>
<tr>
<th>Name</th>
<th>Forename</th>
<th>Date of Birth</th>
</tr>
</thead>
</table>

**Type of pathology and treatments**

**Genetic data**

**Medical history**

Sensormotor development; Tonus; Coordination

Semiotic and Linguistic development

**A- Influential factors**

**Behaviour**

**Cognitive abilities**

**Ventilation function** + daytime: Buccal. or Nas. + night time: Buccal. or Nas SAS

**Auditive function**: tympanum D G Audiology: tonal threshold vocal threshold

- phonetical discrimination: - Tardieu’s test - « Phonetic tests» (from Lafon)

**Dental occlusion**

**Lips occlusion**

**Swallowing** Childhood Adult mixed

**Laryngeal**

**Pharyngeal**

**Tongue** (recoil)

**Faciales inférieures** +

**Mimetic Praxias** +

**Sequenced** + + +

**Melokinetic praxias**

**B- Organic point of view**: Scheme + compensation movements (pillars, pharyngeal constrictors)

**C- Functional point of view**: Screening sentences

-- to objective a closed rhinolalia: "maman et ma nounou m’ont mis au lit" : no Nasal Loss (NL)

-- to objective an open rhinolalia: "flute le fil est coupé, c’est fichu"; "ta toupie va trop vite" : excessive NL

**C1 – Phonetism** + phonemes structured, sketched

substituted by other phonemes (means of compensation or approximation)

<table>
<thead>
<tr>
<th>Structured</th>
<th>sketched</th>
<th>substit</th>
<th>Struct</th>
<th>sketche</th>
<th>subst</th>
<th>Struc</th>
<th>Sketch.</th>
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</table>

+ **Phonology**: Simplification Complexification
C 2 - Dynamic tests with Aerophonoscope

a) Passive movements: Nasal Loss: 

<table>
<thead>
<tr>
<th>continuous oral blow:</th>
<th>yes</th>
<th>no</th>
</tr>
</thead>
<tbody>
<tr>
<td>pulsated oral breath:</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

b) Active movements: % of NL compared with maximal NL while pronunciation of /on/

- moderate (+ 25%)
- middle (++50%)
- great (+++75%)

<table>
<thead>
<tr>
<th>a</th>
<th>ë</th>
<th>o</th>
<th>u</th>
<th>é</th>
<th>i</th>
<th>ou</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pa</td>
<td>Ta</td>
<td>Ka</td>
<td>t’es pas cap</td>
<td>Pi</td>
<td>Ti</td>
<td>Ki</td>
</tr>
<tr>
<td>Ba</td>
<td>Da</td>
<td>Ga</td>
<td>Des bagues</td>
<td>Bi</td>
<td>Di</td>
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</tr>
<tr>
<td>Fa</td>
<td>Sa</td>
<td>Cha</td>
<td>(Elle) se facha</td>
<td>Fi</td>
<td>Si</td>
<td>Chi</td>
</tr>
<tr>
<td>Va</td>
<td>Za</td>
<td>Ja</td>
<td>Je vais au zoo</td>
<td>Vi</td>
<td>Zi</td>
<td>Ji</td>
</tr>
<tr>
<td>La</td>
<td>Ra</td>
<td>Ya</td>
<td>L’oreille</td>
<td>Li</td>
<td>Ri</td>
<td>you</td>
</tr>
</tbody>
</table>

c) Sensitization tests: do at least the tests in bold and underlined

1 - Basic tonus: holding the vowel/on/ or an altered one (/i/ /u/ /ou/): steady unsteady

2 - Tonus of action: effort tests: improvement no improvement

+ Scansion, u-u-u-u: yes no + Glissando towards sharps (with the wolf’s cry /ou/): yes no

3 - Melokineti praxias: opening and closing movements: with alternating of nasal syllables Nasales (SN) oral syllables Orales (SO), (composed of open vowels (/a/o/è/), then closed ones (/i/u/ou)

While repeating the SO, in order to test the consonants above all, at rhythm of his own language. Notice:

- Eventual aggravation of Nasal Loss of the OS (because of contamination) 0 + ++
- Relative amplitude (A%) compared with the NL maximal during the /on/
- The closing speed: quick (< 1/3 sec.) slow

Facultative tests: 1-pronounce OS in italic (?) with closed vowels; 2- acceleration of the rate
For little children: mon papa, mon coco, mon toto, mon baba(r), mon dodo, mon gars-gars, mon foufou, mon seau-sot, mon chat-chat, m’en vais-vais, mon jojo, mon zozo, nous ramons, mon lot-lot, mon yoyo

Conclusion

+ Etiologie(s) of V-P incompetence

Associated factors
+ Dyslalia (complete or incomplete, phonetism and intelligibility): correct / medium / bad

+ Functional criterias of severity:

1 - Low: a) no NL with oral blows; b) soft NL while articulation; c) improvement in effort tests

- normal speed, no contaminations

2 - Middle: a) NL with pulsed blow b) moderate NL in articulation c) slight improvement in effort tests

- moderate contaminations, normal speed

3 - High: a) NL with blows b) significant NL in articulation c) no improvement in effort tests

- frequent contaminations +/- Light slowness

4 - Major: NL ++ with blows and in articulation c) idem

Therapeutic decision:

Proposal of type of surgery:
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