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Sensorimotor Brain Plasticity in Stroke Patients with Dysphagia

A Methodological Study on Investigation and Treatment

MARY HÄGG

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Abstract

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Aims

The aims of the thesis were to validate investigation instruments for stroke patients with dysphagia, and to improve oropharyngeal dysphagia therapies.

Methods/Results

A Lip Force Meter, LF 100, affirmed excellent intra- and inter-reliability, sensitivity and specificity. Controls had significantly stronger lip force (LF) and swallowing capacity (SC) than stroke patients. A normal lower limit of LF was set to 15 Newton. Dysphagia symptoms improved in 7 stroke patients after a 5-week sensorimotor stimulation therapy comprising manual body and facial regulation in combination with palatal plate application. Impaired LF and impaired SC were parallel phenomena in 22 acute stroke patients and did not differ regardless of presence or absence of facial palsy. LF and SC improved and were parallel phenomena in 30 stroke patients and did not differ regardless of presence or absence of facial palsy, time lag between stroke attack and start of treatment, or age. SC was normalized in 19 of 30 dysphagia patients after a 5-8-week daily lip muscle self-training with an oral screen.

Conclusions

LF100 is an appropriate and reliable instrument for measuring lip force. Dysphagia improvement, by body and facial sensorimotor stimulation in combination with palatal plate application, or by training with an oral screen is excellent examples of brain plasticity and cortical reorganisation. . Swallowing capacity and lip force in stroke patients are parallel phenomena. A sub clinical facial paresis seems to be present in most stroke patients. Training with an oral screen can improve LF and SC in stroke patients with oropharyngeal dysphagia.

Keywords: Brain plasticity, Controls, Dysphagia, Deglutition, Facial palsy, Lip force, Muscle training, Orofacial regulation, Reliability, Sensitivity, Specificity, Stroke, Swallowing capacity

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“THE LONG AND WINDING ROAD”

To my two boys and three girls
Hans, Eiliv, Ylvali, Karin, Linn
“All my love”

2007

Cover: Håkan Gustafsson
Image editing: Reimond Dempwolf
Picture design: Mary Hägg

LIST OF PAPERS

This thesis is based on the following papers, referred to in the text by their Roman numerals:

I **Hägg M, Larsson B.** Effects of motor and sensory stimulation in stroke patients with long-lasting dysphagia. *Dysphagia 19:*219-230, 2004.

II **Hägg M, Olgarsson M, Anniko M.** Reliable Lip force measurement in healthy controls and in patients with stroke. A methodological study. *Dysphagia*, accepted for publication and in press, 2007.

III **Hägg M.** Correlation between lip force and swallowing capacity in stroke patients and in controls. Submitted to *Dysphagia*, 2007.

IV **Hägg M, Anniko M.** Lip force training in stroke patients with dysphagia. *Acta Oto-Laryngologica*, accepted for publication and in press, 2007.

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CONTENTS

Abbreviations

BMI	Body Mass Index
CI	Confidence Interval
CT	Conventional Therapy
CV	Coefficient of Variation
DCF	Data Clarification Form
DMP	Data Management Plan
DVP	Data Validation Plan
ICC	Intra-Class Correlation
EMG	Electromyography
GCP	Good Clinical Practice
MRT	Manual Regulation Therapy
LF	Lip force
LFM	Lip Force Measurement
LF100	Lip Force Meter, LF100
SC	Swallowing capacity
SCT	Swallowing Capacity Test
SOP	Standard Operating Procedure
ORT	Orofacial Regulation Therapy
OST	Oral Screen Training
OPD	Oropharyngeal dysphagia
PASS	Postural Assessment Scale for Stroke patients
UCR	Uppsala Clinical Research Center. UCR is a clinical research consultant organisation (CRO) at Uppsala University and University Hospital in Uppsala.
VAS	Visual Analog Scale
VCT	Velopharyngeal Closure Test

1. INTRODUCTION

Dysphagia is in most cases a severe physical handicap with consequences for social and mental health as well. The search for treatment modalitites was initiated in the early 1970s by speech therapists [46] who met patients with various speech problems that are closely related to oropharyngeal dysphagia (OPD). Most patients with OPD have been afflicted by stroke. Stroke patients are therefore most suited for studies on OPD.

In Sweden, more than 30 000 people are afflicted by cerebral stroke every year, 85% due to infarction and 15% due to bleeding. Stroke affects 400 people in every 100 000/year [85] which can give a wide range of neurological impairments of postural control, upper-limb function, visual, cognitive, perceptual and communication abilities, and with problems in eating and swallowing [4, 44, 52, 78]. OPD, i.e. an impaired or unsafe oropharyngeal transit of food or liquids, is common in the acute stage [64, 50, 83, 77]. Unilateral and bilateral cerebral hemispheric infarctions are seen more often than brainstem events [21, 49, 68]. However, dysphagia is more likely to occur when stroke involves the brainstem. In that case the prognosis is serious and will often have a fatal outcome [81]. The incidence of dysphagia symptoms varies in different articles, probably due to how soon after the stroke attack the evaluation has been performed and what investigatory modalities have been applied [21, 49].

OPD is seen in about half of stroke patients during the acute period and after more than 14 days in about one-fifth [49, 67, 8, and 7]. Dysphagia is of particular concern because of its potential risk for malnutrition, poor hydration and aspiration pneumonia. Dysphagia even affects different psychosocial functions and hence also the patient´s quality of life as well as that of relatives and caregivers. When patients with stroke are afflicted by dysphagia the prognosis is more grave than in non-dysphagic patients [49]. They suffer more often from malnutrition [18], and have a slower rate of recovery [20, 84]. Moreover, dysphagia − and its related complications − prolongs emergency hospitalization and is associated with increased mortality, co-morbidity, and increased health care costs [49, 71, and 12].

The presence of aspiration, including silent aspiration, with increased risk of pneumonia [14], ranges from 22 – 42% as assessed at videofluoroscopy [52]. In many patients neither the clinical history, such coughing, impaired gag reflex, and voice changes, nor the neurological evaluation can-predict the presence of silent aspiration [32, 70]. Aspiration following stroke occurs more frequently in those with brainstem lesions [31]. However, patients with lesions in the posterior region and with a history of pneumonia (reported by up to 32%) are at greater risk of impaired pharyngeal safety, which signifies that videofluoroscopic examination is mandatory in these patients [82, 71]. Unfortunately not even not videofluoroscopy nor fiberoptic endoscopy can serve as a perfect "gold standard" for detection of aspiration, because each yields both false-negative and false-positive results. It has been claimed that dental status and good oral hygiene are of great importance in order to avoid the risk of aspiration, especially in these patients [43, 74, 87 and 57].

Dysphagia comprises sensory and motor dysfunction of several different cranial nerves. It is evident from videofluorographic studies of oropharyngeal swallowing that stroke patients have some degree of sensory loss in the pharynx [54, 47, and 48]. Identification of patients with dysphagia is therefore the first vital step in their appropriate management. The primary goals of dysphagia therapy should be to establish optimal nutrition and to eliminate or reduce the risk of developing complications associated with dysphagia [13]. Beside OPD speech difficulties are often present. This is the reason why stroke patients with dysphagia meet a speech therapist in the first row.

Four levels of dysphagia

It seems appropriate to categorize dysphagia into its preoral, oral, pharyngeal and esophageal forms [36]. *Preoral dysphagia* includes all kinds of difficulties in conveying food and liquids from the plate to the mouth. Not only palsy of an arm or hand but also an award position of body and head, neglect, consciousness, and environment can all hamper optimal eating ability[5]. *Oral dysphagia* can be due to palsy of the tongue, facial paresis, reduced oral sensation, abscence of the swallowing reflex in the anterior faucal arcs, jaw dysfunction, dryness of the mucosal membranes, mandibular and maxillar injuries, etc.. *Pharyngeal dysphagia* is due to sensory failure, weakness or palsy of pharyngeal swallowing muscles and hence inability to protect the laryngeal entrance. OPD often leads to aspiration, bronchopulmonary complications, malnutrition, weight loss, and psychosocial complications. *Esophageal dysphagia* is often separated into (i) constant dysphagia with retention of food due to a benign or malignant stricture, or to achalasia cardiae, and (ii) intermittent dysphagia in patients with, e.g., a hiatus hernia.

In stroke patients dysphagia is often of both oral and pharyngeal forms simultaneously.

Oropharyngeal neurophysiology

Chewing and swallowing are dependent on several motor and sensory cranial nerves integrated into a coordinated oropharyngeal function. The swallowing process is usually subdivided into three phases that are related to their differing innervation patterns [55]. Swallowing has also been described in two stages: the oropharyngeal (or buccopharyngeal) and esophageal stages [36]. The former stage of swallowing is of short duration (range 0.6−1.0 s) and is remarkably constant in all humans [36, 15] de spite the extraordinary complexity involving not only pharyngeal and laryngeal muscles (IX, X) but also muscles in the oral cavity such as tongue (XII) and suprahyoid muscles (V, VII, XII). In the esophageal phase (X) the outer longitudinal muscle contracts when the upper esophageal sphincter opens, and the inner circular muscles contract, initiating a peristaltic wave having a transit time of 10 s in the conscious human [36, 15]. The inner and outer muscles of the upper third of the esophagus are striated muscles and the lower two-thirds are smooth muscles.

The motor part of the six different cranial nerves, with striated muscles that are involved in oropharyngeal swallowing, is represented in the precentral motor area 4 in the cortex (Fig.3). The importance of the oral function is best illustrated by the relatively large area in cortex that is occupied by the oropharyngeal cavity (Fig.1, 2). The enormous network of the extrapyramidal tracts from cortex over the basal ganglia and reticular formation to end in the motor nucleus in the brainstem or in the spinal tract is a prerequisite for the brain plasticity. Of similar importance for plasticity are the afferent sensory pathways that, besides their direct connection with the cortical postcentral sensory area have indirect connections via the reticular formation.

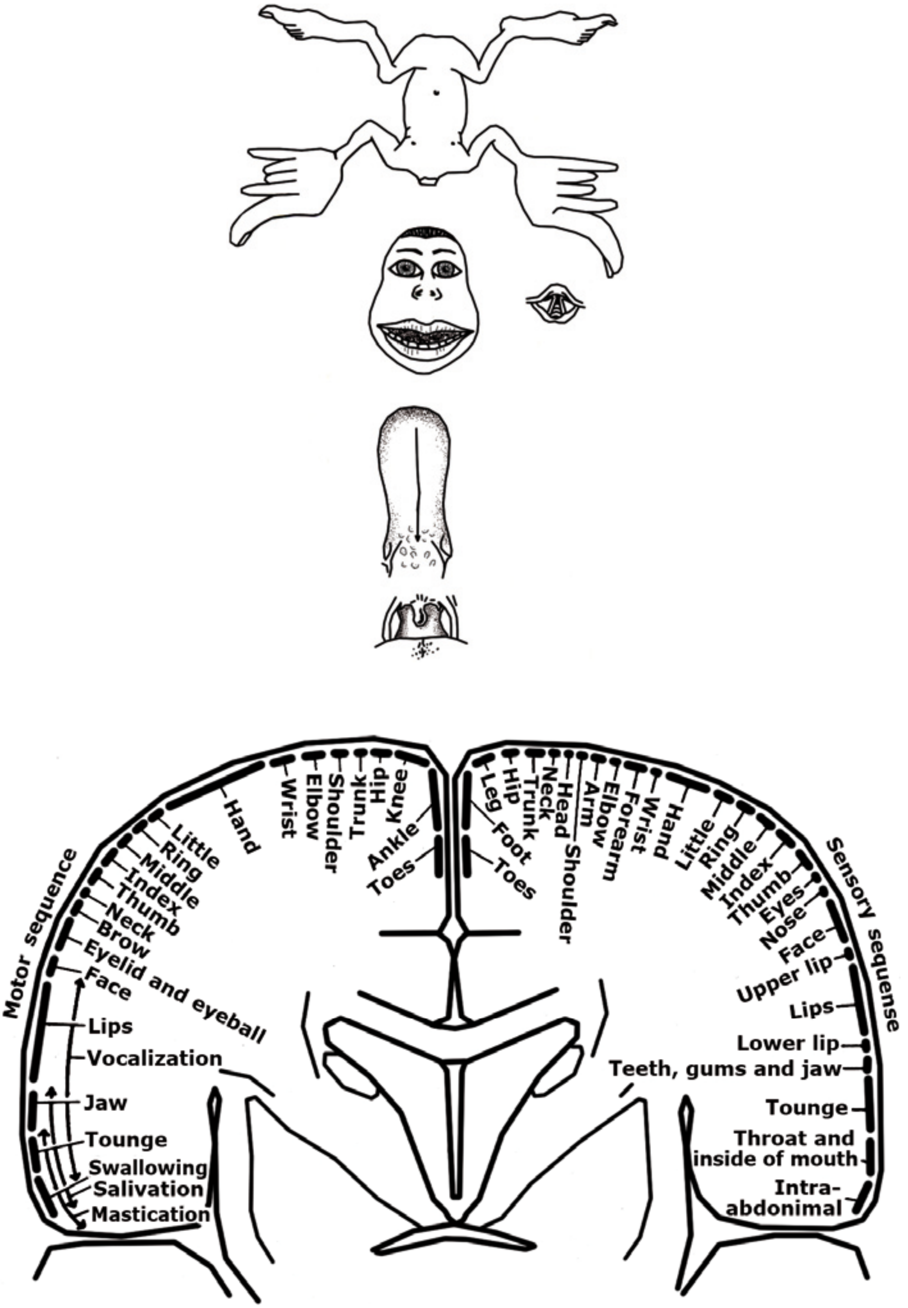
The swallowing reflex centre in the brainstem consists mainly of nucleus tractus solitarius (NTS), nucleus vagus, and nucleus ambiguus, an autonomous function closely connected with the reticular formation as well as with cortico-nuclear pathways.

The cranial facial nerve has two peripheral branches, an upper branch from the forebrain to the eye closure muscles, and a lower branch to the nasolabial muscles and to the buccal and the orbicularis oris muscles. The upper branch has a central bicortical representation and is therefore not clinically affected by unilateral cortical lesions, whereas the lower branch has only unilateral cortical representation. Central facial paresis in stroke patients causes a nasolabial smooth down and a dip in the angle of the lip on the contralateral side.

Six cranial nerves are involved in swallowing: V, VII, IX, X, XI, XII. Of particular interest in this context is the motor supply to the facial nerve (VII; facial mimic muscles, orbicular oris muscles, stylohyoid muscles, posterior parts of the digastric muscles, platysma, m. levator veli palatinae). In central facial palsy, the upper facial muscles are unaffected, thanks to two bilateral cortical representations.

The oral cavity and pharynx are anatomically separate yet functionally integrated regions of the head and neck. These two regions are involved in the complex motor responses that include feeding, chewing, swallowing, speech, and respiration. The oral and pharyngeal phases are closely interrelated and the distinction between them is often unclear. In the oropharyngeal region, several cranial nerves are involved in the sensory-motor reflex arc, which is activated by sensory stimulation via the afferent pathway and the impulses are transmitted to the medullary nucleus tractus solitarius (NTS). Some impulses reach the cerebral motor cortex, area 4, and return via the efferent motor pathways necessary for triggering the swallowing reflex. Perioral, submental, and lingual striated muscles can be controlled by the medullary CPG (central pattern generator) beyond the cortical drive [16, 53]. Food/saliva in the mouth and the cortical drive to the tongue and the floor of the mouth are necessary for voluntarily induced swallowing, whereas triggering of spontaneous swallowing does not require any cortical drive [17]. However, a reflex mechanism does play a role in both types of swallowing. During volitional swallowing, the total volume activity is significantly greater in either hemisphere than that during a reflexive elicited swallow. A reflex swallow produces significant greater left hemisphere activity [42]. Multiple and asymmetric cortical regions in both hemispheres are involved in swallowing, with stronger activity in the right hemisphere.

Not only are these cranial nerves of importance for normal swallowing function; body and head posture and appropriate breathing are also important [10]. Studies evaluating swallowing disorders in stroke patients have found that the soon recover [23], reflecting the enormous neuronal plasticity of the central nervous system [22]. Recovery of swallowing is associated with increased pharyngeal representation in the unaffected hemisphere [23, 22] and is highly dependent upon the frequency, intensity, and duration of sensory stimulus applied [19, 76 and 28]



Figs. 1, 2. Illustrating the vast representation of the oropharyngeal cavity in cortex.

Reproductions by Reimond Dempwolf from [1: Penfield and Boldrey´s homunculus; 2: Rasmussen and Penfielddiagram of sensory and motor sequences in cerebral cortex of man as determined by electrical stimulation. Medical physiology. ISBN 0-8016-3550-0.1974]

The oral phase

The oral phase of swallowing is mainly voluntary and highly variable in duration depending upon taste, hunger, motivation, environment, and consciousness. It even includes reflexive components integrated with feeding and chewing [56]. It is primarily related to oral preparation including activating of jawclosing muscles of the mandible (viz. m. temporalis, m. masseter, medial and lateral pterygoid); (V) chewing and stabilizing the mandible despite activating the movements of the tongue;(XII) propelling the bolus backwards to ward the pharynx. To raise the tongue, especially for a solid bolus, the suprahyoid muscles in the floor of the mouth (V, XII) are particularly important. Similarly, orbicularis oris (VII) and buccinator muscles (VII) close the mouth to prevent food from escaping forwards [75]. Their contraction and muscle tone acts as a valve mechanism [47, 48]. In EMG studies it has been observed that perioral muscle activity ends just before the pharyngeal phase of swallowing, while the masseter activity can continue or reappear [66]. Loss of sensibility in the pharyngeal arcs has been proven to be the main reason for dysphagia and aspiration in stroke patients [2, 3].

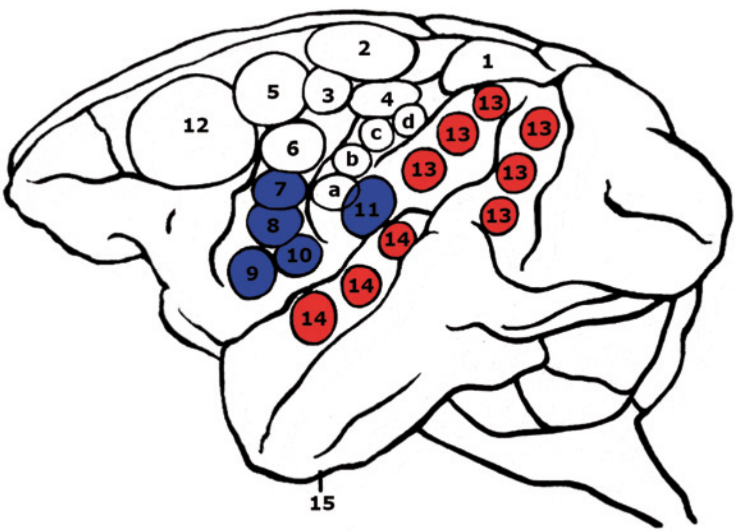


Fig. 3. Orofacial motor function of the cerebral cortex, represented by numbes 7−11: 7, retraction and elevation of the angle of the mouth; 8, elevation of the ala of the nose and upper lip; 9 and 10, opening of the mouth, with protrusion (9) and retraction (10) of the tongue; 11, retraction of the angle of the mouth.

Reproduction by Reimond Dempwolf from [Ferrier´s original motor map of left hemisphere of monkey. In: *Medical Physiology*. ISBN 0-8016-3550-0, 1974]

The pharyngeal phase

The pharyngeal phase is considered to be a reflex response. When a bolus is propelled from the oral cavity to the base of the tongue, to the upper third of the epiglottis, to the pillar of the fauces and to the walls of the pharynx, the tactil-, mechano-, chemo-, and thermoreceptors provide information essential for bolus identification and to trigger of a swallowing. All sensory inputs through the afferent fibres running within the maxillary branch of the trigeminal nerve (V), the glossopharyngeal nerve (IX), and the vagus nerve (X) especially its superior laryngeal branch, reach the brainstem and end in the NTS [36, 56]. The NTS receives the main sensory fibres not only from the oropharyngeal and laryngeal regions, but also from cortical descending inputs. Some sensory inputs that initiate swallowing are transmitted to the region of the caudolateral sensorimotor cortex that facilitates the initiation of the swallowing [26].

Once swallowing is initiated, the cascade of muscle activation and events occur in rapid overlapping succession. The main events are the transport of food to pharyng-esophageal segments by the movements of the tongue, submental/suprahyoid muscles and pharyngeal constrictor muscles, and the relaxation and opening of the cricopharyngeal sphincter muscle (UES). During food transport, the airway is protected and closed by several laryngeal muscles, the larynx is drawn up and the epiglottis is tilted backwards to cover laryngeal entrance. All events cranial to the esophageal phase are controlled mainly by the central pattern generator (CPG) of the brainstem [55, 35, and 56].

Swallowing is a complex sensorimotor behaviour involving the coordinated contraction and inhibition of the musculature located around the mouth and at the tongue, larynx, pharynx and esophagus bilaterally. During a swallow, different levels of the central nervous system from the cerebral cortex to the medulla oblongata are involved and many of the striated muscles innervated by the cranial nerves are excited and/or inhibited sequentially for the execution of the passage of bolus from the mouth to the stomach [55, 36, 37, and 38].

The complexity makes neurophysiologic mechanisms difficult to study in human experiments.

Investigation procedures

One persistent problem when evaluating post-stroke dysphagia is the variability in documentation of dysphagic symptoms, of their functional impact, and of treatment results.

Different outcome scales on oral ingestion of food and liquid, and on identification of the presence of dysphagia and aspiration symptoms are available. The Subjective measures often used suffer from poor established reliability or validity characteristics. However, the clinical examination is important and with efficient screening instruments and with trained investigators, and with speech and language therapist, it is possible to identify preoral, oral, pharyngeal and esophageal dysphagia. Patients with OPD are risk of aspiration and with esophageal dysphagia often need even a videofluoroscopic or endoscopic examination.

The water swallowing test of 30 ml water [65], and changes in voice quality [82] have been identified as very useful and simple screening tools to detect aspiration. The videofluoroscopic swallowing study (VSS) is regarded as the "gold standard" in this field, but it has its limitations [71]. Not all patients can be transported to a radiological department and positioned as required; radiology entails radiation exposure; there is limited standardization among centres with respect to volumes, consistencies, or textures of food and fluids or screening used; VVS may not identify all problems encountered in the clinical meal observation [13].

Different investigation tools

Assessment sets for dysphagia usually comprise various examinations such as different water swallowing test*s,* some combined with auscultation, oxygen saturation monitoring, or bedside assessments, meal observation, body posture/head control, orofacial motor function, sensory function, jaw function, gag reflex, voice quality, motor speech function, voluntary cough capacity, laryngeal elevation on saliva swallowing, electromyography, radiology, and videofluoroscopy. Recent advances in functional brain imaging including fMRI (magnetic response imaging) and PET (positron emission tomography) studies now offer the opportunity to examine the cortical representation of swallowing in humans [26, 59 and 51].

Therapeutic procedures

Currently available therapy modalities are **1) *compensatory procedures and* 2) *acitive exercises*** combined with swallowing of food or liquid, so-called direct therapy, or indirect procedures combined with swallows of only saliva by patients who aspirate [48].

1. ***Compensatory procedures*** control/improve/or changes the flow of food and can eliminate the patient symptoms but do not necessarily change the pathophysiology. The procedures also include postural techniques, to improve sensory input, adapted diet modifying volume/consistency/food presentation, and finally intraoral prosthetics.

2. ***Active exercises*** are designed to improve the range of motion of oral and pharyngeal structures of lips, jaw, tongue, tongue base, larynx, and vocal folds, to improve *sensory input* (thermal-taste-tactile stimulation), and to take voluntary control over timing/coordination of selected oropharyngeal movements through swallow manoeuvres and respiration.

Other treatment modalities are orofacial regulation therapy [10, 34], insertion of a palatal plate and [34] or an oral screen, DPNS (deep pharyngeal neuromuscular stimulation), FMEP (facial muscular exercise program), and so-called Vitalstim (neuromuscular electrical stimulation; (Logemann JA. The Effects of VitalStim on Clinical and Research Thinking in Dysphagia. *Dysphagia 23:*11-12, 2007).

2. AIMS OF THE STUDY

- To assess the effects of sensorimotor stimulation on orofacial and swallowing dysfunction persisting for more than 6 months in stroke patients **(I)**.

- To test the reliability of lip force measurements with a Lip Force Meter LF100 (LF100) **(II)**.

- To assess a normal lower limit of lip force (LF) **(II)**.

- To determine sensitivity and specificity of the LF100 method with regard to LF **(II)**.

- To investigate if there is a functional relationship between LF and swallowing capacity (SC) in acute stroke patients both with and without facial palsy, and in healthy controls **(III)**.

- To investigate whether there is a correlation between LF or SC and age **(III)**.

- To ascertain if training with an oral screen can improve lip force **(IV)**.

- To ascertain whether training with an oral screen can improve swallowing capacity **(IV)**.

- To establish whether improvement in LF and SC is connected with **(IV)**:

- the presence or absence of central facial palsy
- the time interval between the onset of a stroke and initiation of treatment
- age
- sex

3. METHODS

Diagnostic procedures

Anamnesis (Appendix)

- demography
- date of stroke
- social situation
- environment
- allergy
- smoking/alcohol habits
- other illnesses
- vision/hearing
- height/weight/ Body Mass Index (BMI)
- medical therapy
- symptoms
- Visual Analogue Scale; 0-100 (VAS)
- Activity in Daily Living; 0-6 (ADL)

Investigations (Appendix)

- general health
- Reaction Level Scale; 1-8 (RLS)
- communication

■ **gross motor skills**

- Postural Assessment Scale for Stroke patients; 0-36 (PASS),
- postural control (0-4)
- head control (0-4)

■ **breathing**, Velopharyngeal Closure Test (VCT)

■ **orofacial motor skills (0-4)**

- facial expression
- lip motility
- jaw function
- tongue motility
- velum motility

- **lip force (LF)** (Newton, N)

- **sensory function** (0/1)
  - oral stereognosia
  - 2-point discrimination
- **intraoral examination**
  - mouth opening ability (mm)
  - jaw relation (normal/deviant; 0/1)
  - teeth supply (fully supplied-lack of teeth; 0-4)
  - palate shape (normal/deviant,; 0/1)
  - parodontal status (no inflammation-severe infl.; 0-3)
  - bite force capacity (normal-missing; 0-3)
  - saliva production (normal-dry; 0-4)
  - drooling (normal-abnormal; 0-4)
- **swallowing capacity test (SCT)**

- **meal observation** (0-4)

- **videofluoroscopy** (0-3)

Anamnesis

A thorough anamnesis is always mandatory in any medical investigation, and this context, anamnesis also plays a fundamental role in the understanding of the diseases and their complexity (See p.21 and all appendixes at the back of this thesis).

Body Mass Index – BMI

Weight (kg)/height (m2) was calculated.

Visual Analogue Scale – VAS (0-100)

The impact of dysphagia on their quality of life was estimated by the patients on a 100 mm VAS (0 = no impact, 100 = unbearable impact). Also a history was taken regarding the frequency of bronchopulmonary complications, hoarseness and caughing in connection with meals and the patient's mental status and hobbies.

Activity in Daily Living – ADL (0-6)

The participant's ability to manage daily life activities, i.e. bathing, dressing/undressing, going to the toilet, movement, continence and eating, were assessed according to the Katz ADL index [40]. This index is graded as: 0=independent in all functions – 6=dependent on help in all 6 functions.

Investigations

Reaction Level Scale – RLS (1-8)

The patients were assessed for consciousness using RLS [79]. Ranks 4-8 indicated that the patient was not mentally responsive, i.e. was unconscious. If patients fluctuated in consciousness the higher (worse) rank was chosen.

Gross motor skills

Postural Assessment Scale for Stroke patients -– PASS (0-36) [6] is a clinical scale for assessing stroke patients with respect to their capacity for postural control. It comprises an assessment of the patient's capacity to retain or change his or her posture while lying down, sitting, or standing. The ability to walk is not evaluated. The scale comprises twelve activities judged according to a four-degree scale (0-3), which gives a range from 0 to 36 points. The method assesses performance for different postures and activities at varying levels of difficulty. The scale is primarily intended for acute stroke patients but may also be used later on in the rehabilitation process.

Postural control includes assessments of head, body, pelvis, and foot control [10].

The movements related to *head control* includes 6 variables (flexion, extension, rotation and lateral flexion to the right and left). The different items of postural, and head control are scored from 0 = normal to 4 = severe dysfunction, and are registered in a test protocol. Motility test of head control was videotaped.

Breathing – Velopharyngeal Closure Test (VCT)

The ability to increase the intra-oral pressure was tested by instructing the patients to inhale deeply and then exhale through a straw at a constant pace and for as long as they could against a water pressure of 12 cm. The generally accepted lower normal limit is the ability to exhale against a water pressure of 5 cm for at least 5 sec [63].

Orofacial motor skills (0-4)

The patients were placed in an upright and slightly forward position in a chair in front of a table and instructed to perform 23 different movements divided into 5 sections; these movements reflect the motor functions of facial muscles, lips, jaw, tongue and soft palate [30].

The movements relate to *facial expression*, *(4 variables, Va), n VII facialis:* close the eyes tightly, make the eyes wide open and wrinkle the forehead, pull the brows close together, wrinkle the nose; *lips, (7 Va), n VII facialis:* pout the lips, smile with closed lips, smack as loud as possible, blow up the cheeks against pressure of a finger, suck the cheeks together; repeat “oh-eeh” and “pah” three times as quickly and rhythmically as possible (oral diadochokinesy); *jaw,(5 Va, assessing the functions of the four chewing muscles), n V trigeminus ; n mandibularis:* open and close the mouth; move the lower jaw forward, backward and to the left and right side; *tongue, (8 Va), n XII hypoglossus:* stretch out the tongue as much as possible, move the tongue to the left and to the right corner of the mouth, move the tongue three times alternatively to the right and to the left as quickly and rhythmically as possible, point the tip of the tongue upwards and downwards, lick the lips all around and the front side of the teeth in the upper and lower jaws three times; *velum, (1 Va), n X vagus, n V trigeminus, n VII facialis:* say “ah” for evaluation of velum lift.

Lip force (LF), in Newton (N)

Lip force was measured, with a **Lip Force Meter (LF100, MHC1 AB Detector, Sweden),** blindly 3 times with a 2 minutes rest between and the maximum force value was registered in newton (N).

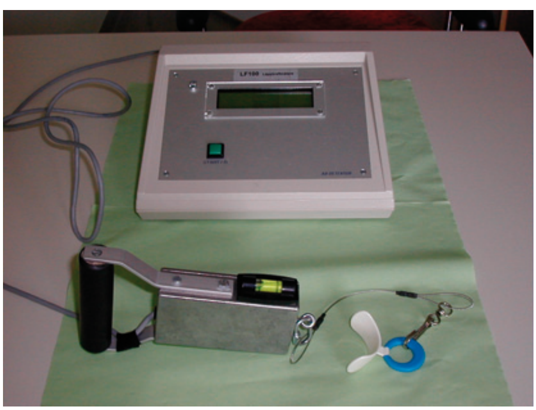


Fig. 4. Lip Force Meter (LF100) is a measuring device. The handle, consisting of a box with a water-level, is connected to an oral screen.

The Lip Force Meter (LF100) was developed by Mary Hägg and Anette Westberg at the Speech & Swallowing Centre/ENT clinic in Hudiksvall, Carl-Axel Wannerskog, MHC1 AB Detector, Gothenburg, Madeleine Wertzén, Mölndal Hospital, Gothenburg, and Lotta Sjögreen, at the Mouth-H-Centre in Gothenburg, all from Sweden, and was set into use in 2003.

The LF100, designed by MHC1 AB Detector (Gothenburg, Sweden), is a lip force measuring device (Fig.4) approved and certificated according to the Medical Device Directives in Sweden. It consists of a strain gauge attached to an aluminium ring taking up the pulling force on an oral screen. The detector is connected to an electronic unit for measuring maximal lip force. In order to obtain the greatest possible reproducibility of the measurement the pulling force must be applied at a right angle to the patient's mouth. To accomplish this end, a small box with a water-level is attached to the device.

The subjects were seated in a certified chair (REAL 9100 EL, Mercado Medic AB, Sweden) with the body and the head in a strict upright position, with support for the feet, the knees in a straight angle position, and the hands resting in the lap. The investigator applied the force by pulling the handle gently with increasing force for 10 seconds, or until the patient/subject lost the grip of the screen.

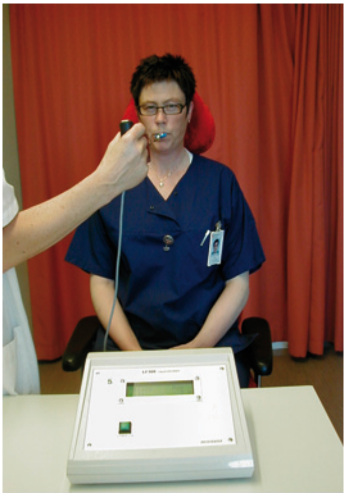
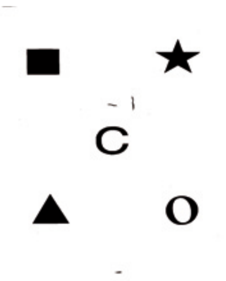


Fig. 5. The subject to be investigated was seated in a certified chair (REAL 9100 EL, Mercado Medic AB, Sweden).

Fig. 6. During the lip force measurement, the pulling force had to be applied at right angles to The patient's mouth.

Sensory function



The oral sensory function was examined through *stereognosia tests* [9]. Eight metallic objects of two different sizes (10 mm and 20 mm in diameter) and four different shapes (full circle, half circle, star and triangle) were placed in the mouth of the patient, who was asked to match the shape against a picture of five different objects. The time allowed for identification was at most 15 seconds. The objects were administered randomly and each one was presented twice to the patient.

Two-point discrimination [9] was tested with a pair of compasses. The two points of the compasses were placed with equal pressure on the epithelium until a slight indentation of the area was seen. The space between the points differed depending on the area to be tested; the smallest distinguishable distances in millimetres (the upper normal limit) were set to 15 mm for the cheeks, 5 mm for the lips, 3 mm for the tongue, and 3 mm for the anterior faucial arch.

Intraoral examination

Jaw relation (0/1 = normal/deviant).Teeth supply (0-4 = fully supplied – lack of teeth).

- Open-the-mouth ability (mm).
- Palate shape (0/1 = normal/deviant).
- Periodontal status (0-3 = no inflammation – severe parodontitis).
- Saliva production (0-4 = normal –dry).
- Drooling (0-4= normal – abnormal).
- Bite force capacity on the left/right side: (0-3 = normal, reduced, missing).

Swallowing capacity test (SCT), in ml/sec

The patient was asked to swallow 150 ml of cold tap water in one sweep and as quickly as possible. The subject was instructed to sit upright with the glass close to the lower lip, to start drinking when the “go” signal was given, and stop drinking in case of difficulty. The time was measured from the onset of drinking until the last swallow was completed. Remaining water in the glass was measured. A swallowing capacity index of 10ml/sec is regarded as the lower normal limit [61].

Meal observation, scored (0-4)

Each patient was served a meal consisting of 2 dl sour milk (yoghurt that is liquid, but thicker than ordinary milk), one slice of hard bread, and 1.5 dl of water. During the meal observation [4], the patient was recorded with a video camera on video tape and simultaneously observed by one of the authors, who also filled in a questionnaire with the following parameters, each scored from 0-4 (0=normal, 4=severe dysfunction):
Length of meal: 1= >20 min, 2= >30 min, 3= >40 min, 4= inability to complete the meal.
Oral preparation time (time from intake to initiation of swallowing):
1= sometimes > 10 sec, 2= often > 10 sec, 3= always > 10 sec, 4= complete inability to swallow.
Drooling/food leakage: 1= sometimes, 2= often, 3= always, 4= inability to keep saliva and food in the mouth.
Coughing when eating: 1= sometimes, 2= often, 3= always.
Leakage to the nose: 1= sometimes, 2= often, 3= always.
Hoarseness (the patients were asked how frequently they experienced hoarseness at meals): 1= sometimes, 2= often, 3= always.

Videofluoroscopy, scored (0-3)

The following parameters were analysed by means of videofluoroscopy using a low-density barium contrast medium [29]: bolus control, oral retention, epiglottic closure, retention in vallecula, retention in the pyriform sinus, aspiration (before, during, or after swallowing), and cough with aspiration. All variables were given a score from 0-3 (normal - severe dysfunction).

Therapy

The so-called orofacial regulation therapy developed by Castillo Morales comprises three levels:1) manual body and 2) orofacial regulation in combination with 3) different oral devices such as a palatal plate used in study I, or an oral screen as in study IV. The therapy has shown promising results in stroke patients.

The first hypothesis

The first hypothesis by Castillo Morales that body and orofacial regulation have impact on dysphagia is based on the interdependence of the orofacial complex (orofacial muscles, mandible and oropharynx), breathing, head control and body posture at deglutition – the first pattern way of motion [44].

To reach optimal results in the treatment of swallowing it is necessary to recognize head, neck, and body as a functional entity [10, 1]. Normal overall function depends on a complicated interplay of sensory and motor functions involving a large number of muscle groups that must achieve a proper balance. The goal of the therapy, therefore, is to secure that balance. The hyoid bone is directly connected to the skull, to the mandible, and to the shoulder girdle by minor muscle chains, and indirectly to the pelvis through the large muscles (Fig.7, 9). This is why the hyoid bone always has to adjust to the body posture.

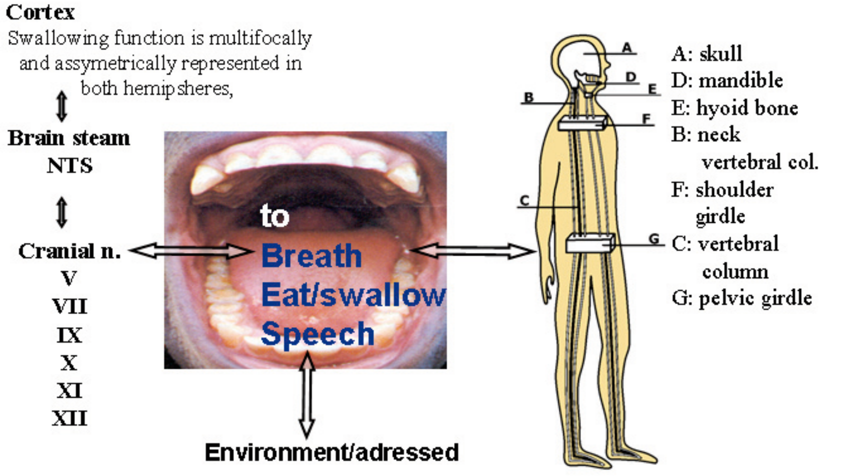


Fig. 7. The orofacial regulation therapy is based not only on muscle exercises but also on an improvement of the entire sensory-motor reflex arc involved in normal deglutition, and on the knowledge that the function of face and oropharynx at deglutition is closely interrelated with the entire body posture as well with appropriate breathing.

The second hypothesis

The second hypothesis by Castillo Morales is that different oral devices (such as a palatal plate used in study I, or an oral screen as in study IV) and orofacial regulation have an impact on swallowing dysfunctions based on the sensory-motor reflex arc, which is activated by sensory stimulation through the afferent path returning back as an impulse in the efferent motor path. Five cranial nerves in the mouth are involved in that reflex arc - the second pattern way of motion.

Function of the palatal plate and the oral screen

The palatal plate (Fig.12) and the oral screen (Fig.13) are designed to stimulate oral tactile receptors (passively) and oral motor function (actively and passively), thus enabling a negative intraoral pressure, motility of the tongue, and initiation of the swallowing reflex. The prerequisites for a negative intraoral pressure are good lip closure, good activity of the buccinator muscles, and the closure of nasopharynx, which are achieved by the sensory-motor reflex arc. The plate can also elicit a constant search of the tongue for unfamiliar intraoral objects. Furthermore, the plate improves the contact between tongue and palatum, raises the tip of the tongue, helps the tongue to contract upwards and backwards, activates m. levator anguli oris, m. zygomaticus minor and major, and m. buccinator, thus indirectly facilitating swallowing. [10, 48].

Body regulation

Body regulation (Fig.8, A-G) was restricted to the shoulder-neck-head region. It aimed at achieving optimal head control, and equilibrium of the infrahyoidal (n XII hypoglossus) and suprahyoidal muscles (n VII facialis, n V trigeminus, n XII hypoglossus) (Fig.9), ín order to facilitate swallowing. Body regulation included seven procedures (A-G); each procedure was performed three times in 15 minutes. The therapist sat behind the patient who was resting in supine position with a pillow under the knees. The patient's muscles were stretched under pressure and vibration, and then quickly released to evoke contraction. A muscle with low tonus demands short intermittent vibration. A muscle with high tonus demands long vibration under firm pressure. The same applies to orofacial regulation therapy. For a detailed description, see the method section in Study I.

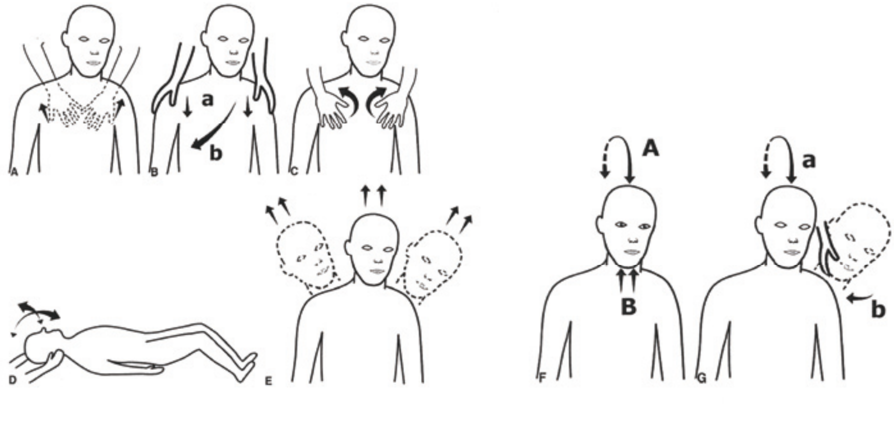


Fig. 8. Seven procedures (A-G) on body regulation therapy

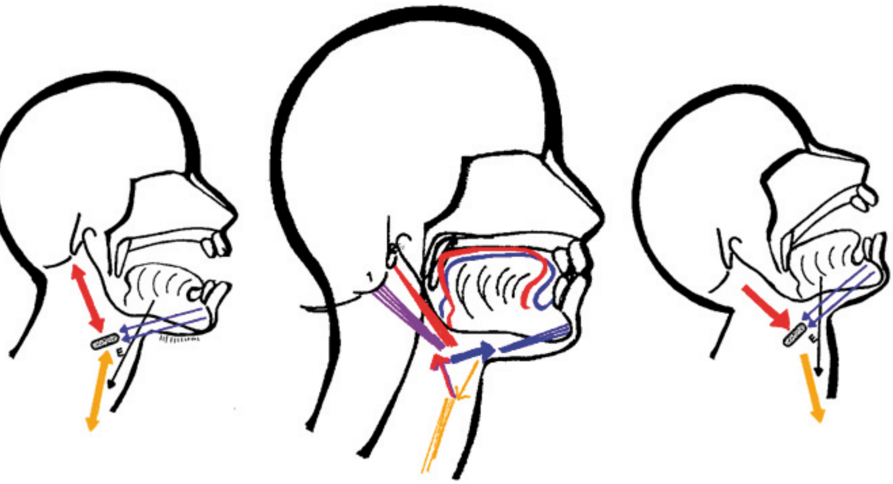


Fig. 9. Body regulation is aimed to achieve optimal head control, equilibrium of the infrahyoidal *(n XII hypoglossus)* and suprahyoidal muscles *(n VII facialis, n V trigeminus, n XII hypoglossus),* and to stimulate the swallowing reflex.

Orofacial regulation therapy

Orofacial regulation therapy included 14 different procedures that are summarized in Figs. 10 and 11. For a detailed description, see the method section in Study I.

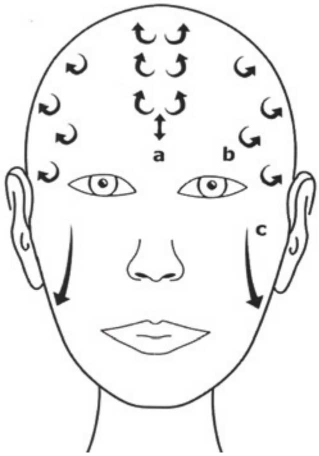


Fig. 10.

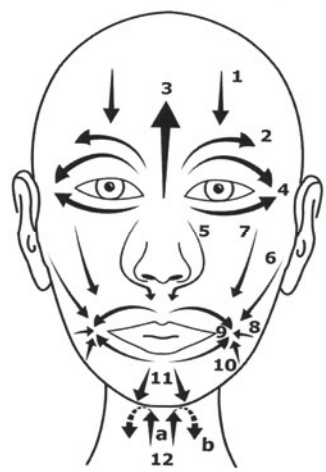


Fig. 11.

Palatal Plate

The palatal plate (Fig.12) was inserted 2–3 times daily for 10–30 minutes before eating (Study I). The main plate, made of thin acrylic material with spring retention elements, covers the entire palatal region. Four vestibular small acrylic plates (“bumpers”) with knobs in stainless steel act as stimulators for the upper lip and the buccinator mechanism [69]. For stimulation of the tip of the tongue, a mobile cube of stainless steel is attached to a dentoalveolar arch placed behind the incisors and in line with the canine teeth. For tongue base stimulation, a velum arch provided with three small pointed convexities in the middle and to the sides was placed close to the A-line that is the border between the soft and hard palate. Three of the stroke patients had full dentures and received a duplicate of their upper denture fitted with the same type of stimulators. The patients were also encouraged to actively exercise **a)** upper lip, **b)** tip of the tongue, **c)** tongue base, and **d)** the cheek, making at least three movements against each stimulator each time.

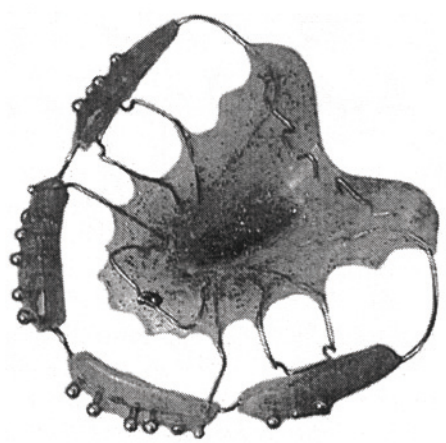


Fig. 12. Palatal plate. Note the knobs on the small stimulating plates (“bumpers”) and the sharp convexities on the velum arch for sensory stimulation. The patient can place the mobile cube in the middle, left or right side of the dentoalveolar arch.

Oral screen training

Patients in Study IV were instructed to train with the oral screen (Fig.13) at home three times daily before eating. Each exercise session consisted of horizontal, gradually increasing pulling manoeuvres three times, for 5-10 seconds or until the patient lost the grip of the oral screen (Fig.14). For training, the patient pulled the loop and tried to withhold the screen with the lips.

If possible, the training was to be performed with the patient sitting in a chair, the body and head in a strictly upright position, with support for the feet, and the knees flexed at right angles. When the patient was unable to hold the oral screen, relatives or ward staff were instructed to assist with the traction. The training period was set to at least 5 weeks.

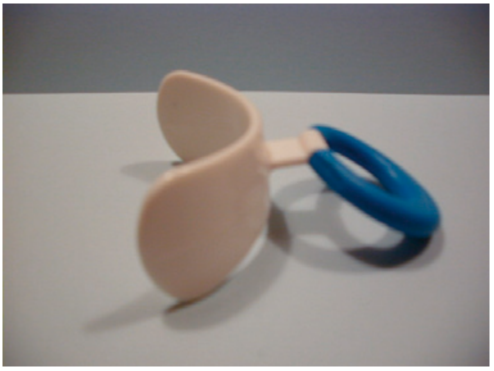


Fig. 13. An oral screen consists of a predental shield with a loop.

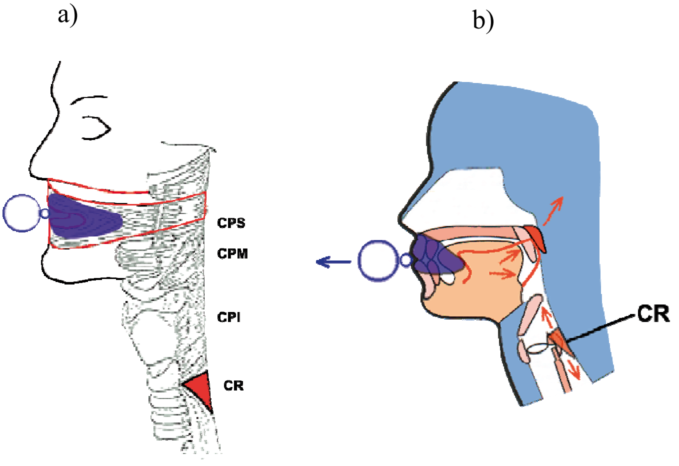


Fig.14. (a) The buccinator mechanism involving m. orbicularis oris, m. bucccinator, m. constrictor pharyngeus superior (CPS) at rest, and (b) during activity with an oral screen placed predentally. CR (m. cricopharyngeus) = upper esophageal sphincter.

Breathing – Velopharyngeal Closure Training (VCT)

The patient was instructed to train the capability for increasing the intraoral pressure by performing three expirations against a water pressure of 5-10 cm H_2O, three times a day before meals. The patient was instructed to sit upright with the upper end of a tube (one centimetre in diameter) inserted in the mouth and the other end of the tube resting on the bottom of the water glass without pressure. The patient had to blow bubbles as evenly as possible and for as long as possible each time.

Statistics

Study 1

The average of each variable, for each patient, period and judge, has been divided into quintiles. Agreement between each judge and quintiles was assessed with the kappa coefficient. The kappa coefficient is in the range 0-1 and can be interpreted as follows: 0.00-0.20, slight agreement; 0.21-0.40, fair agreement; 0.41-0.60, moderate agreement; 0.61-0.80, substantial agreement; 0.81-1.00, almost perfect agreement [Study I ref.8].

Study II

Intra-investigator and inter-investigator reliability were assessed using intra-class correlation (ICC) and the Bland–Altman plotting method [Study II ref.12]. An ICC value of 1.0 indicates complete agreement. Examination of the literature on interpretation of ICC values revealed that there are no "hard-and-fast" rules for inferring acceptable reliability. In general, a value of 0.70 or above suggests good reliability. Estimates of intra-investigator and inter-investigator ICC were derived in the framework of a one-way random effect model and a two-way random effect model, respectively. The lower limit (LL) of one-sided 95% confidence intervals (CI) was estimated using the method described by Fleiss [Study II ref.13]. The analysis of the inter-investigator reliability was based on the first measurement made by observer M.H. Student's *t*-test was used to assess the difference in lip force between stroke subjects and controls. Each test was based on the mean of three LF100 measurements. All calculations of intra-reliability and inter-reliability were performed for the stroke group and control group separately. A Receiver Operating Characteristics (ROC) curve was used to determine the optimal cut-off value needed to classify the subjects as healthy subjects or stroke patients with oropharyngeal dysphagia . The ROC curve was based on the mean of three LF100 measurements.

A p-level of < 0.05 was deemed significant. All statistical analyses were performed using SAS. 9.1software (SAS Institute Inc., Cary, NC, USA).

Study III

Professional statisticians and a data manager from Uppsala Clinical Research Centre (UCR) were involved from the outset in planning the study design. The Good Clinical Practice (GCP) database consolidated all study data and all analyses, which were performed according to the initial protocol. Student's *t*-test was used to assess the difference in LF between stroke patients and controls. Multiple linear regression analyses and Pearson's correlation coefficient was used to assess the relationship between LF, SC, and age. A p-level of < 0.05 was deemed significant. All statistical analyses were performed using SAS. 9.1 software (SAS Institute Inc., Cary, NC, USA).

Study IV

Professional statisticians and a data manager from Uppsala Clinical Research Centre (UCR) were involved from the outset in planning the study design, to consolidate all study date collected and for all analyses, which were performed. The Wilcoxon signed rank test for paired observations was used to asses the treatment effect on lip force and swallowing capacity. Spearman's rank-order correlation was used to assess the relationship between LF, SC, interval between stroke attack and start of treatment, age and sex in stroke with and without facial palsy. Differences between subgroups in SC and LF were evaluated with the Mann-Whitney U-test. Median values = M in the Tables. A p-value <0.05 was regarded as significant.

Ethical considerations

Studies I - IV were approved by the Ethical Committee for Human Research at the Medical Faculty of Uppsala University, Sweden: study I (Ups 97340); study II, III, IV (Dnr 2004: M-435). All the patients gave written consent to participate in the studies.

4. STUDY DESIGN-SUBJECTS-RESULTS

Study 1

“Effects of Motor and Sensory Stimulation in Stroke Patients with Long-lasting Dysphagia”

Orofacial regulation therapy, developed by Castillo Morales [10], comprises body regulation and orofacial regulation in combination with a palatal plate application; it has shown promising results in stroke patients. This therapy is based not only on muscle exercises, but on an improvement of the entire sensory-motor reflex arc involved in normal deglutition, and on the knowledge that the deglutition function of the face and oropharynx is closely related to the entire body posture and appropriate breathing. The treatment concept is relatively unknown to caretakers, partly owing to a lack of scientific evaluation of treatment results.

Therefore, the aim of this study was to assess the effect of motor and sensory stimulation in stroke patients with dysphagia that had persisted for more than six months.

Methods

Seven stroke patients participated in the study. Despite conventional therapy comprising sitting and head position recommendations, adapted diet, and instructions in good oral hygiene, these seven patients had suffered dysphagia for a median period of 1.5 years. The patients were evaluated with respect to orofacial and pharyngeal motility and sensory function, both before and two weeks after a five-week treatment period. Patients were treated once a week at the Speech and Swallowing Centre, and by a physiotherapist . All subjects were instructed to train at home three times daily before each meal; this training program consisted of facial stimulation (buccinator mechanism, the lips, and the oral floor) manually or with an electrical toothbrush, use of the palatal plate, and VCT.

The evaluation comprised a swallowing capacity test, a meal observation test, clinical examination of oral motor and sensory function, a velopharyngeal closure test, and videofluoroscopy. In addition, patients evaluated and assigned scores to their dysphagia symptoms.

Results

Swallowing capacity (SC) improved in six patients, with a mean increase of 59%; the mean SC was 5.1 ml/s (range 0.6-14.4) before treatment, and 9.5 ml/s (range 1.7-18.9) after treatment. In the meal observation tests, all patients improved with a mean severity score of 2.5 before treatment and 0.7 after treatment. The most pronounced improvement was seen with respect to drooling, coughing during meals, oral preparation time, and meal duration time. All seven patients improved their orofacial motility, where the most pronounced improvements occurred with respect to the facial, lip, and tongue muscles; the mean severity score in this case improved from 1.8 to 0.7. Kappa coefficients were conducted on all reliability data, both inter- and intra-rate reliabilities.

Conclusion

Sensory and motor stimulation seems to be a promising therapy in stroke patients with long-lasting and persistent oropharyngeal dysphagia.

Study 2

"Reliable lip force measurement in healthy controls and in patients with stroke. A methodological study"

A prefabricated oral screen has shown promising results as a muscle self-training device to improve lip function of stroke patients affected by oropharyngeal dysphagia. However, a technique for effective measurement of lip muscle force, whether in healthy individuals or in stroke patients, is lacking. The present study was designed to (i) test the intra-reliability and inter-reliability of lip force measurements by means of a newly devised Lip Force Meter LF100 (LF100), (ii) determine a normal lower limit of lip force in Newtons (N), and (iii) ascertain the instrument's sensitivity and specificity. LF100 is a modified strain gauge for recording the ability of the lips to withstand pressure from a predentally placed oral screen.

Methods

Forty-two healthy controls and 22 stroke patients consented to participate in the study (Table 1). Among the stroke patients, 12 suffered from unilateral central facial palsy, 6 on the right side of the face and 6 on the left side. The healthy controls had a swallowing capacity (SC) greater than 10 ml/sec, and the stroke patients had a pathological SC below 10 ml/sec. All subjects in the two study groups were examined three times using the LF100, twice by investigator MH, and once by investigator MO; patients were allowed a two-minute rest in between each test.

Characteristics	Controls (*n*=42)	Stroke patients (*n* = 22)	Stroke with facial palsy *(n=12)*	Stroke without facial palsy *(n=10)*
Age (yrs), median (range)	57(25-87)	77 (38-90)	77(38-90)	81(59-85)
Female/ Male	15/27	13/9	7/5	6/4
LF (N), mean ± SD	24.7 ± 6.3	9.5 ± 5.5	8.3±4.0	11.0±6.9

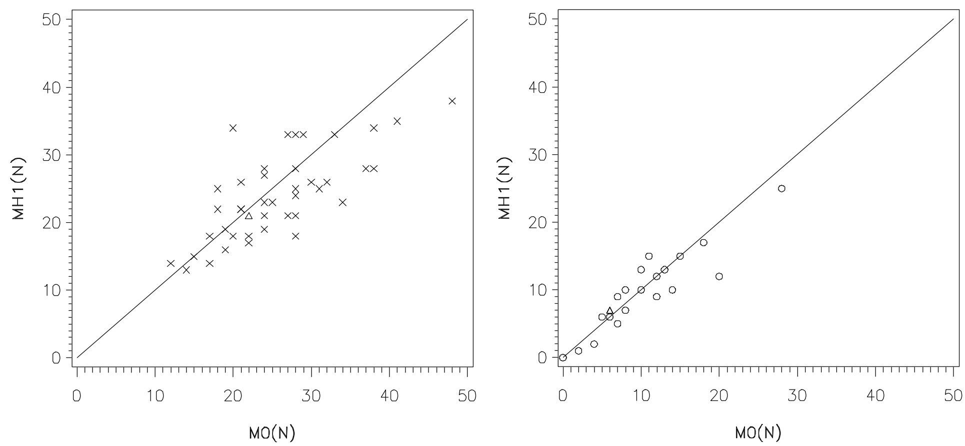
Table 1. Demographic features and mean lip force of healthy controls and stroke patients.

Results

The intra-investigator reliability with the LF100 was excellent for both controls and stroke patients: ICC 0.83 and 0.90 respectively (Table 2, Figs. 15a, b). Inter-investigator reliability was good or excellent in controls and stroke patients: ICC 0.71 and 0.91 respectively (Table 2, Figs. 16a, b).The control group had a significantly stronger lip force than the stroke group (Table 1).The difference between the means of the groups was 15.2 N ($p < 0.001$). Lip force (LF) in 12 stroke patients with facial palsy did not differ significantly from the patients without facial palsy (Table 1).The median age of the control persons was lower than of the stroke patients, but the investigators found no significant correlation between age and lip force. If a lower limit for normal LF is set to 15 N, the sensitivity of the lip force test will be 91%, and the specificity 95%.

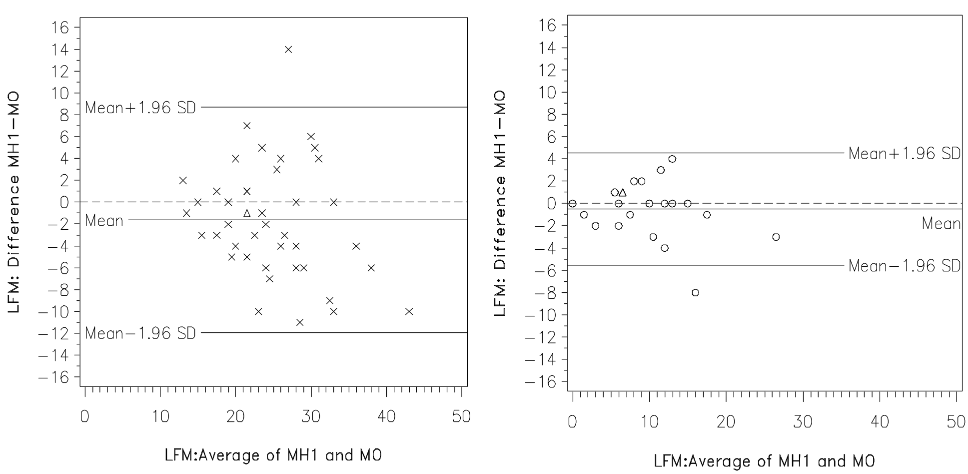
	Intra-investigator		Inter-investigator	
	Healthy n=42	Stroke n=22	Healthy n=42	Stroke n=22
ICC(95% LL)	0.83 (0.73)	0.90 (0.81)	0.71 (0.55)	0.91 (0.82)
M LFM (N)	24.3	9.2	24.8	9.8

Table. 2. Intra-investigator and inter-investigator reliability (ICC and 95% Lower Limit (LL)) of lip force measurements (LFM), M=mean, in newton (N).



a) b)

Fig. 15. Lip Force measurement in Newtons (N) made by investigator MH and MO, with a line of equality. a) Healthy controls (x = n=42), b) Stroke patients (0 = n=22). The symbol Δ represents 2 patients with the same result



a) b)

Fig. 16. Inter-observer reliability plots against their average. Difference between LFM made by investigators MH and MO. a) Healthy controls (x = n=42), b) Stroke patients (0 = n=22). The symbol Δ represents two patients with the same result.

Conclusion

The Lip force Meter LF100 (LF100) makes it possible to obtain reliable lip force measurements. Lip force is significantly higher in control persons than in stroke patients.

Study 3

"Correlation between lip force and swallowing capacity in stroke patients and in healthy controls"

It has been found that impaired lip muscle function (Study I) can be present in stroke patients with dysphagia. Central facial palsy is also a common feature, and it is conceivable that facial palsy will affect lip occlusion and swallowing capacity (SC). Lip force (LF) and SC can be quantified (Study II), but the extent to which they are functionally related and independent of a facial palsy is poorly understood. The present study was designed to investigate (i) the functional relationship between LF and SC in acute stroke patients both with and without facial palsy, and in healthy controls, and (ii) whether a correlation exists between LF or SC and age.

Methods

A prospective blind study was performed in 22 stroke patients with impaired SC and in 45 healthy controls (Table 3). Initial unilateral facial palsy was present in 12 of the stroke patients, 6 on the right side of the face and 6 on the left (Table 3). All subjects were investigated using a Lip Force Meter, LF100 (LF100) for recording the ability of lips to withstand pressure from a predentally placed, preformed acrylic oral screen (Fig.13), and a swallowing capacity test (SCT).

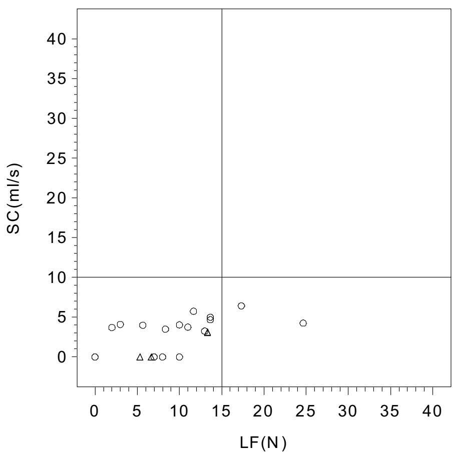
Characteristics	Stroke patients (*n* = 22)	Controls (*n* = 45)	Stroke without facial palsy (*n* =10)	Stroke with initial facial palsy (*n* =12)
Age (yrs), median (range)	77 (38-90)	57 (25-87)	81(59-85)	77(38-90)
Female/ Male	13/9	30/15	6/4	7/5
LF (N), mean ± SD	9.5 ± 5.5	24.4 ± 6.2	11.0±6.9	8.3±4.0
SC (ml/s), mean ± SD	2.7 ± 2.2	22.5 ± 8.4	2.7±2.5	2.7±2.0

Table. 3. Demographic features, lip force (LF), and swallowing capacity (SC) in stroke patients (without and with facial palsy) and in controls. N = Newtons

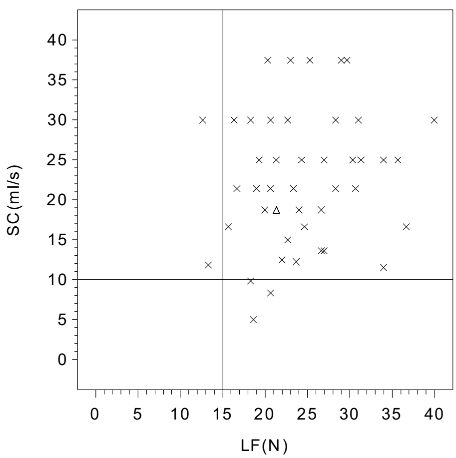
Results

The stroke group showed significantly lower LF values than the control group (Table 3). The difference between the means of the groups was 14.8 N ($p < 0.001$). There were significant differences in SC between stroke patients and controls (Table 3).The correlation coefficient between LF and SC was 0.53 for the stroke patients, and 0.16 for controls (Figs. 17a, b). LF was not age-related (Figs.18a,b). There was no significant correlation between SC and age in stroke patients (Fig. 19a), whereas in the controls there was a significant correlation ($p < .0001$; Fig. 19b).

Regression analysis showed that 73% of the variation in SC is attributable to LF and age. There were no significant differences in either LF or SC between stroke patients without and with facial palsy (Table 3).

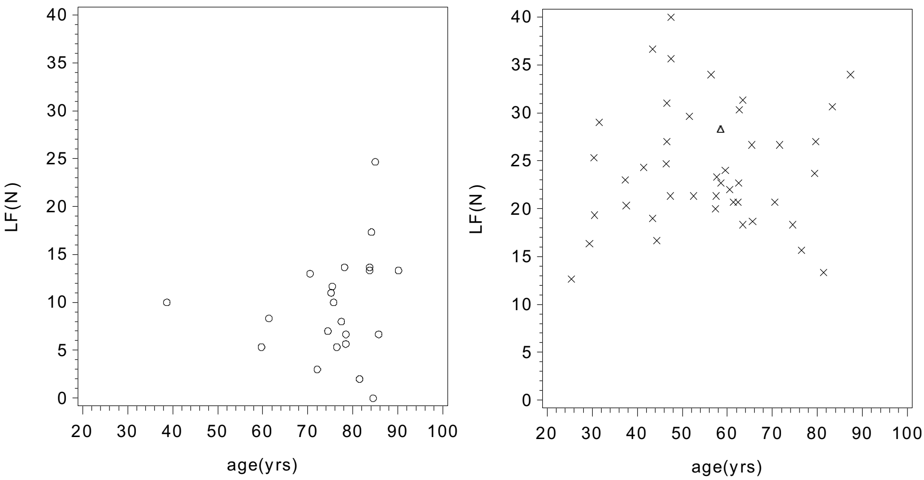


a)



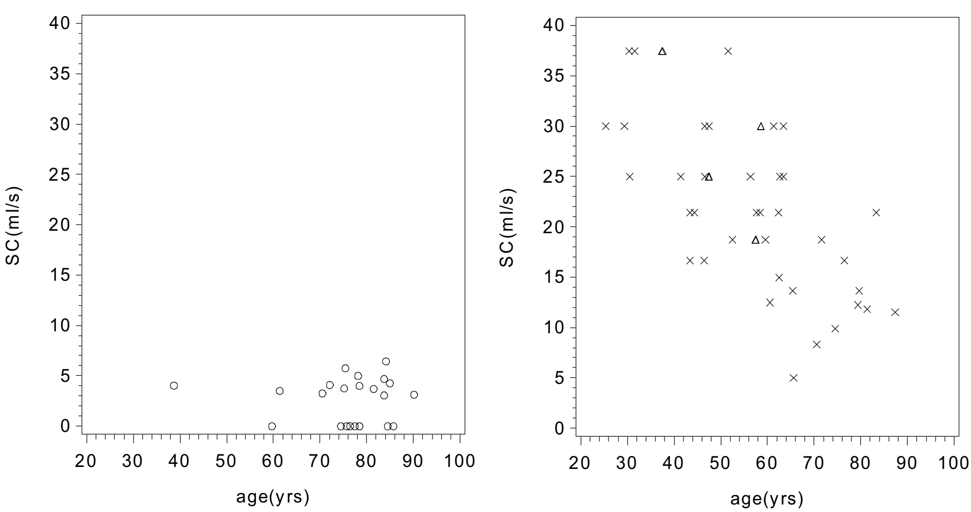
b)

Fig.17. Swallowing capacity (SC) vs. Lip force (LF) (a) in stroke patients= O (n = 22) and (b) in controls= X (n = 45). Δ = 2 O or 2 X.



a) b)

Fig.18. Lip force (LF) vs. age (a) in stroke patients= O (n = 22), and (b) in controls=X (n = 45). Δ = 2 X.



a) b)

Fig.19. Swallowing capacity (SC) vs. age (a) in stroke patients= O (n = 22), (b) in controls=X (n = 45). Δ= 2 X

Conclusion

In patients with stroke, impaired LF and impaired SC are parallel phenomena. Both LF and SC are significantly weaker in stroke patients than in controls. Stroke patients with impaired SC can suffer sub-clinical facial paresis without ordinary signs of unilateral facial palsy.

Study 4

"Lip muscle training in stroke patients with dysphagia"

A close relationship has been found between lip force (LF) and swallowing capacity (SC) in stroke patients, regardless of whether these patients are affected by a central facial palsy (Study III). Just how training of lip function can improve swallowing capacity is not known. Therefore, our aim was to evaluate (i) whether training with an oral screen could improve LF and SC, and to establish if the improvement in LF and SC is independent of (ii) the presence or absence of central facial palsy, (iii) the time interval between the onset of a stroke and the initiation of treatment, (iv) age, and (v) sex.

Methods

A retrospective study was performed on 30 stroke patients with oropharyngeal dysphagia and a swallowing capacity lower than 10 ml/s. An initial unilateral central facial paresis was present in 24 of the patients. All patients had their stroke attack on average one month (range 2 days – 10 yrs) and all had been given conventional therapy and guidance for their dysphagia, comprising swallowing instructions, adapted diet, oral hygiene instructions, exercises involving exhalation against water pressure through a tube, sitting and head position recommendations. The lip training was performed with an oral screen 3 times per session and 3 times daily for least 5-8 weeks.

Results

The median LF was 7 Newtons (N) before treatment and 18.5 N after treatment, (p<0.001). The median SC was 0 ml/s before treatment, and 12.1 ml/s at follow-up, (p<0.001). There was no significant difference in improvement of LF and SC between patients with an initial unilateral facial paresis (n=24; Table 4; Figs. 20a, 21a) vis-à-vis without facial paresis (n=6; Table 4; Figs. 20a, 21a). The SC was normalized in 19 patients (57%), and 8 out of 13 patients had their start of lip training on average 2 years after their stroke attack

(Table 5). The interval between stroke attack and start of treatment, ranging from a few days up to 10 years, had no significant influence on the treatment results (Figs.20b, 21b); nor did age (Figs 20c, 21c) or sex. The facial paresis was improved or at least ameliorated in all patients after the lip training period. We found also that there was a significant correlation between mean body control and the Postural Assessment Scale for Stroke patients (PASS); for the stroke patient before treatment (r = -0.80, p = 0.001; Table 6, Fig. 22a) and after treatment (r = -0.86, p = 0.000; Table 6, Fig 22b).

Facial palsy	LF (B) MV (range)	LF (A) MV (range)	SC (B) MV (range)	SC (A) MV (range)
Yes (*n*=24)	5.5 (0 – 27) N	17.5 (7-44) N	0 (0 – 9.1) ml/s	12.0 (0 – 36.7) ml/s
No (*n*=6)	8.5 (5-13) N	20 (16 – 24) N	0 (0 – 7.1) ml/s	13.4 (9.8 – 15) ml/s

B= before treatment, A= after treatment, MV= median value, N= Newton

Table. 4. Lip force (LF) and swallowing capacity (SC) of stroke patients with and without central facial palsy, (n=24), (n=6)

Duration/age, yrs	Initial LF MV (range) N	LF after treatm. MV (range) N	Initial SC MV range) ml/s	SC after treatm. MV (range) ml/s
10 yrs (49)	2	29	5.3	36.7
8 yrs (63)	18	29	9.1	18.8
5 yrs (71)	2	23	5.6	13.3
4 yrs (68)	7	24	0	13.2
2 yrs (82)	10	23	0	10.5
2 yrs (84)	8	14	4.8	9.3
2 yrs (79)	10	16	0	5.2
6 mths (66)	18	36	7.9	13.3
6 mths (88)	1	17	3.0	8.5
4 mths (77)	6	17	0	9.5
3 mths (81)	0	15	3.1	9.8
2 mths (50)	1	17	0	14.8
2 mths (66)	8	16	0	10.7
Mean values	**7 N**	**21 N**	**3.0 ml/s**	**13.4 ml/s**

Table.5. Lip force (LF) and swallowing capacity (SC) of stroke patients (n=13/30) before and after treatment with the longest interval between stroke attack and start of treatment (duration)

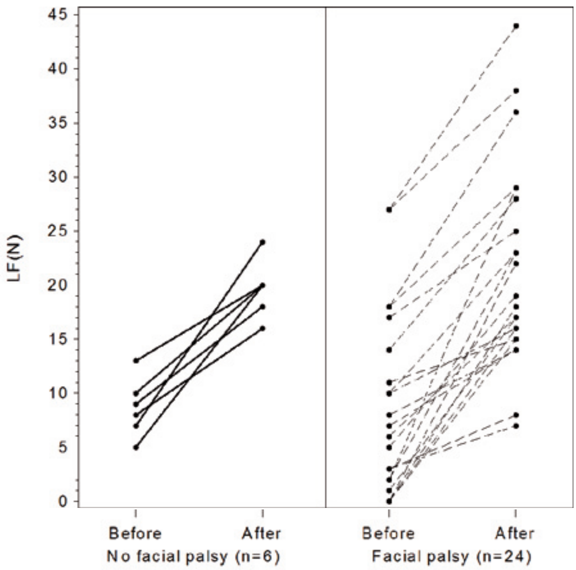


Fig.20a. Lip Force **(LF)** of stroke patients **(a)** vs. *absence (—)/presence (- - -) of central facial paresis* before, and after treatment.

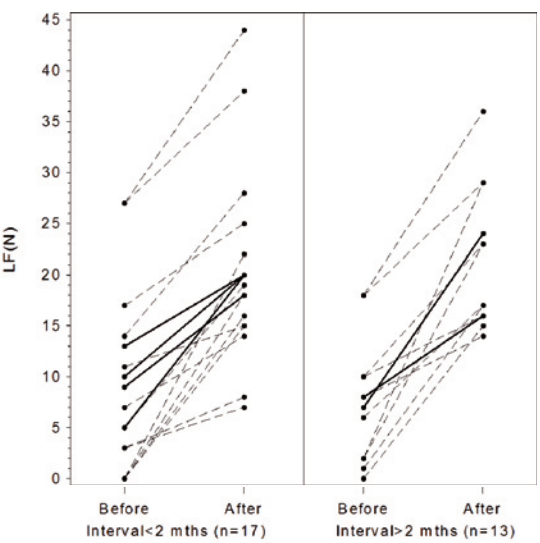


Fig.20b. Lip force **(LF)** of stroke patients vs. *the interval* between stroke attack and start of treatment. Absence (—)/presence (- - -) of central facial paresis.

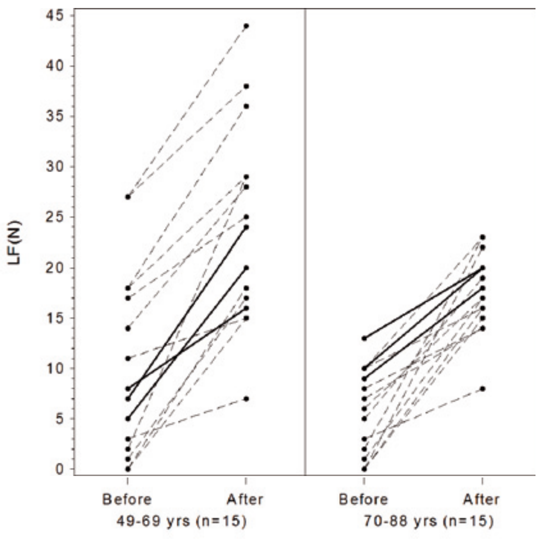


Fig.20c. Lip force (LF) of stroke patients vs. age of stroke patients. Absence (—)/presence (- - -) of central facial paresis.

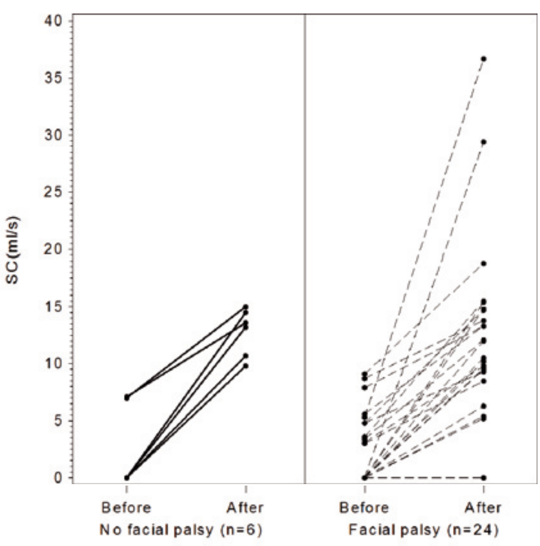


Fig.21a. Swallowing capacity (SC) of stroke patients vs. absence (—)/presence (- - -) of central facial Paresis before, and after treatment.

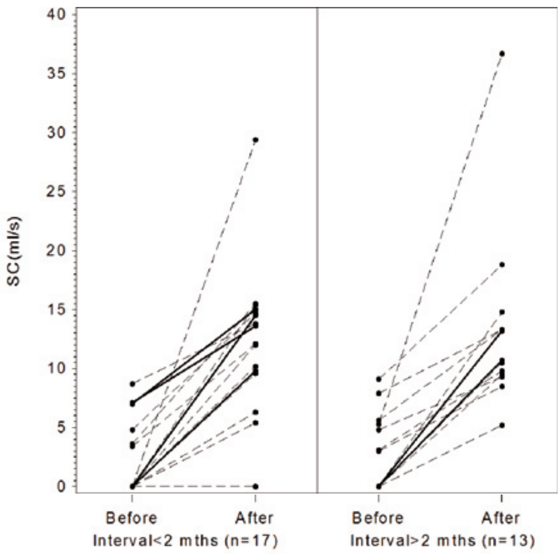


Fig.21b. Swallowing capacity (SC) of stroke patients vs. the interval between stroke attack and start of treatment. Absence (—)/presence (- - -) of central facial paresis.

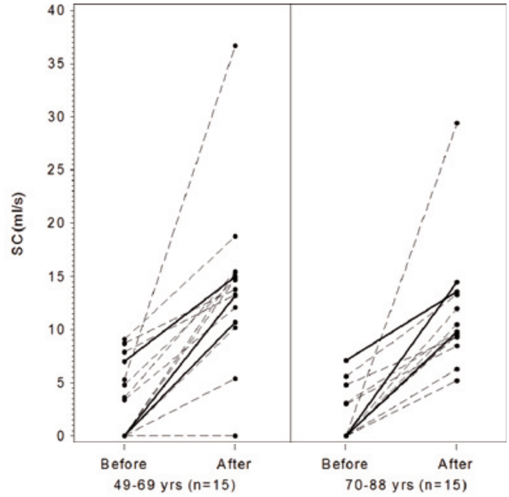


Fig.21c. Swallowing capacity (SC) vs. age of stroke patients. Absence (—)/presence (- - -) of central facial paresis.

Body control (0-4)	PASS (0-36) Spearman Correlation Coefficient = *r*	*p*-value	*n*= pat
Body control B	$r = -0.80$	$p = 0.001$	13
Body control A	$r = -0.86$	$p = 0.000$	13

B= before treatment, A= after treatment

Table 6. Spearman correlation coefficient (r) between mean body control (0-4), and PASS (0-36) of the stroke patients.

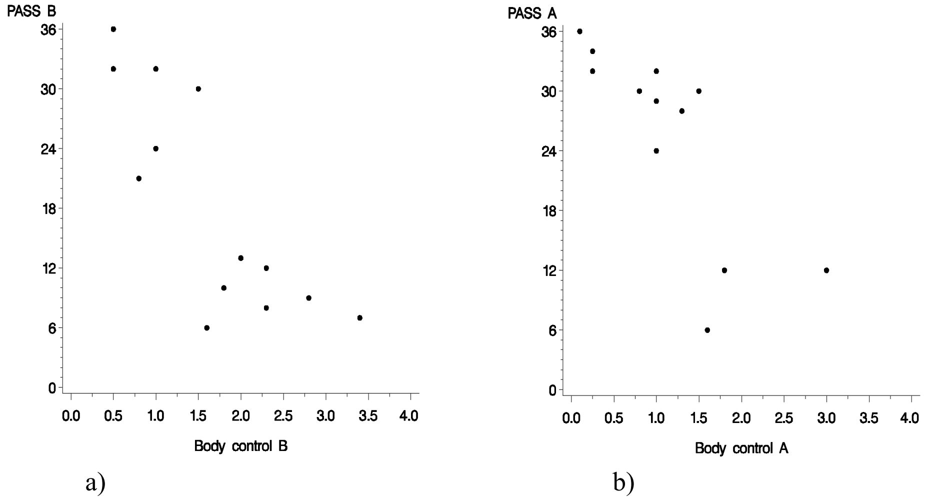


Fig.22. PASS vs. mean body control in stroke patients (a) before treatment and (b) after treatment.

Conclusion

Training with an oral screen can improve lip force and swallowing capacity in stroke patients with oropharyngeal dysphagia, irrespective of presence or absence of a central facial paresis, or of pre-treatment duration of dysphagia, or of age, or sex. It is more likely that the treatment results are more attributable to sensory motor stimulation and the plasticity of the central nervous system, than to the training of the lip muscles *per se*.

5. GENERAL DISCUSSION

Dysphagia following stroke has been found to be spontaneously relieved within 2-3 weeks after the incident [50, 21, 49, 68, 8, and 7], due partly to regression of the inflammatory reaction around the infarction area [80, 24,26 and 86], and partly to functional reorganization in the intact motor cortex [22]. In the last decade, increased understanding of the brain´s plasticity has opened up new possibilities for post-stroke rehabilitation [80]. In Studies I and IV the results of the therapeutic procedures reflected the reorganization capacity and plasticity of the cortex, partly a result of increased pharyngeal activity in the unaffected hemisphere [23, 22], and also slosely dependent upon the frequency, intensity, and duration of the sensory stimulus applied [19, 76 and 28].

The complexity of the oropharyngeal function involving six motor cranial nerves and three sensory nerves, raises questions as to which sensorimotor pathways are of the greatest importance for deglutition. In Study III, many stroke patients with dysphagia showed a complete loss of swallowing capacity (0 ml/min). This could be due to a sensory dropout of the glossopharyngeal branch supplying-the anterior faucal arcs from where the swallowing reflex for water is elicited. Another cause could be hypoglossal nerve paresis with the consequence that the tongue is unable to propel the bolus backward. Therefore the tongue training seems be the most appropriate muscle to activate. This is consistent with Study I, where a palatal plate was used. It also accord with a study by Robbins et al,2007 [73], where lingual exercise increased its strength, with associated improvement in swallowing pressure in both acute cases and chronic dysphagic stroke patients. In Study IV, an oral screen was used for training of the entire Buccinator mechanism. The screen also stimulates the sensory input from the intra-oral membranes and enhances the capacity for negative intra-oral pressure that requires good lip closure and good activity in m. buccinator and velum, motility of the tongue, and the swallowing reflex, in the same way as does the palatal plate. Even if the oral screen training effect was recorded as an increased lip force (Study IV), the improvement in swallowing capacity in Studies I and IV can only be explained by brain plasticity and central reorganisation engendered by this complex sensory motor activity triggered by a palatal plate or by LF training.

Paresis of the lower branch of the facial nerve will affect lip closure and the activity of the posterior part of the digastric muscle. Defective lip closure with leakage and drooling cannot alone make swallowing impossible. Nor does the digastric muscle seem to be of crucial importance for deglutition It is well known in clinical praxis that when a medial cleft branch cyst is surgically removed, the mid part of the hyoid bone is excised a couple of centimetres without any attempt to adjust the lateral bone ends. The digastric muscles as well as the mylohyoid-, geniohyoid-, stylohyoid-, and the infrahyoidal muscles are attached to the hyoid bone. Even if patients have some dysphagia for a couple of weeks, the removal of part of the hyoid bone is thought to be free from complications [62]. Apparently there are many other muscle groups that will compensate for any functional drop-out of the muscles attached to the hyoid bone.

An interesting finding in Study III was that stroke patients with dysphagia−but without clinical facial palsy− had a weak lip force. Yildiz et al, 2005 [86], claimed that facial paresis in stroke patients generally is incomplete and mild because of ipsilateral cortical and multiple innervations out of the infarction area, and recovery is rapid, thanks to cortical reorganization [86]. Perhaps there is a form of subclinical facial paresis in stroke patients with dysphagia that weakens lip force without the usual-signs of unilateral facial paresis. However, a pathological level of lip force and impaired swallowing capacity are parallel phenomena in which the facial nerve is involved (Study III). Apparently oropharyngeal dysphagia can be present even if the facial nerve function is intact

Swallowing and its neurophysiology are difficult to study. The swallowing capacity test (SCT) used in Studies I, III, and IV, has been assessed to have a high validity and intra- and inter-reliability

[61, 39]. Lip force measurement (LFM) is a method in Study II that was shown to have excellent intra-, and inter-reliability. LFM was therefore found suitable for studying the effect of lip force training in stroke patients with longstanding oropharyngeal dysphagia in Study IV. Other investigatory methods, such as meal observation test [4, 5], orofacial muscle function test [30], and videofluoroscopy investigation [29, 45 and 72] used in Study I are, however, not quantifiable to the same extent.

When talking about compensatory procedures, are often alluded to peripheral mechanisms [48]. These include swallowing and breathing techniques, postural techniques, adapted diet, and intraoral prosthetics. These techniques can facilitate deglutition but do not necessarily change the pathophysiology [48]. Another therapeutic way is the active training of a muscle. In this thesis the main therapeutic emphasis has utilized ***brain plasticity*** and been directed towards cortical reorganization, which is ***a central compensatory mechanism, by means of sensorimotor stimulation.***

6. CONCLUSIONS

- Orofacial sensorimotor stimulation seems to be a promising therapy and an excellent example of cerebral plasticity and cortical reorganisation in stroke patients with long-lasting and persistent oropharyngeal dysphagia.

- The LF100 is an appropriate and reliable instrument for measuring lip force (LF) and therefore can be used for evaluation of LF training.

- A normal lower limit of LF is assessed to 15 N.

- With regard to LF, the sensitivity and specificity of the LF100 method are excellent.

- The swallowing capacity (SC) and LF in stroke patients are parallel and concomitant phenomena, making the LF100 a suitable screening instrument for impaired SC in stroke patients.

- LF is not age-related in controls or in stroke patients.

- Training with an oral screen can improve LF and SC in stroke patients with oropharyngeal dysphagia irrespective of the following:
  - the presence or absence of a central facial paresis
  - the pre-treatment duration of dysphagia
  - age, or sex

- Most stroke patients with facial palsy do not differ from those without facial palsy regarding SC and LF. A subclinical facial paresis seems to be present in most stroke patients.

7. PERSPECTIVES FOR FUTURE RESEARCH

- Different therapeutic methods can be separately evaluated; especially oral screen training, manual regulation therapy, and conventional therapy and to verify the results with EMG and PET.

- Study if the therapeutic effect with palatal plate or oral screen application will remain one year or longer after a course of therapy.

8. SAMMANFATTNING PÅ SVENSKA

"Hjärnans sensorimotoriska plasticitet hos stroke patienter med sväljsvårigheter. Undersökn-ings - och behandlingsmetoder - en metodologisk studie"
Avhandlingen utfördes i syfte att öka kunskapen om hur behandling av sväljsvårigheter kan förbättras och att validera/testa säkerheten i instrument för undersökning och utvärdering av behandlingsinsatser på strokepatienter med orofaryngeal dysfagi.

(I) Effekter av motorisk och sensorisk stimulering vid långvarig dysfagi efter stroke. Publicerad i *Dysphagia* november 2004.
Målet var att utvärdera effekten av sensomotorisk stimulering på nedsatt muskelfunktion i ansikte, munhåla och svalg samt på sväljsvårigheter (dysfagi) efter stroke. Sju strokepatienter med dysfagi sedan i medeltal 1,5 år förbättrades efter sensorisk och motorisk stimulering under en 5 veckors behandlingsperiod, vilken innefattade manuell terapi av kropp, ansikte och munhåla i kombination med en gomplatta. De mest framträdande resultaten erhölls med ett sväljkapacitetstest och ett måltidsobserva-tionstest. Resultaten visade på både objektiv och självupplevd förbättring av sväljkapaciteten (SC) hos alla sju patienter. Orofacial sensomotorisk stimulering är en lovande behandling och ett utmärkt exempel på hjärnans plasticitet och kortikala reorganisation i stroke-patienter med länge kvarstående orofaryngeal dysfagi.

(II) Säker mätning av läppkraft i kontrollgrupp och på patienter efter stroke. En metodologisk studie. Accepterad och under publicering i *Dysphagia,* 2007.
I studien, inkluderande en kontrollgrupp med 42 friska individer och 22 strokepatienter med dysfagi, bedömdes intra- och interreliabiliteten, sensitiviteten (91%) och specificiteten (95%) hos en läppkraftsmätare, LF100. Kontrollgruppen hade en signifikant starkare läppkraft, mätt i newton, N (medelvärde 24,7 N ± 6,3) jämfört med strokepatienterna (medelvärde 9,5 N ± 5,5). Reliabiliteten var utmärkt. En normal undre gräns för läppkraft beräknades till 15 N. LF100 är ett lämpligt/pålitligt instrument med hög sensitivitet och specificitet för mätning av läppkraft och kan följaktligen användas för utvärdering av läppkraftsträning.

(III) Korrelation mellan läppkraft och sväljkapacitet i stroke-, och kontrollgrupp. Insänd till *Dysphagia,* 2007.
Vi ville undersöka om det finns ett funktionellt samband mellan läppkraft (LF) och sväljkapacitet (SC). Till studien inkluderades 22 nyinsjuknade strokepatienter, 12 med facialis pares och 10 utan, samt 45 friska individer utan subjektiva sväljsvårigheter (inkluderar delvis samma pat.material som i studie II). I stroke gruppen visade sig en försämrad LF och SC vara till största delen parallella fenomen och skiljde sig inte åt oavsett närvaron eller frånvaron av facialis pares. LF och SC var signifikant högre i kontrollgruppen och dessutom var SC signifikant korrelerat till ålder. I stroke gruppen däremot kunde de låga SC nivåerna inte enbart förklaras av åldern. Då SC/LF i stroke gruppen är i stort sett åtföljande fenomen innebär detta att läppkraftsmätaren, LF100 är ett lämpligt screeningsinstrument vid nedsatt SC.

(IV) Träning av läppkraft vid dysfagi efter stroke. Accepterad och under publicering i *Acta Otolaryngologica,* 2007.
Efter daglig egenträning, 5-8 v, av läppmuskeln med en munskärm normaliserade 19 av 30 strokepatienter sin SC; ett index på 10 ml/sek anger den undre normala gränsen. Åtta av 13 patienter med långvarig dysfagi påbörjade sin läppträning i genomsnitt 2 år efter sin stroke. LF och SC förbättrades

signifikant och ingen signifikant påverkan noterades av vare sig närvaron eller frånvaron av central facialis pares eller av tidsintervallet mellan stroken och behandlingsstarten eller av ålder eller kön. Träning med en munskärm kan förbättra både LF och SC hos strokepatienter med orofaryngeal dysfagi. En subklinisk facialis pares verkar finnas närvarande hos de flesta strokepatienter.

Sammanfattning
Läppkraftsmätaren är ett instrument som ger säkra mätningar av läppkraft. Förbättrad sväljfunktion genom manuell kropps-, och orofacial sensorisk och motorisk stimulering i kombination med gom-platta eller träning med en munskärm är utmärkta exempel på hjärnans plasticitet och reorganisatoriska förmåga.

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Hudiksvall Hospital Ear-Nose-Throat Clinic Speech&Swallowing Centre **Oralmotor investigation**	Patient data
Date of event	
Therapeutic authority	
Place of attendance	Hudiksvall, Bollnäs, Gävle
Referral sent by: Clinic/signature Date:	Referral received by: Clinic/signature Date:
DIAGNOSIS ICD 10	
REASON FOR VISIT including diagnostic number	
ANAMNESIS	
Social factors Relations, need of assistance, participation, social belonging, environmental factors	
Housing environment	
Work/schooling	
Leisure time	
Hypersensitivity	
Warning	
Alcohol/Nicotine/Drugs	
Sickness	
Sight/hearing including field of vision, visual/auditive perception, vestibular function, tinnitus, dizziness	
Length	
Weight	
BMI	
Medicines	
Standby person(s)	
PRESENT STATUS	
Symptoms Food: type, -intake; oral managing of food/ sucking/biting/chewing; breathing-problems; pain; vomiting/nausea; duration of meal; body temperature; appetite; bruxism; drooling; eating in public places; deviant facial expressions; vocal disorders	
Relief/aggravation including environmental factors	
Visual Analogue Scale (0-100) Eating, drinking, swallowing, talking; pain; other factors	
Debut	
Examination/treatment time	
Activities of Daily Living (0-6) Bodily care, dressing/undressing, eliminations, continence/incontinence; movability; food-intake	
Facilities Communication, sight, hearing; meals	

STATUS	Score (0-4): 0 = normal function, 4 = loss of function	
State of health		
Degree of consciousness Including psycho-/emotional functions like motivation, impulse control, attention, sleep, cognitive skills, orientation to time/place/person, memory, fear/anxiety, resignation	RLS 1-8	
Communication Verbal/non-verbal		
Gross motor skills Head control Postural control, sitting position Mobility, muscular function, - tonus, - endurance, reflexes, postural reactions, control of voluntary/non-voluntary reflexes, movability **Fine motor skills**		
Orofacial motor skills Breathing, phonation, facial expression, lips, jaws, tongue, velum, mouth opening wide, chewing, lip force		
Mirror test		
Orofacial sensory function Smelling, tasting, oral stereognosis, two-point discrimination		
Swallowing Capacity Test (SCT) Normal index (10 ml/sec)		
Meal observation		
Intraoral examination Mouth opening wide Biting conditions Teeth Hard palate Tongue Parodontal status Amount of saliva (0-4) Drooling (0-4)		
EXPECTATIONS PATIENT/FAMILY MEMBER		
DYSFUNCTIONS **1. Gross motor** **2. Orofacial:** breathing phonation dysphagia speech motor skills sensory skills drooling biting deviation biting dysfunction oral hygiene	Scale(0-4), 0= normal function, 4= loss of function.	
AIM		
TREATMENT PLAN Step 1, 2 etc.	A. Body therapy B. Orofacial regulation therapy C. Breathing exercises D. Oral screen training	E. Active exercising F. Palatal plate G. Other odontological procedures H. Referrals to other therapists
PROCEDURES Summary of the results of the investigations given to the patient/family Procedures carried out during the investigation Preliminary result of referral Referral to other therapists		
Next visit		

Name ………………………………………… Birth registration number………………….……
Diagnosis:………………..

Orofacial function score								
Date								
GROSS MOTOR SKILLS (0-36 or 0-6) **0 = total loss of function, 36 and 6 respectively = normal function**								
PASS Postural Assessment Scale for Stroke Patients **(0-36)**								
LSS Level of sitting scale **(0-6)**								
Head control (0-4) **0 = normal function, 4 = total loss of function**								
Flexion								
Extension								
Rotation								
Lateral flexion								
Summary								
X (=X/6)								
Body posture – sitting (0-4)								
Head control								
Body control								
Pelvic control								
Foot control								
Summary								
X (=X/4)								
FINE MOTOR SKILLS								
OROFACIAL MOTOR SKILLS								
Breathing								
Against a water pressure of 120 mm. Duration in seconds.								
PEF (Peak Expiratory Flow)								
Phonation (0-4)								
Coughing								
Hawking								
Summary								
X (=X/2)								
Facial expression (0-4)								
Eyes: shutting/closing tightly								
Eyes: opening wide								
Brows: puckering up								
Nose: wrinkling								
Summary								
X (=X/8)								

Date								
Lips (0-4)	**Right**	**Left**						
Pouting								
Smiling								
Smacking								
Cheeks: blowing up								
Cheeks: sucking in								
”u” ”i”								
”pa-pa”								
Summary								
X (=X/11)								
Jaw (0-4)								
Mouth: opening								
Mouth: closing, clenching one’s teeth								
Jaw: protruding								
Jaw: moving sideways right to left, left to right								
Summary								
X (=X/5)								
Chewing force (0-4)								
Lip force (N)								
Tongue (0-4)								
Putting it out								
Licking on the right and left corners of the mouth								
Point of the tongue: moving from side to side								
Point of the tongue: moving downwards								
Point of the tongue: moving upwards								
Dorsum of the tongue: pulling backwards/upwards								
Licking around the lips								
Licking around the rows of teeth								
Summary								
X (=X/9)								
Velum (0-4)	**Right**	**Left**						
Velum: moving upwards/backwards								
MIRROR TEST (0-1)	**0 = normal, 1 = deviant)**							
”s”								
”i”								
”i dag är det tisdag”								
Summary								

Date								
OROFACIAL SENSORY CAPACITY								
Sense of smell (0-1)								
Sense of taste(0-1)								
Oral stereognosis(0-1)	**Tall fig.**	**Small fig.**						
Star								
C-shape								
Circle								
Triangle								
Summary								
Two-point discrimination (0-1)	**Right**	**Left**						
Point of the tongue								
Cheek, upper part								
Cheek, lower part								
Upper lip								
Lower lip								
Lateral half of the tongue								
Dorsum of the tongue								
Palatoglossal arch								
Summary								
INTRAORAL ASSESSMENT								
Gaping capacity (millimeter)								
Biting conditions (0-1)								
Open frontal bite								
Open lateral bite								
Right open bite (mm)								
Left open bite (mm)								
Proclination lower incisors								
Proclination upper incisors								
Retroclination lower incisors								
Retroclination upper incisors								
Neutral bite right/left								
Prenormal bite right/left								
Postnormal bite right/left								
Deep bite with/without gingival contact								
Crossbite								
Scissors bite								
Edge-to-edge bite								
Crowding maxillar/mandibular								
Bruxism								
Other								
Summary								

Date								
Teeth								
Teeth (0-4)								
Abrasion (0-1)								
Erosion (0-1)								
Enamel mineralising (0-1)								
Agenesis (0-1)								
Summary								
Palatal roof (0-1)								
Normal palate								
Narrow/wide								
High, pointed/low, flat								
Stepped palate right/left								
Defined rugae								
Anterior flat/broad wall								
Cleft palate, total/partial								
Other								
Summary								
Tonsils right/left (0-1)								
Tongue (0-1)								
Size								
Shape								
Surface structure								
Coating								
Frenulum								
Diastasis								
Impressions								
Summary								
Parodontal status (0-3)	**Right**	**Left**						
Gingivitis max/mand								
Parodontitis max/mand								
Supragingival calculus max/mand								
Subgingival calculus max/mand								
Summary								
Saliva (0-4)								
Dry mouth								
Drooling								
Swallowing Capacity Test (10ml/s)								
Duration of testing								
Residual volume								
Swallowing capacity (ml/sec)								
Clinical signs of impaired swallowing								
Cervical auscultation (0-1)								
Laryngeal elevation (0-1)								

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Landstinget Gävleborg
Öron-näs-halsmott
Tal & Svälj Center
Hudiksvall

Patientuppgifter: ______________________

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The Postural Scale for Stroke Patients (PASS) - score

	Date				
	Maintaining a Posture				
1	Sitting without support.				
2	Standing with support.				
3	Standing without support.				
4	Standing on non paretic leg.				
5	Standing on paretic leg.				
	Changing Posture				
6	Supine to affected side lateral.				
7	Supine to non-affected side lateral.				
8	Supine to sitting up on the edge of the table.				
9	Sitting on the edge of the table to supine.				
10	Sitting to standing up.				
11	Standing up to sitting down.				
12	Standing, picking up a pencil from the floor.				
	Sum				
	Sign				

Ref:
Benaim C, Pérennou DA, Villy J, Rousseaux M, Pelissier JY: ”Validation of a Standardized Assessment of Postural Control in Stroke patients”; Stroke 1999; 30(9): 1862-1868
Hui-Fen Mao, I-Ping Hsueh, Pei-Fang Tang, Ching-Fan Sheu, Ching-Lin Hsieh: “Analysis and Comparison of the Psychometric Properties of Three Balance Measures for Stroke Patients; Stroke 2002, 33(4): 1022-27

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Tal & Svälj Center
Hudiksvall

Datum *2007-11-09*

The Postural Scale for Stroke Patients (PASS) - manual

Items and Criteria for Scoring:

	Maintaining a Posture	Criteria
1	Sitting without support (sitting on the edge of an 50-cm-high examination table, a Bobath plane for instance, with the feet touching the floor)	**0**= cannot sit **1**= can sit with slight support, for ex by 1 hand **2**= can sit for more than 10 sec without support **3**= can sit for 5 min without support
2	Standing with support (feet position free, no other constraints)	**0**= can not stand, even with support **1**= can stand with strong support of 2 people **2**= can stand with moderate support of 1 person **3**= can stand with support of only 1 hand
3	Standing without support (feet position free, no other constraints)	**0**= can not stand without support **1**= can stand without support for 10 sec or leans heavily on 1 leg **2**= can stand without support for 1 min or stands slightly asymmetrically **3**= can stand without support for more than 1 min and at the same time perform arm movements about shoulder level
4	Standing on nonparetic leg (no other constraints)	**0**= can not stand on nonparetic leg **1**= can stand on non paretic leg for a few sec **2**= can stand on non paretic leg for more than 5 sec **3**= can stand on non paretic leg for more than 10 sec
5	Standing on paretic leg (no other constraints)	**0**= can not stand on paretic leg **1**= can stand on paretic leg for a few sec **2**= can stand on paretic leg for more than 5 sec **3**= can stand on paretic leg for more than 10 sec
	Changing Posture Items 6-11 are to be performed with a 50-cm-high examination table, like a Bobath plane; items 10-12 are to be performed without any support, no other constraints.	

6	Supine to affected side lateral.	**0**= can not perform the activity **1**= can perform the activity with much help **2**= can perform the activity with little help **3**= can perform the activity without help
7	Supine to non-affected side lateral.	**0**= can not perform the activity **1**= can perform the activity with much help **2**= can perform the activity with little help **3**= can perform the activity without help
8	Supine to sitting up on the edge of the table.	**0**= can not perform the activity **1**= can perform the activity with much help **2**= can perform the activity with little help **3**= can perform the activity without help
9	Sitting on the edge of the table to supine.	**0**= can not perform the activity **1**= can perform the activity with much help **2**= can perform the activity with little help **3**= can perform the activity without help
10	Sitting to standing up.	**0**= can not perform the activity **1**= can perform the activity with much help **2**= can perform the activity with little help **3**= can perform the activity without help
11	Standing up to sitting down.	**0**= can not perform the activity **1**= can perform the activity with much help **2**= can perform the activity with little help **3**= can perform the activity without help
12	Standing, picking up a pencil from the floor.	**0**= can not perform the activity **1**= can perform the activity with much help **2**= can perform the activity with little help **3**= can perform the activity without help

Ref:

Benaim C, Pérennou DA, Villy J, Rousseaux M, Pelissier JY: ”Validation of a Standardized Assessment of Postural Control in Stroke patients”; Stroke 1999; 30(9): 1862-1868

Hui-Fen Mao, I-Ping Hsueh, Pei-Fang Tang, Ching-Fan Sheu, Ching-Lin Hsieh: “Analysis and Comparison of the Psychometric Properties of Three Balance Measures for Stroke Patients; Stroke 2002, 33(4): 1022-27

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Landstinget Gävleborg

ENT Department
Speech & Swallowing Center, Hudiksvall Hospital

BMI / ADL / Meals / Blood Test

Social Security No.: …..………………….

Health care personnel (Δ)/pat. evaluation

Name: ……………………………………

Body mass index	**Acute**	**25days ± 4**	**3 months**	**6 months**
BMI = $\frac{\text{weight (kg)}}{\text{height}^2\text{(m)}}$				
Pat height (cm):				
Pat weight for each period:				

ADL index	**Acute**	**25days ± 4**	**3 months**	**6 months**
1. Independent i six activities (bathing, dressing and undressing, toileting, mobility, continence, eating)	=0	=0	=0	=0
2. Independent in five activities	=1	=1	=1	=1
3. Independent in four activities	=2	=2	=2	=2
4. Independent in three activities	=3	=3	=3	=3
5. Independent in two activities	=4	=4	=4	=4
6. Independent in one activity	=5	=5	=5	=5
7. Dependent in all six activities	=6	=6	=6	=6
8. Unable to evaluate	=99	=99	=99	=99

Meals for each period	**Acute**	**25days ± 4**	**3 months**	**6 months**
1. Normal meals	=0	=0	=0	=0
2. Normal meals with restrictions, minced/strained foods	=1	=1	=1	=1
3. Pureed foods	=2	=2	=2	=2
4. Gelatin foods	=3	=3	=3	=3
5. Viscous (thick liquid) foods	=4	=4	=4	=4
6. Feeding via nasogastric tube or via gastrostomy	=5	=5	=5	=5
7. Parenteral food administration	=6	=6	=6	=6

Blood Test	**Acute**	**25days ± 4**	**3 months**	**6 months**
1. P-albumin (g/l)				
Date:				
Signature:				

Gävleborg County Council
Speech & Swallowing Center/ENT
Hudiksvall Hospital

Test Meal

Social Security No.:

Name:

Stroke diagnosis/date:____

EATING/SWALLOWING **Meal served:** **2 dl sour milk, one slice hard bread, one glass fruit drink.**	**25 ± 4 days after stroke debut**	**After 5 weeks of treatment**
1.Does pat require more than 20 min to consume meal? **Exact time for meal ……………** 1= ≥ 25 min 2= ≥ 30 min 3= ≥ 40 min 4= Complete inability to consume a meal	yes no =1 =2 =3 =4	yes no =1 =2 =3 =4
2. Does food/ beverage/saliva remain in pats mouth more than 10 s before pat can swallow? 1= Sometimes > 10 s 2= Often > 10 s 3= Always > 10 s with every mouthful 4= Complete inability to swallow	yes no =1 =2 =3 =4	yes no =1 =2 =3 =4
3. Is there leakage of food/saliva from pats mouth? 1= Drools sometimes 2= Always drools with every mouthful 3= Frequent food leakage/drooling 4= Complete inability to keep food/saliva in mouth	yes no =1 =2 =3 =4	yes no =1 =2 =3 =4
4. Does pat cough during/after eating and drinking? 1= Sometimes 2= Often 3= Always with every mouthful	yes no =1 =2 =3	yes no =1 =2 =3

Gävleborg County Council
Speech & Swallowing Center/ENT
Hudiksvall Hospital

Test Meal

Social Security No.:

Name:

EATING/SWALLOWING	25 ± 4 days after stroke debut	After 5 weeks of treatment
5. Does pats voice become hoarse at food/beverage intake? 1= Sometimes 2= Often 3= always for each mouthful 4= Inability to speak because of need to cough/clear throat ≥1 min	yes no =1 =2 =3 =4	yes no =1 =2 =3 =4
6. Does pat have difficulty raising food to mouth level? 1= Sometimes 2= Often 3= Always (0-4= Ability to blow up the face cheeks? Evaluation according to motor skills test in measurement record).	yes no =1 =2 =3 =	yes no =1 =2 =3 =
7. Is pat conscious of remaining food/beverage in mouth?	yes = 0 no = 4	yes = 0 no = 4
Enter total points in each column		
Enter pats current level of care/placement at time of evaluation		
Date		

Speech & Swallowing Center,
Hudiksvall Hospital, 824 81 Hudiksvall. Tel: 0650-925 92 el 927 54

Hudiksvalls sjukhus
Landstinget Gävleborg

Speech and Swallowing Centre, ENT, Hudiksvall Hospital

MANUAL OF OROFACIAL ASSESSMENT SCORE

Patients admitted to the Speech and Swallowing Centre are assessed according to the model of oralmotor examination.
This manual is used as a scoring as well as a documentation instrument assessing the motor-, sensory- and intraoral status including swallowing capacity and the outcome of the mirror test performed by the patient during the visit.

Date	To be noted on top of each page
GROSS MOTOR SKILLS	
PASS	Used in assessing postural control of stroke-patients (scores 0-36). Manual and documentation of assessment, see Word LG.HH (G:): TSC-gamla \Utvärderingsinstrument\PASS-score or PASS-manual
LSS	Used in assessing postural control, in sitting position, of children with neuromotor deficits (scores 0-6). Manual, see Word LG.HH (G:): TSC-gamla\Utvärderingsinstrument\Level of sitting scale.
Estimation of gross motor and orofacial motor skills according to a score of 0-4: **0=normal, 1=slightly impaired, 2=moderately impaired, 3=seriously impaired, 4=loss of function.** *Assessment of muscular strength, range of motion, coordination and speed.*	
Head control	The patient's performance include flexion, extension, rotation and lateral flexion, and each direction is assessed. *The total score is divided by six.*
Body-posture, sitting	The functions of body, pelvis and feet in the patient's natural sitting posture are assessed and scored. The average score of head control (see above) is included in the total score. *The total score is divided by four.* To be noted: Any preoral motor deficits.
Fine motor skills	Describe any loss of function.

OROFACIAL MOTOR SKILLS	
Breathing	➢ The patient is sitting upright on a chair at a table. In front of him/her there is a pitcher with a lid, containing 120 mm of water. Through the lid there is a tube of 10 mm in diameter. The patient is asked to take a deep breath and then blow out the air through the tube making bubbles for as long time as possible. The examiner takes the time from the first till the last bubble. ➢ The patient, still in the same sitting posture, is asked to exhale with maximum force and as fast as possible into the PEF-meter. The best score out of three is noted. To be noted: Any change of breathing pattern in passivity or activity as well as observations of breathing during speech and breathing through nose and/or mouth.
Phonation	The patient is asked to cough and then to hawk vigorously. To be noted: Any change of voice, like pitch (low, monotonous, unstable), strength (high, low, monotonous, unstable), quality (pressed, raucous, grating, creaky, leaking, tremulous, diplophonic, aphonic, or if there is a register break). *The total score is divided by two.*
Facial expression	The patient is asked to: - shut his/her eyes and close them tightly (m. orbicularis); - make his/her eyes wide open (m. frontalis, and others); - pucker up his/her brows (m. corrugator supercilii, m. procerus); - wrinkle his/her nose (m. levator labii superioris alaeque nasi, and others). Each facial half is assessed independently. To be noted: Any facial asymmetry. Facial expressiveness or inexpressiveness. *The total score is divided by eight.*
Lips	The patient is asked to: - make his/her lips pout (m. orbicularis oris); - draw the corners of the mouth to a broad smile with the mouth open/closed (m. risorius, m. zygomaticus minor/major, m. levator anguli oris); - make a distinct smacking sound; - blow up the cheeks and press a finger against one cheek at a time; - suck in the cheeks; - repeat /u i/ as fast and rhythmically as possible; - repeat /pa pa/ as fast and rhythmically as possible. *The total score is divided by eleven.*
Jaw	The patient is asked to: - open his/her mouth (m. digastricus anterior, m. platysma); - close his/her mouth and clench his/her teeth (m. temporalis, m. masseter, m. pterygoideus medialis); - make his/her jaw protrude and then pull it back into normal (mm. pterygoideus lateralis sin./dx.) - move his/her jaw to the right (m. pterygoideus lateralis sin.); - move his/her jaw to the left (m. pterygoideus lateralis dx). To be noted: Any deviation when opening the mouth wide/putting the jaws together; any inhibited mobility; any snapping sound. *The total score is divided by five.*

Chewing force	The patient is asked to bite onto the breathing tube and not let go of it when the examiner pulls it forward and outward.
Lip force	The patient is sitting with his/her body and head in an upright position, the feet are put firmly on the floor, the knees flexed in a right angle and hands and underarms are resting on the thighs. An oral screen is put between the patient's teeth and lips and thereafter the screen is adapted to the lip force meter. The patient is asked to press his/her lips together as tight as possible around the screen, while the examiner keeps pulling the handle of the lip force meter. The handle is pulled horizontally for 10 seconds with increasing force until maximum force is obtained, or until the patient lets go of the screen. *The lipforce (in Newton) is measured three times and the best score is noted.*
Tongue	The patient is asked to: - put out his/her tongue (m. genioglossus); - lick the right corner of his/her mouth (m. genioglossus sin.); - lick the left corner of his/her mouth (m. genioglossus dx.); - move the point of his/her tongue from side to side as fast and rhythmically as possible; - move the point of his/her tongue downwards (m. longitudinalis inferior); - move the point of his/her tongue upwards (m. longitudinalis superior); - pull his/her tongue backwards/upwards (m. styloglossus); - lick around his/her mouth; - lick along the upper and lower rows of his/her teeth. To be noted: Any sign of atrophia, any fasciculations, involuntary movements and/or impaired coordination.
Velum	The patient is asked to say ”a” with his/her mouth open. The activity in the soft palate is inspected by the examiner. To be noted: Any signs of asymmetry, fasciculations, tremor.
MIRROR-TEST	The patient, sitting upright, is asked to say a long ”s”, a long “i” and “idag är det tisdag” (to be repeated). During this sequence the examiner is putting a laryngeal mirror under the patient's right and left nostril respectively. To be noted: Leakage if any (then the mirror will be misted over). *0=normal, mirror not misted, 1=deviant, misted mirror.*
SENSORY FUNCTIONS	
Smell	The patient is asked if there is any change in the smelling functions. *0=no change, 1=change, deviation.*
Taste	The patient is asked if there is any change in the tasting functions. *0=no change, 1=change, deviation.*
Oral stereognosis	The patient is sitting in an upright position in a chair with a paper showing five different shapes. The examiner has got eight metal objects (of two different sizes: 20 mm and 10 mm) corresponding four of the depicted shapes (star, ring, half circle, triangle). The examiner puts one object at a time on the tongue of the patient. The patient is asked to move

	the tongue and press the object against the palate in order to identify the object's shape as represented on the paper. The bigger sized objects (20 mm) are to be used before the smaller ones (10 mm) in the test.. *0=correct answer, 1=wrong answer.*
Twopoint-discrimination	The patient is sitting in an upright position on a chair. The examiner is using a pair of compasses whose two legs are put on the skin of the patient with an even pressure. The distance between the points of the compasses varies (see below): - the upper part of the cheek (15 mm, right/left); - the lower part of the cheek (15 mm, right/left); - the upper lip (5 mm, right/left); - the lower lip (5mm, right/left); - the lateral part of the tongue (3mm, right/left); - the dorsal part of the tongue (3 mm, right/left); - the tip of the tongue (3 mm); - palatoglossal arch (3 mm, right/left). The patient is asked to tell if he/she can feel one or two points. *0=normal, 1=deviant.*
INTRAORAL ASSESSMENT	
Mouth opening wide	To be measured in millimeters.
Occlusal conditions	To be assessed by a dentist: - open bite, frontal/lateral; - over bite, horisontal/vertical; - proclined incisors, upper/lower; - retroclined incisors, upper/lower; - neutral, pre-/postnormal bite; - deep bite with/without gingival contact; - crossbite, scissors bite; - edge-to-edge bite. *0=normal, 1=deviant.* To be noted: Bruxism, uncontrolled bite reflex.
Teeth	To be assessed: 0=own teeth; 1=own teeth and bridge (upper/lower) or prosthesis (upper/lower); 2=prostheses, upper and lower; 3=ill-fitting bridge or prosthesis; 4=few teeth/no teeth and no bridge or prosthesis. To be noted: Any sign of abrasion, erosion, enamel mineralization or agenesis. *0=normal, 1=deviant.*
Hard palate	To be assessed: - narrow/wide; - high and pointed/low and flat; - stepped palate, right/left; - defined rugae; - anterior flat/broad wall; - cleft palate, total/partial. *0=normal, 1=deviant.*

Tonsils	To be assessed: *0=normal, 1=deviant.*
Tongue	To be assessed: any deviation regarding size, shape, surface structure, coating, frenulum, diastasis, impressions. *0=normal, 1=deviant.*
Parodontal status	To be assessed: Any sign of gingivitis, parodontitis, supragingival calculus, subgingival calculus. *0=no finding, 1=mild, 2=moderate, 3=grave.* To be noted: Any redness, mucosal change, pain, hyperplasia, gingival retraction.
Saliva	To be assessed: Any sign of dry mouth or drooling. *0=no finding, 1=mild, 2=moderate, 3=much, 4=very much.*
SWALLOWING CAPACITY TEST	The patient is sitting on a chair in an upright position. A pulse oximeter is put on his/her index finger. He/she gets a glass containing 150 ml water, lifts it up so that the brim of the glass is resting against the lower lip. At a given signal the patient is to start drinking all of the water if possible and as fast as possible. The patient is told to discontinue if this feels difficult. The examiner takes the time from start on until the last swallowing, when larynx is lowered into resting position. A cervical auscultation is carried out. To be assessed: - time (sec.); - residual volume if any (ml); - swallowing capacity (ml/sec.); - cervical auscultation (*0=normal, 1=deviant*); - larynx elevation (*0=normal, 1=deviant*); - saturation before/after 2 minutes (%). To be noted: Any clinical signs of swallowing problems, changed voice, coughing, hawking or leaking through the nose.
MEAL OBSERVATION	To be assessed: normal meal and/or specific testing meal according to Karin Axelsson 2003-01-28.

Note: Extra observations are to be listed within each section of the Orofacial Assessment Score.

RECORD OF VIDEOFLUOROSCOPY
Hudiksvall Hospital

Social Security No.:

Name:

Diagnosis/severity: ____

At examination:
Position – standing or sitting
Bolus presentation with cup (possible HDB with spoon)
LDB = Low-density barium contrast
HDB = High-density barium contrast

Score			
Normal			**Severe Dysfunction**
0	**1**	**2**	**3**

ANALYSIS of SWALLOWING FUNCTION on a scale (0-3); see above.

Date (Yr-Mo-Day)					
Barium contrast	LDB	HDB	LDB	HDB	
Oral phase	1st exam.		Follow-up		**Comments**
Lip closure					
Bolus control					
Leakage over base of tongue					
Tongue sweep					
Asymmetrical tongue movement					Reduced right / left
Oral retention					
Elevation of velum					
Penetration to epipharynx					
Total:					
Oropharyngeal phase	1st exam.		Follow-up		**Comments**
Vocal cord function					Symmetrical / Reduced right / left
Larynx elevation					
Epiglottis movement					
Oropharyngeal contraction					Symmetrical / Reduced right / left
Opening of pes					
Retention in vallecula					
Retention in pyriform sinuses					Symmetrical / Reduced right / left
Wrong way swallowing					Before / During / After swallowing
Wrong way swallowing, how often?					Seldom / Often / Regularly
Cough with aspiration					Simultaneously / Afterward
Total:					

Social Security No.:

Name:

Score			
Normal		**Severe Dysfunction**	
0	**1**	**2**	**3**

Date:					**Comments**
Esophageal phase	**1st exam.**		**Follow-up**		
Reduced motility					
Presbyesophagus					
Reflux					
Total:					
Morphological change					
Impression of osteophytes					
Plummer-Vinson membrane					
Zenker's diverticulum					
Esophageal ring					
Hiatus hernia					
Achalasia					
Stricture					
Malignancy					
Total:					

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