



Facial motor and non-motor disabilities in patients with central facial paresis: a prospective cohort study

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Abstract

Although central facial paresis (CFP) is a major symptom of stroke, there is a lack of studies on the motor and non-motor disabilities in stroke patients. A prospective cohort study was performed at admission for inpatient rehabilitation and discharge of post-stroke phase of 112 patients (44% female, median age: 64 years, median Barthel index: 70) with CFP. Motor function was evaluated using House-Brackmann grading, Sunnybrook grading and Stennert Index. Automated action unit (AU) analysis was performed to analyze mimic function in detail. Non-motor function was assessed using the Facial Disability Index (FDI) and the Facial Clinimetric Evaluation (FaCE). Median interval from stroke to rehabilitation was 21 days. Rehabilitation lasted 20 days. House-Brackmann grading was \geq grade III for 79% at admission. AU activation in the lower face was significantly lower in patients with right hemispheric infarction compared to left hemispheric infarction (all $p < 0.05$). Median total FDI and FaCE score were 46.5 and 69, respectively. Facial grading and FDI/FaCE scores improved during inpatient rehabilitation (all $p < 0.05$). There was a significant increase of the activation of AU12 (Zygomaticus major muscle), AU13 (Levator anguli oris muscle), and AU24 (Orbicularis oris muscle) during inpatient rehabilitation (all $p < 0.05$). Multivariate analysis revealed that activation of AU10 (Levator labii superioris), AU12, AU17 (Depressor labii), and AU 38 (Nasalis) were independent predictors for better quality of life. These results demonstrate that CFP has a significant impact on patient's quality of life. Therapy of CFP with focus on specific AUs should be part of post-stroke rehabilitation.

Keywords Central facial paresis · Quality of life · Facial grading · Action units · Facial Disability Index · Facial Clinimetric Evaluation Scale

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Introduction

Central facial paresis (CFP) is a frequent initial symptom in patients after stroke with a prevalence of about 45% [1]. It manifests in most cases as a unilateral impairment of facial muscle movements opposite to the side of the stroke with predominance in the lower face. As a consequence, the patients suffer from drooping of the mouth, dribbling from the corner of the mouth, impaired smiling, and speech and eating limitations [2]. The classical model interprets this pattern with bilateral corticonuclear projections from each primary motor area to the motoneurons innervating the upper facial muscles and uniquely contralateral projections to the motoneurons innervating the lower facial muscles [3]. Recently, this model has been challenged by investigations in rhesus monkeys. It might be that upper and lower face are controlled by different cortical areas [4]. Furthermore, a recent fMRI study using action units (AUs) based on the

Facial Action Coding System (FACS; [5]), as the smallest units of facial movements suggest that there are also right-left side differences in facial muscle control [6].

Although CFP is frequent and its functional consequences seem to have an important impact on patients' quality of life after stroke, only a few studies have evaluated CFP in stroke patients in detail [2, 7]. From peripheral facial palsy, it is well known that both the motor but also the non-motor disabilities of the patients influence patient's quality of life [8, 9]. Therefore, it is important not only to evaluate the motor function by standard facial grading system, but also to the non-motor deficits using patient-reported outcome measures (PROM) [10].

Hence, the present prospective clinical study was performed during inpatient rehabilitation of patients with CFP to evaluate facial motor function using standard grading systems, and facial-specific quality of life to evaluate the non-motor disabilities. Furthermore, facial movements were studied in detail by automated AU analysis, and the predictive value of AU activation on quality of life was analyzed.

Methods

Study design and setting

A prospective observational study was performed. Approval for the study was obtained through the local institutional review board and informed consent was obtained from all study participants. Patients with CFP in the sub-acute post-stroke phase admitted to the Department of Neurology, Moritz Klinik Bad Klosterlausnitz, Bad Klosterlausnitz, Germany, for inpatient rehabilitation after stroke between February 2014 and December 2015 were included. 15 patients were excluded for various reasons: missing assessment at discharge ($n=3$), recurrent stroke ($n=4$), history of peripheral facial palsy with chronic ectropion ($n=1$), and missing consent ($n=7$). 33% of all patients with the diagnosis of stroke had CFP during the observation period (unpublished data). Finally, the study cohort comprised 112 patients. The therapy of stroke patients comprised physiotherapy, occupational therapy, speech therapy and neuropsychological therapy in a multiprofessional team. The specific therapy of CFP entailed a multidimensional therapy approach with physical training of related muscles, tapping and mirror therapy. All assessments were performed twice, at admission and at discharge.

Assessment of the level of dependency

The degree of disability during daily living was assessed with the German version of the Barthel Index (BI) and a score of activities of daily living (ADL). The Barthel

Index is a 10-item ordinal scale (0 = absolute dependency; 100 = absolute independency) [11, 12]. The seven ADL items (yes/no) were as follows (0 = absolute independence; 7 = absolute dependency): (a) dressing (including putting on shoes and socks), (b) eating (such as cutting up your food), (c) using the toilet (including getting up and down), (d) bathing and showering, (e) getting in and out of bed, (f) self-controlling urination and defecation, and (g) walking across a room [13].

Standard photographs of facial expression

Patients were routinely photographed using static posed facial expressions in a standardized manner. Participants were seated in a brightly lit room and instructed to focus a digital camera. The patients were instructed to perform a facial expression as demonstrated by the professional photographer. The patients were requested to perform the expression spontaneously. Furthermore, facial expressions were not exercised prior to the photographs. The sequence of static posed 9 expressions was always constant: (1) at rest, (2) closing both eyes gentle, (3) closing both eyes with maximal effort, (4) frowning, (5) wrinkling the nose, (6) lifting corners of mouth with closed mouth, (7) showing the teeth, (8) pursing the lips, and (9) pull down both corners of mouths. Hence, normally 9 images were taken as a set per patient per time of assessment (Online Resource 1). All images were transferred serially from the digital camera into the electronic medical record of patients.

Facial grading

The facial paresis was graded using the photograph series according to the House–Brackmann grading [14], the Sunnybrook grading [15], and also according to the Stennert Index [16]. The House–Brackmann Scale is a gross six-point facial grading system (I = normal; VI = total paralysis). Sunnybrook grading is a regional weighted system that rates three subscores: resting symmetry, the degree of voluntary facial muscle movement, involuntary muscle contraction (synkinesis). The three subscores are used to calculate a composite score (0 = total paralysis; 100 = normal function). The Stennert Index classifies the face at rest (0–4 points; 0 = normal to 4 = complete loss of resting tone) and during motion (0–6 points; 0 = normal to 6 = no motion) separately. Both subscores are summed up to the Stennert total score. Two trained observers independently graded all photograph series. In case of disagreement, the photograph series was evaluated together to find an agreement.

Automated facial action unit coding

Recently, a fast and marker-free automated method for unilateral facial grading was developed based on random decision forests and active appearance models (AAM) [17, 18]. An AAM approach for automated action coding of facial expressions defined as action units (AUs) in patients with facial paresis was developed [19]. The AU concept based on the Facial Action Coding System (FACS; [5]), which is a central concept in the present study. AUs are simultaneous movements of one or for many AUs of more than one muscle. The FACS originally describes 46 AUs. The automated discrimination allowed the detection of the following 22 AUs: 1, 2, 4–7, 9, 10, 12–18, 20, 23–26, 30, 38 (cf. example in Online Resource 1).

Assessment of facial paresis specific quality of life

The FaCE Questionnaire is a validated quality of life instrument that is used to assess facial impairment and disability after facial paralysis [20]. It involves 15 statements, each using a five-item Likert scale. The total score ranges from 0 (worst) to 100 (best) and incorporates all domains. The validated German version was used [21]. The FDI is composed of 10 Likert-type questions measuring the physical and social function related to the facial paresis [22]. The total scale is scored from 0 (worst) to 100 (best). The validated German version was used [21].

Statistical analysis

All statistical analyses were performed using IBM SPSS (version 25.0.0; IBM, Armonk, NY). If not otherwise indicated, data are presented as mean \pm standard deviation. The nonparametric Wilcoxon test (for metric data) and the Chi-square test (for nominal dichotomous data) were applied to analyze differences between the two assessments at admission and at discharge. The Chi-square test was also used to compare patients with left side to patients with right side lesions (only the subgroup of patients with unilateral infarction). The absolute changes of the patients' responses were determined by subtracting the values of the assessment at the discharge from the values of the assessment at admission. Spearman's correlation coefficient was calculated to measure the strength of association between the changes of the two questionnaires (FDI, FaCE) and several patients' characteristics or AU activations. Significant associations ($p < 0.05$) were included into multivariate linear logistic regression models for the analysis of potential independent predictors of these changes. In general, all p values are results of two-sided tests. The significance level was set at $p < 0.05$.

Results

In total, 112 patients participated in the study. Of these patients, 61% were male, with a median age of 64 years. The main reason for inpatient rehabilitation for stroke was an ischemic infarction (88%). CFP occurred on the right side in 40%, on the left side in 58%, and on both sides in 2% of the patients. Median interval between onset of the paresis and admission for inpatient rehabilitation was 20 days. The median duration of the rehabilitation was 21 days. Demission took place after a median time of 41 days after the stroke event. Data are displayed in Table 1.

Facial motor and non-motor disabilities

At admission, average BI was 57.2 ± 43.3 (median 70). Average ADL was 1.9 ± 2.5 (median 0). Median House–Brackmann grading, Sunnybrook grading, and Stennert Index grading were 3, 80, and 1, respectively. Median FDI was 46.5 and median FaCE was 69. Basic activity, facial nerve motor function, and self-reported motor and non-motor disabilities all improved during inpatient rehabilitation (Table 2, all $p < 0.05$; Figs. 1, 2). FDI and FaCE results correlated to each other ($p < 0.001$; Online Resource 2). Only the FaCE but not the FDI showed a consistent correlation to the facial grading (Online Resources 2, 3).

Action unit activation

The sum of AU activations and also the absolute difference between the AU activations on the healthy and affected side for each of the 9 tasks did not change (Table 3). AU12, AU13, AU24, and AU25 were activated by more patients at discharge compared to admission (Table 4, all $p < 0.05$). AU4 was the only AU less frequently used at discharge ($p = 0.037$). From the perspective of each of the different tasks, only the task smiling with open mouth and the task depress lower lips showed an increase of AU activation from admission to discharge (all $p < 0.05$; Online Resource 4): For smiling with open mouth, the AU10, AU12, AU13, and AU25 were increasingly used (all $p < 0.05$). During the task to depress the lower lip, AU14 and AU25 were increasingly activated ($p = 0.025$ and $p = 0.024$; respectively).

The correlation between AU activation versus FDI and FaCE results at demission is summarized in Online Resource 5 and at discharge in Online Resource 6. At demission, AU16, AU20, and AU38 showed a significant correlation to FDI and FaCE (all $p < 0.05$). At demission, AU14, AU16, AU17, AU20 AU26, and AU38 always correlated both to FDI and FaCE (all $p < 0.05$). The multivariate regression analysis (Table 5) revealed that the non-use of AU2

Table 1 Patients' characteristics ($N=112$)

Parameter	<i>N</i>	(%)
Gender		
Female	44	39.3
Male	68	60.7
Etiology		
Ischemic, right arteria cerebri media	60	53.6
Ischemic, left arteria cerebri media	38	33.9
Ischemic, bilateral, multiple foci	2	1.8
Hemorrhagic, right basal ganglia	4	3.6
Hemorrhagic, left basal ganglia	8	7.1
Side of central facial paresis		
Right	45	40.2
Left	65	58.0
Bilateral	2	1.8
	Mean \pm SD	Median, range
Age, years	63.4 \pm 12.5	64, 30–87
Interval onset to admission, days	24.0 \pm 14.0	20, 4–111
Duration inpatient rehabilitation, days	21.1 \pm 4.9	21, 13–48
Interval onset to demission, days	45.1 \pm 14.3	41, 25–132

Table 2 Comparison of the assessment at admission and discharge

Parameter	Admission	Discharge	<i>p</i>
Basic activity			
ADL	1.9 \pm 2.5	1.2 \pm 2.0	<0.0001
Barthel Index	57.2 \pm 43.3	75.0 \pm 30.6	<0.0001
Facial grading			
House–Brackmann	2.9 \pm 0.5	2.6 \pm 0.7	<0.0001
Sunnybrook	78.1 \pm 11.6	85.5 \pm 10.9	<0.0001
Stennert, total	1.8 \pm 1.6	1.2 \pm 1.3	<0.0001
Stennert, at rest	0.9 \pm 0.7	0.6 \pm 0.7	<0.0001
Stennert, motion	0.9 \pm 1.3	0.6 \pm 0.9	<0.0001
Quality of life			
FDI	45.4 \pm 6.5	48.9 \pm 4.7	<0.0001
FaCE	66.9 \pm 9.4	69.8 \pm 9.1	<0.0001

ADL activities of daily living, *FDI* Facial Disability Index, *FaCE* Facial Clinimetric Evaluation

and the activation of AU16 at admission, and the non-use of AU14 and AU 24, as well as the use of AU12 and U17, were independent predictors for the FDI result. Activation of AU10 at admission as well as the non-use of AU14 and AU26, respectively, and the activation of AU17 were predictors for the FaCE score.

In a subgroup analysis, the results for infarction on the right side (facial paresis on the left side) were compared to patients with infarction on the left hemisphere (facial paresis on the right side). Basic activity, facial grading, and quality

of life did not show any side difference at admission and at discharge (all $p > 0.05$; data not shown). At admission, patients with infarction on the right hemisphere showed a lower frequency of AU10, AU25, and AU30 activation (all $p < 0.05$; Online Resource 7). These patients showed at demission a lower activation of AU12, AU23, and AU30 (all $p < 0.05$; Online Resource 8).

Discussion

More than 100 patients with CFP in the sub-acute post-stroke phase were first assessed after a median time of 20 days after the stroke event. The assessment of the disabilities on daily living showed that many of the patients were already again largely independent and mobile (median BI and ADL scores 70 and 0, respectively). Nevertheless, and although facial paresis was incomplete, the House–Brackmann grading varied from grade II to IV (79% \geq grade III), the total Sunnybrook score from 22 to 96, and the total Stennert Index from 0 to 6. Consequently, a high number of patients still had a relevant disability of facial motor 3 weeks after stroke onset. Even at demission, i.e. after a median time of 41 days after onset, still 60% of the patients have a House–Brackmann grade \geq III. It is frequently claimed CFP recovers very quickly compared with the limbs paresis because of the multiple sources of corticonuclear innervation and therefore CFP is not frequently found in the chronic stage after stroke [23]. Interestingly, often the same study in Danish language from

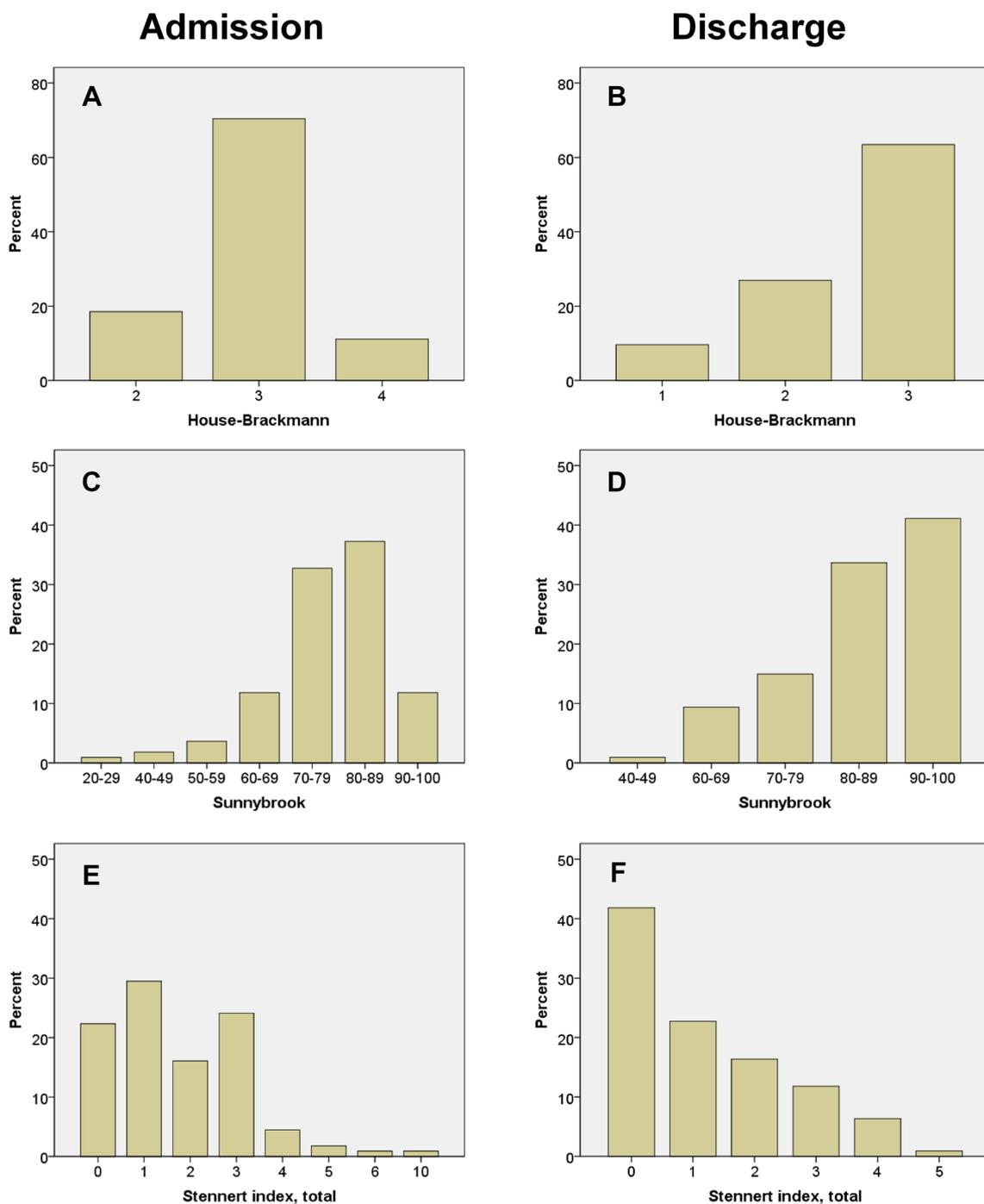


Fig. 1 Facial grading at admission for inpatient rehabilitation (**a, c, e**) and at discharge (**b, d, f**). House–Brackmann grading (**a, b**), Sunnybrook grading (**c, d**), and Stennert Index (**e, f**) were improving

1992 and no other study is cited to substantiate this assertion: Svensson et al. studied 35 patients with facial paresis after stroke in a rehabilitation hospital [24]. Due to the English abstract of the study, a significant improvement in facial function occurred spontaneously after 1 month in rehabilitation. After 6 months 2/3 of the patients had normal facial

function or mild dysfunction. In fact, the available data are poor and the spontaneous recovery rate is unclear. But even this poor data reports, that about one-third of the patients are still suffering under facial dysfunction after 6 months.

The present study suggests that stroke patient benefit from the specific rehabilitation program addressing the CFP. Of

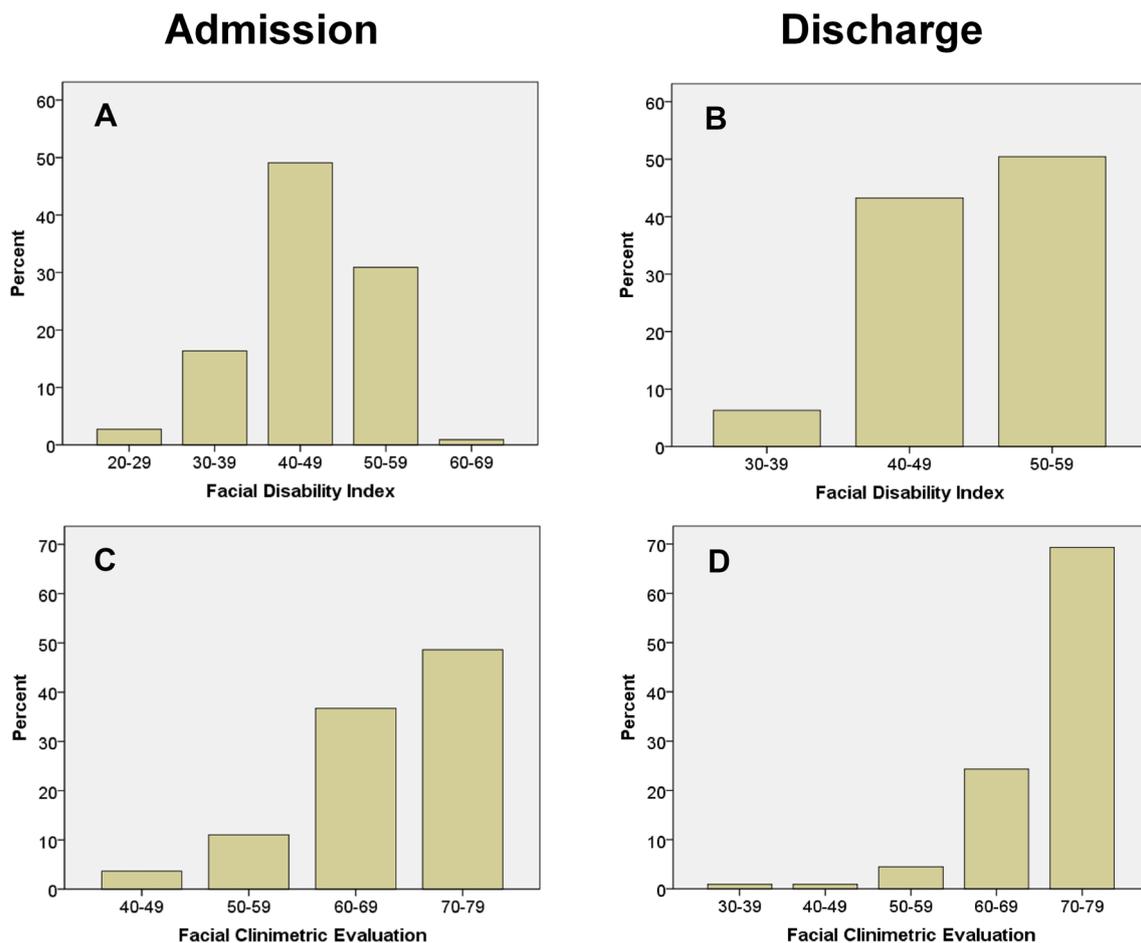


Fig. 2 Facial nerve specific quality of life at admission for inpatient rehabilitation (**a, c**) and at discharge (**b, d**). Facial Disability Index (**a, b**) and also the Facial Clinimetric Evaluation (**c, d**) score were improving

course, this has to be proven in a controlled clinical trial in comparison to standard rehabilitation. House–Brackmann, Sunnybrook and Stennert grading were improved in 33%, 10%, and 46% of the cases, respectively. It has to be taken into account that these and any other facial grading system were developed for peripheral facial palsy. A validation for CFP was never performed before. The grading systems might underscore the improvement of patients with incomplete paresis with a focus on the lower face. Therefore, the analysis with AU concept based on FACS ([5]) seems to be advantageous. AUs can be seen as the smallest units of facial movements [6]. The automated analysis of the AUs allows an objective way to describe regional facial movements on the level of one to a few mimic muscles. The present study showed a significant increase of the activation of AU12 (zygomaticus major muscle), AU13 (levator anguli oris muscle), and AU24 (orbicularis oris muscle) during inpatient rehabilitation reflecting the predominant impact of the stroke on the lower face function. The decreased activation of AU4 (depressor glabellae, corrugator, depressor supercillii

muscles) and AU26 (depressor labii inferioris, or relaxation of mentalis or orbicularis oris) can be interpreted as a decline of compensatory use of unaffected muscle groups on the unilateral side. In addition, the integrated bilateral AU analysis (cf. Fig. 3) showed that the compensatory activation of the contralateral lower face is decreasing during rehabilitation. For instance, AU9 seems to show a compensatory overactivation on the paralyzed side at admission. This overactivation might be a compensation to overcome the paresis of other but paralyzed muscles in the lower face normally activated during smiling. This overactivation disappeared during rehabilitation as the paralyzed muscles of the lower face, especially AU24, showed a strong recovery. These fine effects were not and cannot be registered when only classical facial grading systems are used.

Studies on rehabilitation concepts for CFP are sparse and mainly report on single-center experience with small sample sizes. Orofacial rehabilitation might not only affect the facial movement but also on the mental state of the patients [2, 25]. Mirror therapy might be an element to enforce the

Table 3 Action unit (AU) activation on the side of the facial paresis during the different tasks at admission and discharge

Task	Admission Sum of AU activation Mean \pm SD	Discharge Sum of AU activation Mean \pm SD	<i>p</i>
At rest	0	0	
Raising eye brows	7.9 \pm 3.9	7.6 \pm 3.2	0.752
Closing eyes gentle	8.3 \pm 3.3	10.0 \pm 3.7	0.363
Closing eyes tight	8.1 \pm 3.7	8.3 \pm 3.0	0.753
Nose wrinkling	8.9 \pm 3.3	9.3 \pm 2.9	0.411
Smiling with closed mouth	8.5 \pm 3.5	9.0 \pm 2.9	0.304
Smiling with open mouth	9.7 \pm 3.1	9.6 \pm 2.7	0.916
Puckering lips	9.1 \pm 3.1	9.2 \pm 3.1	0.522
Depress lower lip	8.2 \pm 3.1	7.9 \pm 3.2	0.617
Task	Admission Δ AU activation Mean \pm SD	Discharge Δ AU activation Mean \pm SD	<i>p</i>
At rest	0	0	
Raising eye brows	-0.3 \pm 4.0	-0.2 \pm 3.7	0.805
Closing eyes gentle	0.1 \pm 3.8	-0.4 \pm 3.2	0.130
Closing eyes tight	0.4 \pm 3.5	0.4 \pm 3.1	0.973
Nose wrinkling	0.4 \pm 3.4	-0.2 \pm 3.4	0.293
Smiling with closed mouth	0.6 \pm 3.6	0 \pm 3.0	0.210
Smiling with open mouth	0.5 \pm 3.5	0.7 \pm 3.3	0.591
Puckering lips	0.3 \pm 3.9	0.1 \pm 3.3	0.548
Depress lower lip	0.3 \pm 3.5	0.5 \pm 3.2	0.513

Difference Δ = score of healthy side minus score of the paresis side

rehabilitation [26]. Interesting, none of the large clinical guidelines for rehabilitation after stroke is even mentioning CFP (for instance, [27, 28]).

At admission for rehabilitation, the median total FDI and FaCE score were 46.5 and 69, respectively. In comparison, German patients with acute peripheral facial palsy showed a total FDI and FaCE score of 69.5 and 63, respectively [9]. Same results for peripheral facial palsy have been revealed in different other countries [20, 22, 29–32]. Hereafter, the non-motor impairment of patients with CFP is as severe as in patients with peripheral facial palsy. As known from peripheral facial palsy, the severity of the paresis did not strongly correlate to the FDI and FaCE scores [8, 9]. The AU analysis shows some new aspects. At least the activation of AU14, AU15, AU16, AU20, AU25, AU38, i.e. mainly the activation in the lower face was directly correlated to better facial-specific quality of life.

There is some evidence that patients with right brain damage are significantly more impaired in imitating several AUs of upper and lower face than persons with left brain damage [33]. One study has shown that patients with

right-sided CFP showed a significantly better improvement at 6 months as compared to patients with left-sided CFP [24]. The right hemisphere seems to be more involved in specific facial movements [6]. Primary emotions also seem to evolve from the right hemisphere (spontaneous facial expressions begin in the left face), whereas voluntary smiles seem to begin in the majority of the cases on the right side of the face [34]. This fits to the observation of the present study that patients with infarction on the right side (paresis on the left side) showed a lower activation in several AUs on the paretic side compared to patients with infarction on the left hemisphere (paresis on the right side). This side difference did not show any influence on the FDI or FaCE results.

In conclusion, this prospective longitudinal cohort study of 112 patients demonstrated that CFP has a significant impact on patient's quality of life. Classic clinical Facial grading systems are no good predictor for the impact on quality of life. The smallest units of facial movement, AUs, are better predictors. The ability to activate some specific AUs of the lower face is a good predictor of patient's non-motor function and related quality of life.

Table 4 Relative number of patients with action unit (AU) activation on the side of the facial paresis at admission and discharge

AU	Target muscles	Admission Number of patients with AU activation (%)	Discharge Number of patients with AU activation (%)	<i>p</i>
1	Frontalis, pars medialis	37.6	39.7	0.397
2	Frontalis, pars lateralis	38.5	39.1	0.787
4	Depressor glabellae, corrugator, depressor supercilii	44.8	39.5	0.037
5	Levator palpebrae superioris	40.2	38.7	0.574
6	Orbicularis oculi, pars orbitalis	37.6	32.9	0.056
7	Orbicularis oculi, pars palpebralis	42.2	39.7	0.312
9	Levator labii superioris alaeque nasi	35.4	34.6	0.716
10	Levator labii superioris, caput infraorbitalis	19.8	20.1	0.888
12	Zygomaticus major	64.8	71.9	0.004
13	Levator anguli oris (caninus)	29.1	37.2	0.001
14	Buccinator	39.2	35.4	0.122
15	Depressor anguli oris (triangularis)	44.3	44.9	0.822
16	Depressor labii	14.2	11.7	0.142
17	Mentalis	48.8	48.9	0.989
18	Incisivi labii superioris, Incisivi labii inferioris	25.5	25.7	0.936
20	Risorius	21.6	20.0	0.425
23	Orbicularis oris	46.8	48.9	0.411
24	Orbicularis oris	43.5	48.7	0.041
25	Depressor labii inferioris, or relaxation of mentalis or orbicularis oris	19.0	12.6	0.001
26	Masseter; relaxed temporalis and internal pterygoid	34.8	32.9	0.420
30	Jaw, sideways	5.8	6.9	0.382
38	Nasalis, pars alaris	34.2	32.8	0.564

Summarized for all tasks

Significant *p*-values ($p < 0.05$) are in bold

Table 5 Linear regression analysis for independent AU predictors of the FDI and FaCE

AU	Muscles	Beta	95% CI lower	95% CI upper	Stand.* beta	<i>p</i>
FDI at admission; $R^2=0.194$; $p<0.0001$						
2	Frontalis, pars lateralis	-1.647	-2.645	-0.649	-0.119	0.001
16	Depressor labii	1.726	0.146	3.306	0.089	0.032
20	Risorius	0.338	-1.002	1.678	0.021	0.620
25	Depressor labii inferioris, or relaxation of mentalis or orbicularis oris	1.166	-0.117	2.449	0.068	0.075
38	Nasalis, pars alaris	1.142	0.109	2.176	0.080	0.030
FaCE at admission; $R^2=0.182$; $p<0.0001$						
10	Levator labii superioris, Caput infraorbitalis	2.303	0.803	3.803	0.118	0.003
15	Depressor anguli oris (triangularis)	-0.453	-1.575	0.670	-0.029	0.429
20	Risorius	0.618	-0.759	1.994	0.033	0.379
25	Depressor labii inferioris, or relaxation of mentalis or orbicularis oris	0.421	-1.117	1.960	0.021	0.591
38	Nasalis, pars alaris	1.464	0.256	2.673	0.090	0.018
FDI at discharge; $R^2=0.078$; $p<0.0001$						
12	Zygomaticus major	0.141	0.040	0.242	0.099	0.006
14	Buccinator	-0.140	-0.243	-0.038	-0.112	0.007
15	Depressor anguli oris (triangularis)	0.035	-0.069	0.139	0.029	0.509
16	Depressor labii	-0.111	-0.262	0.041	-0.059	0.152
17	Depressor labii	0.149	0.058	0.240	0.124	0.001
20	Risorius	-0.063	-0.187	0.061	-0.042	0.318
24	Orbicularis oris	-0.073	-0.169	0.024	-0.061	0.140
26	Masseter; relaxed temporalis and internal pterygoid	-0.183	-0.279	-0.086	-0.143	<0.0001
38	Nasalis, pars alaris	0.043	-0.052	0.138	0.034	0.371
FaCE at discharge; $R^2=0.056$; $p<0.0001$						
5	Levator palpebrae superioris	0.537	-0.697	1.772	0.037	0.393
7	Orbicularis oculi, pars palpebralis	-0.336	-1.508	0.836	-0.023	0.574
14	Buccinator	-2.432	-3.573	-1.292	-0.165	<0.0001
16	Depressor labii	-0.908	-2.687	0.870	-0.042	0.316
17	Mentalis	1.309	0.270	2.348	0.093	0.014
20	Risorius	-0.782	-2.254	0.690	-0.044	0.297
23	Orbicularis oris	0.682	-0.542	1.907	0.048	0.274
26	Masseter; relaxed temporalis and internal pterygoid	-1.235	-2.426	-0.044	-0.082	0.042
38	Nasalis, pars alaris	-0.079	-1.212	1.054	-0.005	0.892

Significant *p*-values ($p < 0.05$) are in bold

FDI Facial Disability Index, *FaCE* Facial Clinimetric Evaluation, *CI* confidence interval

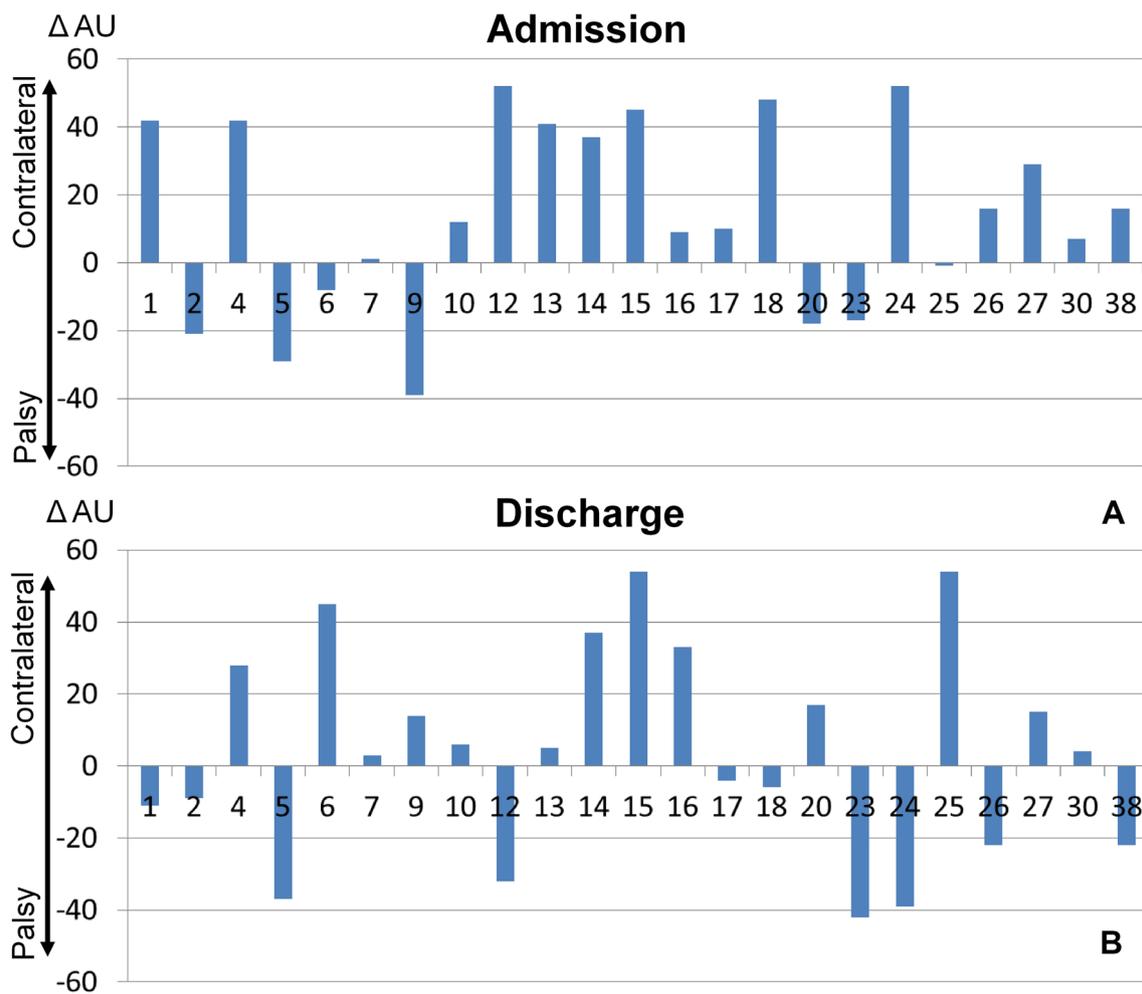


Fig. 3 Activation of action units (AUs) AU1–AU38 as absolute difference (Δ AU) of the sum on the contralateral side minus side of the facial palsy at admission for inpatient rehabilitation (a) and at

discharge (b). A positive value represents more AU activation on the contralateral side where as negative value represents more AU activation on the side of the facial palsy

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Compliance with ethical standards

Conflicts of interest On behalf of all the authors, the corresponding author states that there is no conflict of interest.

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