Validation of the Glasgow Facial Palsy Scale for the assessment of smile reanimation surgery in facial paralysis

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Objectives: To evaluate the Glasgow Facial Palsy Scale as a tool to assess facial reanimation surgery in facial palsy. Software analysis of digital video data is used to measure facial movements, comparing the affected to the normal side. We present the first use of the Glasgow Facial Palsy Scale following facial re-animation surgery.
Design: A comparison of the Glasgow Facial Palsy Scale against the Nottingham scoring system. Subjects undergoing unilateral surgical smile reanimation procedures were selected. Comparison was made with the Nottingham facial palsy scale and the House-Brackmann Scale pre- and postoperatively.
Setting: Patients were recruited in the facial palsy clinic of Canniesburn Plastic Surgery Unit, Glasgow.
Participants: Seven consecutive patients were selected who were due to undergo unilateral facial reanimation.
Main outcome measures: The difference in pre- and post-surgical facial movement as measured using the Glasgow Facial Palsy Scale with this value being compared to that obtained using the Nottingham scoring system. Note was also taken of the correlation with House-Brackmann system and clinical correlation.
Results and Conclusions: Statistical analysis indicated a linear relationship between the Glasgow Facial Palsy Scale and the Nottingham System. The Pearson correlation test was used to confirm the relationship between the two methods giving a result of −0.587, which indicates significant correlation between the two methods. We conclude that the Glasgow Facial Palsy Scale is a standardised objective method of assessing the change in facial movement following smile reanimation surgery. We commend it as a useful tool to objectively assess surgical results in this challenging field.

Introduction

The aim of this study is to validate the Glasgow Facial Palsy Scale (GFPS) as a tool to objectively measure improvement in facial movement following facial re-animation surgery under heterogenic circumstances. We have correlated the results using this system with the Nottingham System,[1] which is our present standard clinical method of assessment. The GFPS calculates not only the overall House-Brackmann[2] grade but also the movement in each separate region of the face. The aim of smile reanimation surgery in the presence of an established facial palsy is to produce a dynamic restoration of facial movement particularly during smiling. Dynamic restoration techniques require dynamic methods of assessment. An objective standardised method of assessing movement would be a useful clinical tool to monitor clinical changes and audits the surgical results in subjects with facial palsy having reanimation surgery. In this article, we assess a group of subjects with a permanent unilateral facial palsy having reanimation surgery and present the first clinical use of the GFPS for surgical audit.

The House-Brackmann grade is the most commonly accepted method of overall measurement of facial palsy and is the standard adopted by the American Academy of Otolaryngology Head and Neck Surgery. It requires the subject to perform a series of movements (raise eyebrows, close eyes gently, close eyes tightly, smile, turn up the nose), which are clinically assessed and subjectively

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In this paper, the Glasgow Facial Palsy Scale (GFPS) is compared with accepted measurement scale to assess and validate the result of a group of patients with unilateral palsy to challenge its reliability under heterogenic conditions and circumstances before and after surgery. GFPS utilizes software to assess facial movements captured on standard digital video footage to give a quick and reproducible digital measurement of palsy degree. This is the first paper that involves the use of GFPS to evaluate facial palsy patients pre- and postoperatively.

assigned to an overall grade from Grade I (normal) to Grade VI (no movement). It has the advantage that it is quick and easy to perform, does not require any technology and produces a single figure description of facial function. The main disadvantages are that as it requires a subjective evaluation of movement, there is intra- and inter-observer variation and that a single overall figure does not allow for assessment of regional differences in function.[3] Also, it categorises motor function jointly with secondary defects. For example, the presence of synkinesis limits the assessment to Grade III or higher. GFPS[4] is a recently developed automated objective method of measuring the House-Brackmann grade as well as the movement in the different regions of the face. A video is recorded with a standard video camera of the subject against a plain background performing five standard movements over a 22 period. The output from the camera is sent via Firewire connection to a 32-bit laptop computer with the GFPS software installed. Using facial recognition techniques, the boundaries of the different regions of both sides of the face are identified in the first resting frame before each movement and then in every frame during each movement. The software recorded the pixel changes per frame in each separate region of the face during each movement and compared to the resting frame by subtraction algorithm. The pixel changes on the palsied side of the face are then compared to those in the corresponding regions of the normal side. Artificial neural networks[5] are then used to assess the relationship of the pixel changes to the clinical grading of not only the House-Brackmann overall grade but also of the different regions of the face. By digital computing, the programme automatically produces a consistent objective measurement of the House-Brackmann overall grading and also a consistent measurement of the movement in the different regions of the face. Reproducing the Audiogram model, the results are graphically represented describing the five regions of interest (Fig. 1), where pixel change replaces measurements of decibels. Interpretation is intuitive as it is expressed as percentage of the movement of the healthy side. No facial markers, special lighting or head fixation are required. A plain background is recommended, although no specific colour is needed. The Facogram graphics produced in 7–15 min depending on the speed of hardware and amount of information recorded.

The Nottingham System is simple to calculate and provides both an overall and a regional evaluation, which is useful in smile assessment. It is an automated objective method of assessing facial palsy producing a continuous result expressed as a percentage with lower intra- and inter-observer variation compared to previous grading scales.[6]

The Nottingham System is divided into three parts. In the first part, which assesses movement, the subject is instructed to fix on a still camera at eye level and 2 m directly in front. Still images are obtained at rest and then at maximal effort of eyebrow raising, closing eyes tightly and smiling. Lines are drawn on each side of the four images. The first is a vertical line through each pupil on the ‘at rest’, eyebrows raised and eyes closed tight images. The point where these lines cross the upper border of

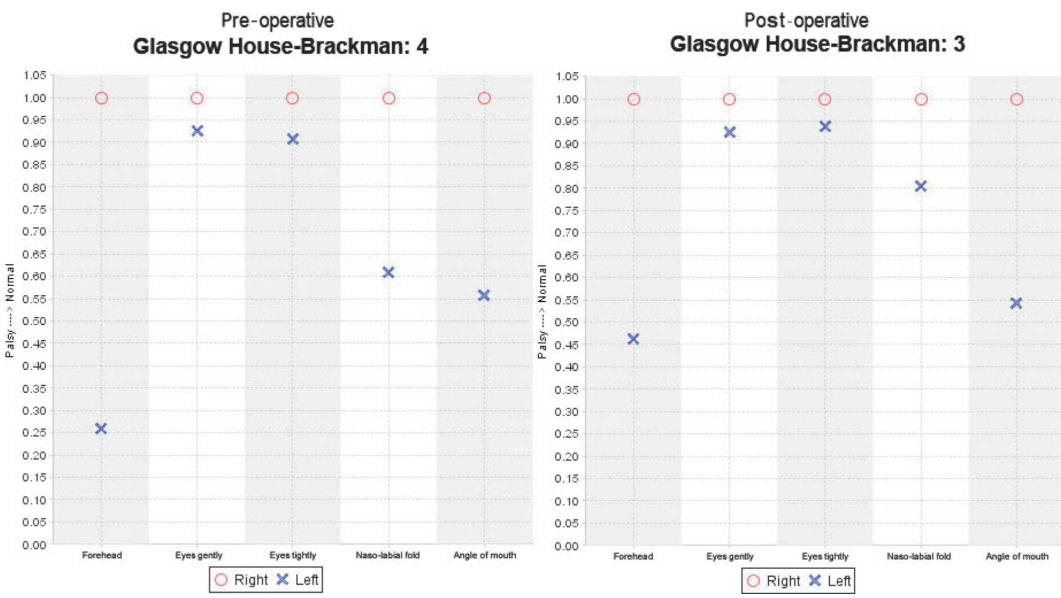

Fig. 1. Pre- and postoperative Facograms, showing the five areas of interest. Red circles represent the normal side (100% of movement), and the blue crosses the affected side and the relative loss of function. Corresponding House-Brackmann score is reported.

each eyebrow is marked as the Supra-Orbital point and where it crosses the Infra-Orbital rim is marked as the Infra-Orbital point (Fig. 2). The Supra-Orbital to Infra-Orbital distances on each side are measured on the 'at rest' image, and the differences compared to the Supra-Orbital to Infra-Orbital distance in both the raising eyebrow and in the closing eyes images are calculated. Markings are also made on the Lateral Canthus of each eye and the modiolus on each side of the on the 'at rest' and smile images. The Lateral Canthus to Mouth distances on each side are measured on the 'at rest' image, and the differences compared to the Lateral Canthus to Mouth distances in the smiling image are calculated. The total of the three differences on the palsy side is summated, divided by the total of the differences on the normal side and multiplied by 100 to give an overall percentage of normal movement with normal movement giving a result of 100% and a total palsy a result of 0%.

The second part of the Nottingham System is a measure of secondary signs, and the third part is a measure of secondary symptoms. This study is confined to movement, and therefore only the first part of the Nottingham System was used when comparing the results of the two assessment methods.

Subjects

The study was carried out in a tertiary referral facial palsy clinic in a Regional Plastic Surgery Unit. Over a 1-year period all seven consecutive subjects, two male and five female with a mean age of 36 (range, 15–59 years) undergoing various reanimation procedures were included in the study. The aetiology of palsy and consequent surgical procedures are reported in Table 1. All subjects had a preoperative assessment with two or three postoperative assessments as facial movements became established.

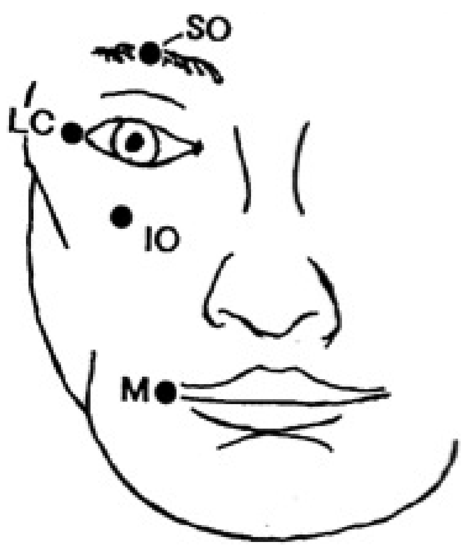

Fig. 2. Main landmarks of Nottingham Score. SO, Supra-Orbital; IO, Infra-Orbital; M, Modiolus; LC, Lateral Canthus.

Materials and methods

Ethical considerations

Digital evaluation of palsy is based on facial recognition software that uses the corners of the mouth and eyes as landmarks. Privacy was guaranteed all the time by written consent form according to NHS Scotland privacy policy; all patients' data were identified by a code and not directly traceable. The GFPS technology is virtually no invasive and requires less efforts and time than many other tested systems already available, demonstrating to be suitable to any kind of patients including children.

The video clip for the GFPS was obtained with a Sony Domestic (Sony Corporation, Tokyo, Japan) video camera model DCR-PC105E. It has a MiniDV digital tape format output, which was passed via a Firewire door to a 32-bit Windows based OS on a laptop with 512 Ram and the dedicated GFPS programme preloaded. The programme that produces the House-Brackmann and the GFPS corresponding graphic (Facogram, Glasgow, Scotland, UK) will accept an input from any Mini DV camera with a digital tape format output that windows XP or higher recognises. The software is open source on the website http://www.GFPS.org.uk along with start up advice.

The GFPS results were obtained at each visit by recording a video of the subject performing five standard movements and imputing the video clip to the dedicated programme, which then automatically measures the

Table 1. This table shows the age, sex, aetiology and surgical procedure performed on each of the seven subjects

Subject	Age	Sex	Cause of palsy	Surgical procedure
1	17	M	Congenital palsy	Cross Facial+ Free Gracilis
2	54	F	Acoustic Neuroma	Free Gracilis + Nerve to Masseter
3	30	F	Acoustic Neuroma	Free Gracilis + Nerve to Masseter
4	45	F	Adenocarcinoma of Parotid	Free Latissimus Dorsi single stage
5	21	F	Bell's Palsy after pregnancy	Cross Facial + Nerve Graft
6	10	M	Congenital Palsy	Cross Facial+ Free Gracilis
7	9	F	Congenital Palsy	Cross Facial+ Free Gracilis

overall House-Brackmann grade as well as the weakness in the different regions of the face by production of a Facogram. Only the results for smile from the Facogram were used to compare to the NS measurements, as surgery only affects smiling and the Nottingham System does not include gentle eyes closure or nasal scrunch.

The Nottingham System results were also obtained at each visit by recording still facial images at rest, with maximal-effort eyebrow raised; with eyes closed gently; closed tightly and with a smile. The changes in the Supra-Orbital to Infra-Orbital measurements between the 'at rest' and eyebrow raised, the Supra-Orbital to Infra-Orbital measurements between the 'at rest' and eyes closed gently, tightly and the Lateral Canthus to Mouth measurements between the 'at rest' and smiling were recorded for regional assessment and also used to calculate the overall Nottingham System grade by comparing the palsy side to the normal side.

Results

Two sets of data are presented in Table 2. The left-hand columns show the overall assessment results of the House-Brackmann grade obtained from the GFPS and also the overall Nottingham System percentage score. It can be seen that each of the seven subjects had a recorded improvement when comparing the pre- to the postoperative recordings of both the House-Brackmann grade, which decreased, and the Nottingham System percentage, which increased.

Table 2. Preoperative and postoperative values comparing in the columns on the left the House-Brackmann to the Nottingham Facial Palsy Scale

	House-Brackmann (produced with Glasgow Facial Palsy Scale)	Nottingham facial palsy scale	Lateral canthus to mouth measurement (LC to M)	Facogram smile pixel change (percentage of the normal sign on smiling on logarithmic scale)
Subject 1				
Pre-op	4	30	10	1.5
12 months post-op	4	43	10	3.5
18 months post-op	3	45	12	6.6
Subject 2				
Pre-op	4	0	0	0
12 months post-op	4	19	30	6
18 months post-op	3	38	44	10
Subject 3				
Pre-op	4	38	53	2
12 months post-op	3	19	56	4
18 months post-op	2	50	76	7
Subject 4				
Pre-op	4	3	17	0
12 months post-op	4	13	45	4
18 months post-op	3	52	61	7
Subject 5				
Pre-op	4	0	31	0
12 months post-op	3	6	27	0
18 months post-op	2	18	41	3
Subject 6				
Pre-op	4	7.5	40	3
12 months post-op	4	9	49	3
18 months post-op	2	30	76	9
Subject 7				
Pre-op	5	6	38	2
12 months post-op	4	23	44	5
18 months post-op	3	34	69	7

The two columns on the right compare the Facogram values for Pixel change during smiling with the lateral canthus to mouth distance percentage of the normal side on smiling. Column four reports values on a logarithmic scale; for example, a value of 1,5 means a 15% of movement.

These results from the two overall methods are also presented in graphic form in Fig. 3. A Kolmogorov–Szmirnov test showed that the results did not have a normal distribution, and therefore a Pearson correlation test was used to confirm any relationship between the two methods. This test gave a result of −0.473, which indicates an average correlation between the two methods of overall assessment. Four of the individual subjects had an improvement of two grades and three an improvement of one grade giving an average House-Brackmann improvement in 1.5 grades. With the Nottingham System, the range of percentage improvement was from 29% to 12% giving an average 26% overall improvement.

The surgical procedures were aimed at smile restoration rather than forehead movement or eye closure; therefore, the second set of data shown in the two right-hand columns in Table 2 shows only the changes in the angle of mouth region as measured by the pixel changes in the diagram of the GFPS and the percentage relationship of the measurement from the lateral canthus to the angle of mouth, which is done as part of the Nottingham System evaluation. Again, comparing the pre- to the post-operative results in all seven subjects, there is an improvement in that there is an increase in the ratio of the number of pixels changing during smiling in the Facogram results within the GFPS and an increase in the percentage relationship of the measurement from the lateral canthus to the angle of mouth of the palsy side compared to the normal side.

These results from the two methods of smile measurement are also presented in graphic form in Fig. 4. Again, a Kolmogorov–Szmirnov test showed that the results did not have a normal distribution, and therefore, a Pearson correlation test was used to confirm any relationship between the two methods. This test gave a result of −0.587, which again indicates an average correlation between the two methods of smile assessment. The improvement in the ratio of the number of pixels moving during smiling with the computerised assessment was from 3 to 10 with an average improvement of the ratio of 6. The change in the LC to M measurement had a range of 2–44 mm with an average improvement of 27 mm.

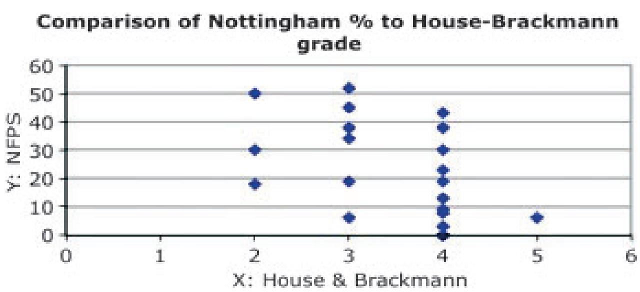

Fig. 3. Comparison of the Nottingham percentage with the House-Brackmann Scale (calculated with the VFG) for overall evaluation of facial movement using the Pearson Test. The result of −0.473 suggests a medium to large correlation between the two methods of overall assessment.

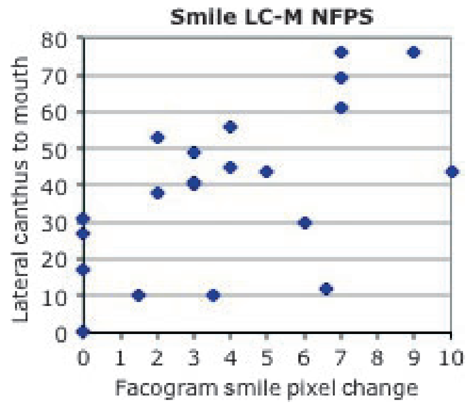

Fig. 4. Comparison of the Nottingham measurement from the lateral canthus to the angle of mouth and the Facogram result for pixel changes both from evaluation of smile movement. The Pearson test has a value of −0.587, which indicates a large correlation between the two methods.

Discussion

The House-Brackmann Scale is universally familiar and accepted by surgeons dealing with facial palsy despite some recognised disadvantages. Rather than develop an entirely new method of assessment, the GFPS is an attempt to improve the reliability and objectivity of the House-Brackmann method. It is necessary for robust surgical audit that the assessments of any results are obtained by objective measurements. The training of the artificial neural networks for the GFPS is a subjective exercise, but once they are trained, the House-Brackmann and regional assessments are measured in a consistent and objective way.

Comparison with other studies

It was previously demonstrated by one of the Authors (B. O'Reilly) that GFPS is capable to track clinical changes in untreated patients with facial palsy. To date the GFPS has not been validated in patients following surgery. In 2011, Kecskes and Al. [7]published a 40-patient study but with no reference to surgical resolution. In this article, the GFPS is compared to the Nottingham System analysing the results of different surgical techniques postoperatively, which was not specifically studied in the over mentioned articles.

There have been many other attempts to improve the objectivity of the measurement of facial palsy[8] starting with a method where a microscale[9] was superimposing on a video and used to measure vertical movement of the eyebrows and the horizontal movement of the modiolus as in the Nottingham System method; this gave reproducible results, but it was very time-consuming. Objective systems to measure movement have been developed in two dimensions (photographic digital evaluation)[8,10,11] and even in three dimensions,[12–16] but both methods have the disadvantage of requiring the application of facial markers to identify the various regions of the face during analysis. Only in recent times, new methods have been developed to measure face movements without markers.[17] The GFPS was the first method, which overcame these disadvantages but required validation in a clinical setting.

Clinical applicability of the study

The video camera and computer required for GFPS are both of standard domestic quality, and with the program open access on the website, the system can be set up with minimal expenditure. It requires only very basic computer skills and is easily within the competence of an audio-visual technician or an audiometrician. As the time taken to take the video, assess the pixel changes and print the graph is <15 min (up to 7 min), the assessment can be made as part of a one stop clinic. If the date of onset is entered at the time of the first assessment, then every future graph will indicate the number of days or months since onset, saving time for the clinician. The graph produced can be printed and stored in the case note or stored electronically along with the video. With subjects who are disheartened by the lack of any clinically obvious return of function, the graphs can be useful to demonstrate even slight improvement to one of the regions thereby encouraging the subject to persevere with the agreed management plan.

Conclusions

This study has shown both the House-Brackmann grade measured with the GFPS and the Nottingham System grading systems are able to identify the overall improvement in facial weakness after smile reanimation surgery. The improvement in the regional angle of mouth movement measurements within both systems can also be selectively measured and used to audit the results of smile reanimation procedures. There is good correlation in the results from both systems, but the automated GFPS is faster and reduces the possibility of inter- and intra-observer error compared to manual Nottingham System and is therefore more useful in a clinical setting.

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Conflict of interest

All authors deny any personal or economical involvement that could have influenced or altered the study.

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