INTRAOPERATIVE MONITORING AND FACIAL NERVE OUTCOMES AFTER VESTIBULAR SCHWANNOMA EXCISION

Dissertation

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VELLORE

CERTIFICATE

This is to certify that the work contained in this study entitled

"INTRAOPERATIVE MONITORING AND FACIAL NERVE OUTCOMES AFTER VESTIBULAR SCHWANNOMA EXCISION" ***is a bonafide work of Dr.Chabungbam Gautam Singh, submitted in partial fulfillment for the degree of M.Ch. Neurosurgery (Part III) examination conducted by Dr.MGR Medical University, Chennai in February 2011.***

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AIMS AND OBJECTIVES

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To determine the utility of proximal to distal facial nerve amplitude and latency ratios in predicting postoperative facial nerve function in patients undergoing excision of vestibular schwannomas.

INTRODUCTION

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Acoustic tumors are benign neoplasms of Schwann cell origin that occur predominantly on the vestibular branches of the acoustic nerve (80%) and from the cochlear part in only about 5-7% (1). The tumors variously known as acoustic neurinomas, acoustic neuromas, and vestibular schwannomas constitute an important intracranial pathology entity, accounting for 6 to 8% of all intracranial neoplasms and 80 to 90% of tumors of cerebellopontine angle (2). Since they arise from the superior division of the vestibular nerve and not from the acoustic division of the eight cranial nerve, and are composed of Schwann cells in the neurilemma, the more accurate term "vestibular schwannoma" has been proposed (4). The majority of acoustic schwannomas are sporadic and unilateral (3). Bilateral tumors are hereditary and constitute less 5% of all schwannomas (4). They present commonly in the fourth to sixth decade and it is a decade earlier in India (5, 6).

The clinical presentation of acoustic neuromas can vary widely, but the earliest symptom is usually hearing loss. A history of progressive unilateral hearing loss, usually over many months and sometime years, is the hallmark of an acoustic neuroma. Compression of the facial nerve obviously occurs early, but the facial symptoms are rare in the early stages. When they do occur, fasciculation's are the most common manifestation.

Anatomic and functional preservation of the facial nerve is a primary goal during microsurgical resection of vestibular schwannomas. While the anatomic integrity of the facial nerve can be preserved in a majority of cases, this does not guarantee functional preservation (7). A normal initial facial nerve examination after surgery strongly correlates with long term functional preservation of the facial nerve even in the setting of delayed weakness. Patients with immediate postoperative facial nerve weakness represent a small but important group that is at increased risk for a poor facial nerve outcome. The ability to predict recovery versus permanent dysfunction would be beneficial in counseling patients as well as planning facial nerve rehabilitation. Intraoperative facial nerve monitoring has been shown to improve facial nerve outcome in multiple studies (8). Several intraoperative monitoring parameters have been used to predict functional facial nerve preservation. In this study we assessed two independent intraoperative monitoring parameters: proximal to distal facial nerve amplitude and latency ratios in predicting long term facial function.

REVIEW OF LITERATURE

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The first presumptive case of vestibular schwannoma dates back to the second half of the 18th century. As reported by Ahn, et al. (9), in 1777 Eduard Sandifort, described at autopsy the first unilateral acoustic tumor. Several reports on tumors related to the auditory nerve followed, but it was not until 1830 that Charles Bell gave an accurate description of what appears to be a definitive case of acoustic tumor. A few years later, Curveilhier published a detailed report on the progression of clinical symptoms and the postmortem findings in a patient. During the last decades of the 19th century, advances in the histological and pathological characterization of tumors led to a more solid correlation of a patient's clinical symptoms with the actual diagnosis obtained at autopsy. Sternberg (1900) is credited with the first accurate pathological description of an acoustic neurinoma (10).

The first reported case of successful surgery in the cerebellopontine angle (in which patient survived) was performed in 1894 by a British surgeon, Sir Charles Balance (11). In early part of this century most patients with vestibular shwannomas presented with very large tumors and significant brainstem compression. The aim of surgery was to decompress the posterior fossa and surgical mortality was 80%. In 1917 Cushing advocated subtotal resection of acoustic tumours and with improved surgical technique and haemostasis was able to lower perioperative mortality to 20% (12). Dandy was the first American surgeon to perform total resection of acoustic tumors successfully and the first to describe the unilateral approach to the cerebellopontine angle. Because many patients at this time presented with facial palsy, postoperative facial nerve palsy was a uniform complication. This trend prevailed until the latter half of the last century; it is only in recent decades that emphasis has been placed on preservation of facial nerve function.

The achievements in vestibular schwannoma surgery were conspicuously marked by the following advances: 1) a better understanding of the microsurgical anatomy; 2) the use of operating microscope; and 3) significant advances in neuroanaesthesia, neurophysiology, and in standard microsurgical techniques.

In 1931 Cairns was the first surgeon to document preserved facial nerve function. It was only until 1940, when Olivecrona employed an operating room nurse to observe facial twitching during tumor resection (12). In 1961, William House pioneered a new era in acoustic surgery with introduction of the operating microscope. He introduced the translabyrinthine and middle fossa approaches for removal of vestibular schwannoma tumours. In 1957, Theodore Kurze for the first time resected a vestibular schwannoma using an operating room microscope. In 1965, Kurze and Rand (13) reported suboccipital transmeatal microdissection to remove vestibular schwannoma totally, affording the possibility of preservation of the facial and cochlear nerves. These approaches and refinement of the technique also led to an increased rate of facial nerve preservation during tumor resection.

Further refinements by M. Gazi Yasargil in the microsurgical techniques and instruments revolutionized vestibular schwannoma surgery. He was influenced by the idea of Kurze and others to make microsurgery a fundamental part of modern neurosurgery (14).

Using his extensive experience in vestibular schwannoma surgery, Majid Samii has established landmark outcomes with respect to the preservation of facial and hearing functions (15, 16).

In the cerebellopontine angle, tumor growth distorts normal anatomic relationships, making neural identification difficult. Of all the surgeries that entail surgery near the facial nerve, resection of acoustic neuroma involves the highest risk of iatrogenic injury (17). The intracranial facial nerve is more susceptible to injury because of the absence of fibrous epineural protective layer found peripherally. In addition, the facial is thinned, attenuated and displaced by acoustic neuromas in the mid cerebellopontine angle. This segment of facial nerve, medial to the porus acousticus in the cerebellopontine angle, is the site of most injuries. Even anatomical preservation of the facial nerve during cerebellopontine angle surgery does not ensure normal or even satisfactory function (18).

A variety of techniques are available for the electrodiagnosis of the pathologies of muscle, peripheral nerve, and their central nervous system distribution. Historically, the earliest investigations were performed in the late 18^{th}

century by Galvani, who published his observations on electricity and muscle contraction. In 1848, Dubois-Raymond discovered the action potential and described it as a negative variation of the standing potential of a nerve related to the conduction of a nerve impulse. Soon thereafter, Hermann von Helmholtz recorded the conduction velocity in a median nerve in a human (19).

HISTORY OF FACIAL NERVE MONITORING

In performing intracranial surgery that requires prolonged dissection and retraction of vital centers and cranial nerves, intraoperative electrophysiological monitoring is useful to the surgeon in localization as well as in assessing the extent of the manipulation of these structures. Cranial nerves two to twelve can be monitored by evoked response potentials (visual evoked potentials, BAEPs), triggered EMG, or a combination of the two. Except for cranial nerves two and eight, the remaining nerves can be monitored by compound muscle action potential (CMAP) triggered by manipulation or direct nerve stimulation. The nerves most commonly monitored during vestibular schwannoma surgery are cranial nerves seven and eight.

In 1893, Krause noted that low-current electrical stimulation of the seventh cranial nerve produced contractions in the facial muscles during sectioning of the eighth cranial nerve for tinnitus. Before 1960, a large percentage of patients who underwent vestibular schwannoma surgery had significant long term facial nerve dysfunction, House-Brackmann grade 3 or worse (20). In 1970's and early 1980's, before the common use of intraoperative facial nerve monitoring (IOFNM), facial paralysis after acoustic neuroma surgery was still a significant issue. By the early 1990's, the advantages of IOFNM in cerebellopontine angle surgery were clear.

Historically, detection of facial nerve activity during surgery was possible by observation of facial muscle movement or by ingenious inventions such as suturing bells to the patients face and listening for a response. J. David Williams in 1988 described a technique in which "jingle bells" were sutured in three positions on the face at the points of maximum excursion of the facial musculature when stimulated by a Hilger nerve stimulator set at 2 mA (21). This procedure was used to monitor movement of the facial nerve while surgeon dissects the nerve in the cerebellopontine angle and internal auditory canal.

To facilitate preservation of the facial nerve during resection of large acoustic neuromas, Delgado, et al, (22) in 1979 developed a modified system of intraoperative electromyography. This method involved stimulation of the facial nerve with a probe during surgery. Surface electrodes over the facial muscles detected the evoked responses and an oscilloscope was used to monitor the activity of the facial nerve. They photographed the EMG recordings for the purpose of detecting small changes that might occur during the operation and that would indicate deterioration of facial nerve function.

In 1982, Sugita and Kobayashi (23) monitored facial nerve function by positioning accelerometers over the facial muscles and transducing the output to an audiometry signal that could be heard by the surgeon. For recognition of the facial muscle responses to stimulation, they used a newly designed facial monitor. Accelerometers weighing 3 gm were attached to the orbicularis oculi and oris muscles. The facial movements were converted to sound by means of an accelerometer, amplifier, and speaker. Thus the surgeon was thus able to recognise the facial responses without necessity of having the patient's face observed under the drapes by an anesthesiologist or ancillary personnel.

Later in 1984, Moller and Jannetta (24) combined the audiometry feedback features with the use of EMG to develop a more sophisticated level of monitoring. In addition these investigators introduced monopolars, low impedence constant voltage stimulation to localize the facial nerve and assess its functional integrity. The electrical activity (EMG responses) of the facial muscles were recorded from two needle electrodes (Grass Type E2 subcutaneous platinum needles), one placed in the orbicularis oris and the other in the orbicularis oculi. The ground electrode was placed on the forehead. The potentials from these two electrodes are amplified differentially using a Grass P511J amplifier equipped with a current limiting probe. The potentials were displayed on an oscilloscope, and wave made available through a loudspeaker using an audio-amplifier.

Anatomy and Physiology of Nerve Conduction and Electrophysiological basis of monitoring

The peripheral nerve trunk contains motor, sensory and autonomic axons, which may be myelinated or unmyelinated; the myelinated ones have a faster conduction velocity. Conduction has two types: continuous or saltatory. The former occurs in unmyelinated nerve fibers and is continuous and bidirectional. Saltatory conduction occurs in myelinated fibers. When a mixed nerve is maximally stimulated and recorded monophasically, there is a somewhat irregular contour to the action potential based on the different velocities and thresholds of the nerve (this is called a “compound nerve action potential” CMAP). Following the fall of the electrical response in the action potential, there are two low amplitude, relatively low deflections, based on prior spike activity. The first is a negative after-potential. The nerve is still excitable at this point, and, in fact, may be more easily excitable. Following this, a positive after-potential occurs where the nerve has a high threshold to activation. Both states relate to Na+ permeability. A motor unit consists of a motor axon and the population of muscle fibers innervated. The neuromuscular junction is a synapse at which the neural impulse stimulates the release of acetylcholine from the axon terminals, resulting in a brief muscle contraction. The consequent electrical response is the CMAP (19) Fig. 1.

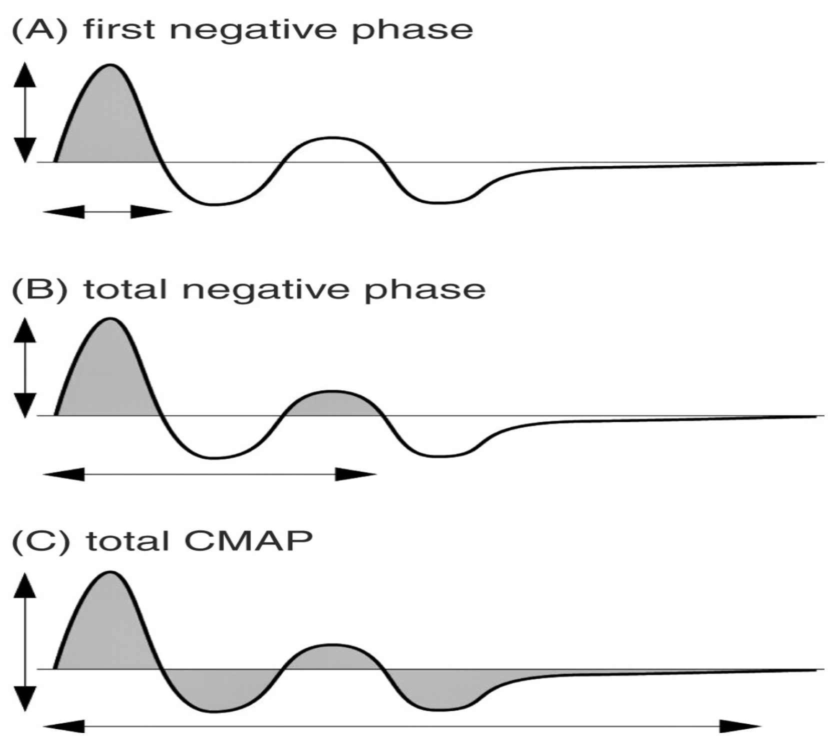

Fig. 1 CMAP variables. CMAP = compound muscle action potential; vertical arrows = CMAP amplitude; horizontal arrows = CMAP duration; shaded phases = CMAP area.

The technique of performing intraoperative electrophysiological monitoring of facial nerve is described in the methodology.

FACIAL NERVE MONITORING AND POSTOPERATIVE FUNCTION

Prior to the use of intraoperative monitoring, the anatomical preservation rate of facial nerve ranged from 30-96.6% and the functional preservation rate ranged from 20-77% in various studies (Table 1). The premise of using intraoperative facial nerve monitoring in acoustic neuromas is that facial nerve outcome will be improved in the immediate and late postoperative period. The facial nerve function following acoustic tumour surgery with the use of monitoring showed anatomical preservation rate of 80–100% and the functional preservation rate from 53–100% in various studies (Table 2).

(Table 1)

Facial Nerve Outcome Without Intraoperative Facial Nerve Monitoring

S.NO	Author/Year	Year	Number of Patients	Anatomical Preservation (%)	Functional Preservation (%)	Total tumor Removal (%)
1	Alfredo & Olivecrona H, et al.,(25)	1949	300	30	20	72
2	Hullay J, et al.,(26)	1965	50	64	36	96
3	Charles G. Drake (27)	1967	30	48	26	90
4	Herbert Olivecrona (28)	1967	282	39.4	10	100
5	Ephraim I.Z, et al.,(29)	1979	120	54.2	45	100
6	House W.F, et al.,(30)	1979	500	96.6	48	93.4
7	King T.T & Morrison A.W (31)	1980	150	54	39	NA
8	Richard H.L, et al., (32)	1982	33	83	45	84
9	Glasscock M.E, et al., (33)	1986	616	82	NA	99
10	Sterkers J.M & Bowdler DA (34)	1988	800	94	50	NA
11	Tos M & Thomsen J (35)	1988	300	95	67	NA

12	Hardy D.G, et al.,(36)	1989	100	82	77	97
13	V.K.Jain, et al., (74)	2005	259	79	39	96.5

NA - Not addressed in article

(Table 2)

Facial Nerve Outcome With Intraoperative Facial Nerve Monitoring

S.NO	Author/Year	Year	Number of Patients	Anatomical Preservation (%)	Functional Preservation (%)	Total tumor Removal (%)
1	Sugita K, et al.,(23)	1982	65	90	78	93
2	Moller A.R, et al.,(24)	1984	10	100	100	NA
3	Harner S.G. & Ebersold M.J,(5)	1985	160	81	75	98
4	Benecke J.E, et al.,(37)	1987	18	100	94	94
5	Richard L.P, et al.,(38)	1987	20	95	75	95
6	Ryuzo S, et al.,(39)	1988	89	80	73	87
7	Niparko J.K, et al.,(40)	1989	29	100	86	NA
8	Hammerchlag P.E, et al.,(41)	1990	111	NA	82	NA
9	Dickins John & Graham S,(42)	1991	41	NA	85	NA
10	Ebersold M.J, et al.,(43)	1992	255	92.6	64	97
11	Arriaga M.A, et al.,(44)	1993	515	NA	87	98.6
12	Lalwani A.K, et al.,(45)	1994	129	99.2	90	77
13	Briggs R.J.S, et al.,(46)	1994	167	92	NA	NA
14	Barbara A.E, et al.,(47)	1994	70	100	84	50
15	Taha J.M, et al.,(48)	1995	20	100	65	100
16	Samii M, et al.,(15)	1997	1000	93	70	97.9
17	William B.G, et al.,(50)	1997	179	99.4	96	99

18	Prakash Sampath, et al., (12)	1997	611	97.5	89.7	99.5
19	Todd H. Lanman, et al.,(51)	1999	190	94	53	96.3
20	Morikawa M, et al.,(52)	2000	18	100	83	100
21	Brandon Isaacson et al.,(53)	2003	229	100	87	NA
22	Vincent D, et al.,(49)	2004	312	96	71	97.5
23	Samii M, et al.,(54)	2006	200	98.5	81	98
24	Abraham Jacob, et al.,(55)	2007	359	NA	>90 (I-III)	NA

NA - Not addressed in article

Niparko, et al, (40) in 1989 for the first time reported the results of correlating proximal to distal amplitude ratios with facial nerve outcome in 29 patients who underwent translabyrinthine excision of the acoustic neuroma and were followed for one year. Of these 29 cases, 24 demonstrated equal responses with proximal and distal stimulation (1:1) at the completion of the procedure. 16 of these 24 patients (67%) demonstrated normal facial function (House and Brackmann Grade I) 1week postoperatively. One year postoperatively, 21 of these 24 patients (88%) had Grade I facial function. None of these 24 patients demonstrated complete postoperative facial paralysis. Thus, equal distal-proximal evoked responses suggested a good prognosis for the eventual recovery. 4 out of the 29 cases demonstrated a reduced proximally evoked response. In one of these 29 cases, proximal stimulation evoked no response. Two of the four cases with a reduced proximal response demonstrated facial weakness (Grade III and V) 1 week postoperatively. One of these two cases regained normal facial function after 1 year. The single case of absence of the proximally evoked response demonstrated complete paralysis (Grade VI) 1 week and 1 year postoperatively. Thus it was concluded that a reduced proximal response at the end of the procedure may indicate postoperative facial weakness. The mere presence of a response with proximal stimulation at the end of the procedure, however, indicates that the facial nerve is at least partially intact. However, the authors did not correlate the values of proximal to distal amplitude ratios with final facial nerve outcome and did not study the association between intraoperative amplitude ratios, initial postoperative facial nerve function, and final facial nerve function.

Ebersold, et al., (43) in 1992 reported that proximal to distal amplitude ratios greater than 0.9 were associated with good initial and final postoperative facial nerve function; ratios between 0.5 and 0.9 were associated with significant initial postoperative facial nerve weakness but good final facial nerve function; ratios less than 0.5 were associated with poor initial facial nerve function and varying degrees of final facial nerve weakness.

Taha, et al, (48) in 1995 reported the first detailed analysis of the association between proximal to distal facial nerve amplitude ratios and initial and final postoperative facial nerve function. The facial nerve was stimulated using a monopolar stimulator probe with a constant current of 4 pulses per second for 100 msec. The stimulus was set at the lowest intensity required to elicit an EMG response, beginning at 0.05 mA and not exceeding 1 mA. The facial nerve was stimulated at the proximal and distal points after tumor excision. The response amplitudes were recorded in microvolts. Six readings were obtained: three from proximal and three from distal stimulation. The highest proximal to distal ratios were used to predict initial and final postoperative facial nerve function. They found that higher proximal to distal amplitude ratios were associated with better initial and final postoperative facial nerve function. All patients with ratios greater than 2:3 had grade III or better initial postoperative facial nerve function and grade I final facial nerve function. 90% of patients with ratios between 1:3 and 2:3 had grade III or worse initial postoperative facial nerve function and all had grade III or better final postoperative facial nerve function. All patients with ratios less than 1:3 had grade IV or worse initial and final postoperative facial nerve function. However, the result of this study was inconclusive because the rates of facial nerve recovery in different patient groups overlapped and the number of patients (twenty) was too small.

Sobottka, et al, (56) in 1998 also evaluated amplitude ratios for a series of 40 patients. They also evaluated proximal and distal absolute EMG amplitudes and stimulation threshold for prediction of initial postoperative nerve function and recovery of function. Good initial facial nerve outcome (modified House and Brackmann grading I & II) was found in 15/16 patients with a proximal EMG amplitude greater 800 microvolts and in 19/22 patients with proximal stimulation threshold of less than 0.3 mA. Sixteen of

16 patients with proximal stimulation threshold equal to or greater than 0.3 mA had moderate to severe facial palsy (HB III or worse). Six of six patients with without evokable proximal amplitude initially had poor facial nerve function (HB IV). A proximal amplitude of 300 microvolts or less and a proximal to distal amplitude ratio below 1: 3 were found in the absence of functional recovery in 6/8 (75%) and 5/6 (83%) patients with initial HB IV, respectively. They concluded that absolute values of proximal amplitudes were more reliable predictors than proximal to distal ratios.

Goldbrunner RH, et al, (57) in 2000 did a quantitative analysis of absolute values and ratios (proximal/distal) of evoked EMG parameters (amplitude, latency and duration) in 137 patients and were correlated with postoperative (1week, 6 weeks and 6 months) facial nerve function. Absolute values of EMG amplitude and amplitude ratios (proximal/distal) demonstrated a good predictive power. For EMG latencies, only the ratios revealed a significant correlation with facial nerve function. Latencies and latency ratios are also easily influenced by intraoperative maneuvers that lead to nerve edema and reversible nerve blocks. They found that an amplitude ratio of greater than or equal to 0.3 had a good chance for facial nerve function recovery and in contrast, a ratio of less than 0.1 had poor facial nerve function outcome. Because absolute values of CMAP amplitudes are available at every phase during surgery, these are the most appropriate parameters for routine assessment of the status of the facial nerve during surgery. So it was concluded that due to their lower predictive power, latency ratios should be used only as supplementary parameters and statements concerning expected facial nerve outcomes should be based on the amplitude ratios, which are the strongest predictors.

Isaacson et al, (53) in 2003 did a retrospective case review of 229 patients undergoing resection of vestibular schwannoma with intraoperative facial nerve monitoring at a single institution. They found that the proximal to distal amplitude ratio and proximal electric threshold were statistically significant in predicting facial nerve outcome. They concluded that use of intraoperative facial nerve monitoring may be useful to predict poor long term outcomes and thus modify the timing of rehabilitation.

Various parameters have been studied during the facial nerve monitoring in acoustic nerve tumor and cerebellopontine angle surgeries. Table 3 shows the parameters which have been studied during facial nerve monitoring.

Table (3)

VARIOUS PARAMETERS USED IN INTRAOPERATIVE FACIAL NERVE MONITORING

SN	Author/Year	Year	Amp of CMAP	Latency of CMAP	Prox to Dist ratio of CMAP Amp	Prox to Dist ratio of CMAP Lat	Duration of CMAP	Dura tion of stim.	Stim. threshold	Prox. to Dist. ratio of stim. thres	F wave	Train time	Burst pattern	Useful Parameters
1	Prass R.L, et al.,(38)	1987	Yes									Yes	Yes	1, 10, 11
2	Ryuzo S, et al.,(39)	1988	Yes											1
3	Niparko J.K, et al.,(40)	1989	Yes		Yes							Yes	Yes	1, 3, 10, 11
4	Hammerchlag, et al.,(41)	1990	Yes						Yes			Yes	Yes	1, 7, 10, 11
5	Dickins& Graham S (42)	1991	Yes									Yes	Yes	1, 10, 11
6	Beck D.L, et al.,(58)	1991	Yes						Yes					1, 7
7	Prasad S, et al.,(59)	1993							Yes					7
8	Lalwani A.K, et al.,(45)	1994							Yes					7
9	Silverstein H, et al.,(60)	1994							Yes					7
10	Taha J.M, et al.,(48)	1995	Yes		Yes				Yes					1, 3, 7
11	Selesnick S.H, et al.,(61)	1996						Yes	Yes					6, 7
12	Hone S.W,et al.,(62)	1997							Yes			Yes	Yes	7, 10, 11
13	Sobottka S.B, et al.,(56)	1998	Yes		Yes				Yes					1, 3, 7
14	Goldbrunner, et al.,(57)	2000	Yes	Yes	Yes	Yes	Yes	Yes						1, 2, 3, 4, 6
15	Isaacson B, et al.,(53)	2003	Yes		Yes				Yes					1, 3, 7
16	Wedekind C,et al.,(75)	2003									Yes			9
17	Grayeli A.B, et al.,(63)	2005							Yes	Yes				7, 8
17	Neff B.A., et al.,(64)	2005							Yes					7
19	Samii Majid, et al.,(54)	2006	Yes											1
20	Julian Prell , et al.,(65)	2007										Yes		10

The correlation between the sizes of the tumor with the facial function outcome after surgery of acoustic tumors has been reported in various studies. Table 4 compares the outcome of facial nerve function in different tumor size groups. The functional preservation rate was 80-100 % in tumor size less than 2 cm. But there was a wide range of 20-85 % functional preservation rate in tumor size more than 4 cm.

Table (4)

Tumor size and facial nerve outcome

S. N O	Author/Year	Year	Number of Patients	Facial Nerve Monitoring	Size of Tumor (cm)	Facial Function Preservation (%)
1	Michael V.D, et al.,(66)	1978	79	No	< 2	100
					2 to 4	93
					> 4	84
2	Ephraim I.Z, et al.,(67)	1979	120	No	< 2	100
					2 to 4	78.9
					> 4	35.6
3	King T.T & Morrison A.W (31)	1980	150	No	< 1	100
					1 to 2.5	80
					> 2.5	20
4	Richard H.L, et al.,(32)	1982	33	No	< 1	83
					1 to 2.5	NA
					> 2.5	70
5	Ryuzo S, et al.,(39)	1988	89	Yes	< 2	89
					2 to 4	70
					> 4	77
6	Tos M & Thomsen J, et al.,(68)	1988	300	No	< 2.5	97
					2.5 to 4	87

					> 4	66
7	Hardy D.G, et al.,(36)	1989	100	No	< 2.5	83
					2.6 to 3.4	85
					3.5 to 4.4	71
					> 4.5	61
8	Ojemann R.G, et al.,(69)	1993	410	Yes	< 1	98
					1 to 1.9	96
					2 to 2.9	75
					3 to 4	56
					> 4	56
9	Barbara A.E, et al., 1994.(47)	1994	70	Yes	< 1.5	96
					1.6 to 2.5	100
					> 2.5	85
10	Grey P.L, et al.,(70)	1996	276	Yes	< 1.5	74
					1.5 to 2.5	62
					> 2.5	37
11	Goldbrunner R.H, et al.,(57)	2000	137	Yes	< 1	100
					1 to 1.5	88
					1.6 to 2.0	90
					2.1 to 2.5	86
					> 2.5	45
12	John T.M, et al.,(71)	2000	100	Yes	< 1	100
					1 to 2.5	98.6
					2.5 to 4	100
					> 4	71

MATERIAL AND METHODS

MATERIAL AND METHODS

Study design

Retrospective analysis of a prospective database.

Study population

100 consecutive cases operated for vestibular schwannoma in Neurosurgery Unit 1 from September 2003 by a single neurosurgeon were included.

Inclusion criteria

1. Follow up period greater than 3 months.
2. Preoperative magnetic resonance imaging of the brain available.

Methods

All the patients underwent a retrosigmoid approach and excision of the tumor in sitting position with intraoperative electrophysiological monitoring of facial nerve.

The patient information were recorded in a proforma (enclosed) which includes patients preoperative clinical (facial nerve function) and radiological details along with intraoperative (electrophysiological readings) and early postoperative/ follow up clinical data.

ASSESSMENT OF FACIAL NERVE FUNCTION

Using the House and Brackmann scale (72), facial nerve function was assessed preoperatively, initially 4-7 days after surgery and then at follow up.

HOUSE AND BRACKMANN GRADING OF FACIAL NERVE FUNCTION

Grade I - Normal.

Grade II - Mild dysfunction.

Gross: Slight weakness on close inspection.

May have slight synkinesis

At rest, normal tone and symmetry.

Motion : Forehead moderate to good function

Eye closure complete with minimal effort

Mouth slight asymmetry.

Grade III – Moderate dysfunction

Gross: Noticeable but not disfiguring difference between the two sides, noticeable but not severe synkinesis, hemi-facial spasm, contracture or both

Normal tone and symmetry at rest.

Motion: Moderate function of forehead

Eye closure complete with effort

Mouth, slightly weak with maximal effort

Grade IV – Moderately severe dysfunction

Gross: Obvious weakness/ disfiguring asymmetry at rest.

Normal tone and symmetry at rest.

Motion: Forehead none, eye closure incomplete with maximal effort, mouth asymmetric with maximal effort

Grade V – Severe dysfunction

Gross: Barely perceptible motion, asymmetry at rest.

Motion: Forehead none, eye closure incomplete mouth slight movement.

Grade VI – Total paralysis.

RADIOLOGICAL DATA

Only patients who had at least a 3 months follow- up were included in the analysis and the following parameters were analysed –

1**. Size of the tumor**: largest extrameatal diameter in axial, sagittal, or coronal in magnetic resonance imaging scans.

2**. Brainstem distance**: horizontal distance from anterior lip of internal acoustic meatus to the brainstem on the MRI.

3. **Size of the porus** : distance between the medial and lateral lip of internal acoustic meatus

4. **Facial nerve length**: measured intraoperatively from the porus to the root entry zone.

5**. Consistency of the tumor**: predominantly solid or cystic

6. **Absolute value of amplitudes at root entry zone and porus.**

7. **Absolute value of latencies at root entry zone and porus.**

8**. Proximal to distal amplitude and latency ratios.**

Facial nerve length measurement

Intraoperatively facial nerve length was measured by placing a sterile thread along the nerve from the root entry zone to the porus under high magnification. Then with the help of a measuring scale the length of the thread was measured.

Stimulation

Stimulation and recording were done using an intraoperative machine (Nicholet: Viking IV or Endeavor, Maddison USA). For electrical stimulation of the facial nerve, a monopolar platinum tip stimulator was used with a constant current of 0.10 mA, frequency of 4.7 Hz and pulse width of 0.5 msec.

After complete tumor removal, monopolar stimulation was first done at the most proximal part of the facial nerve {exit from the brain stem – root entry zone (REZ)} and then at its entry into the porus acousticus (PORUS).

Recording and Data Acquisition

For data acquisition, Intraoperative Monitor (Nicolet Software, USA) with the help of an amplifier was used. Compound muscle action potential (CMAP) responses were recorded using needle electrodes inserted subdermally into the orbicular muscles of the eye, mouth and in the frontalis muscle for three channel recording. During dissection stimulation was done using a custom made monopolar platinum electrode.

The following stimulation parameters were used during the surgery:

Frequency : 4.7 Hz

Stimulation duration: 0.5 msec

Stimulation strength: 0.1 mA. If responses were not obtained at 0.1 mA no attempt to increase the current was made.

The following recording parameters were used during the recording:

Time base: 50 msec

Low frequency filter: 10 Hz.

High frequency filter: 1 KHz.

Notch filter: 50 Hz

Reference Electrodes were placed at: Nasion & Orbicularis oris

Ground Electrode was placed at : Masseter

CMAP's were displayed on a monitor screen, and stored into disc for further analysis.

From the stored data the following parameters were extracted :

CMAP Amplitudes (Fig 2)

CMAP Latencies (Fig 3)

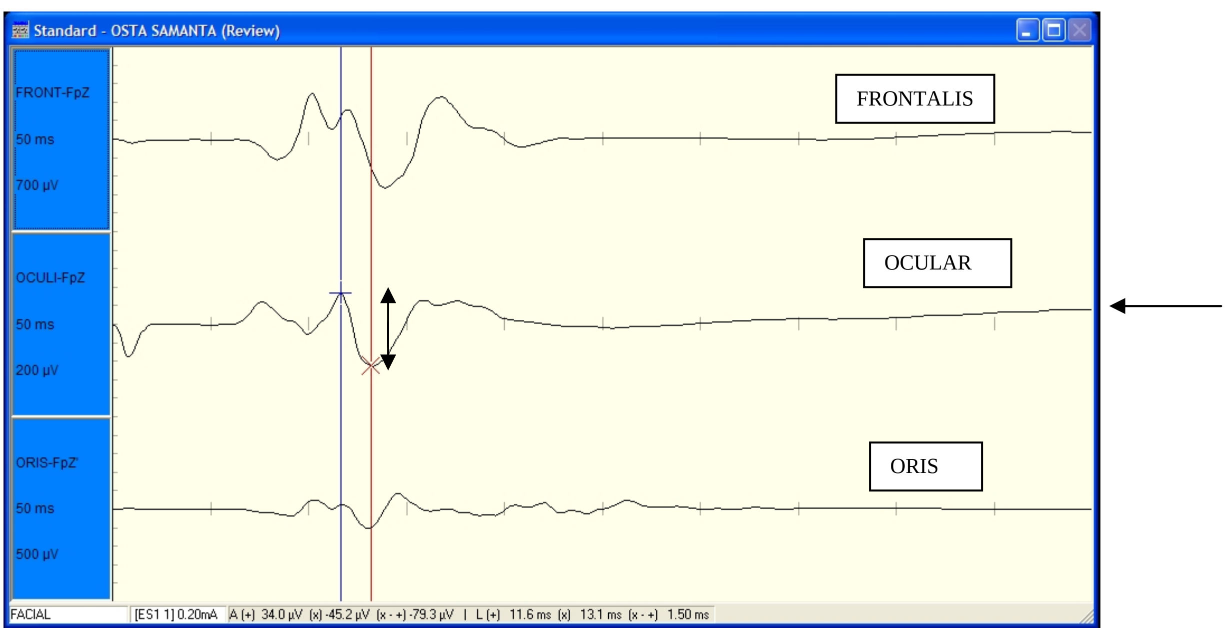

Fig. 2 CMAP Amplitude of ocular muscle

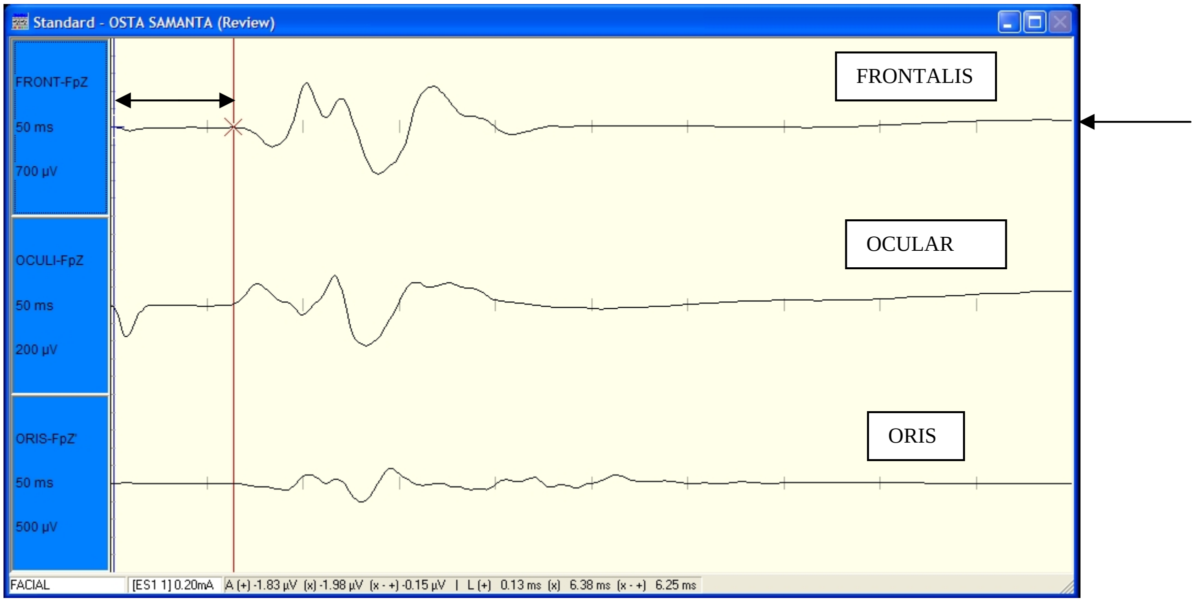

Fig. 3 CMAP Latency of Frontalis muscle

For statistical analysis of the predictive value of different parameters, a multivariate analysis using the logistic regression model was performed. The level of significance was set at $P < 0.05$. For analysis, facial nerve function was categorized as good (Grades I/II) and poor (Grade III/IV/ V/VI). Grades I and II were considered as an acceptable function.

The accuracy of monitoring parameters in predicting long term function was evaluated using 2 × 2 tables. This allowed the calculation of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for these parameters in predicting good long-term facial nerve outcome. For the purpose of clarity, these terms will be defined. Sensitivity is the probability of parameters to be within the defined zone, given that the patient has good outcome. Specificity is the probability that parameters will be outside the defined zone, given that the patient has poor outcome. PPV is the probability of having good outcome if the parameter is within the defined zone. NPV is the probability of having poor outcome if the parameters are outside the defined zone. Of these four, probably the PPV and NPV are more valuable in providing information helpful in counseling patients regarding their long-term facial nerve function.

RESULTS

RESULTS

Between September 2003 to August 2009, 100 patients with vestibular schwannoma were surgically excised via the retromastoid transmeatal approach in the sitting position. The age distribution ranged from 14 to 71 years (mean 42.5 years) of which 47 were men and 53 were women (Fig 4). There were 55 right-sided and 45 left-sided tumors. The average size of the tumor was 4.45 cm (range from 2.4 to 6.5 cm). Total tumor excision was done in 89%, subtotal in 9% and partial excision in 1% (as per patient's request) of the patient. There were 7 Neurofibromatosis-2 patients.

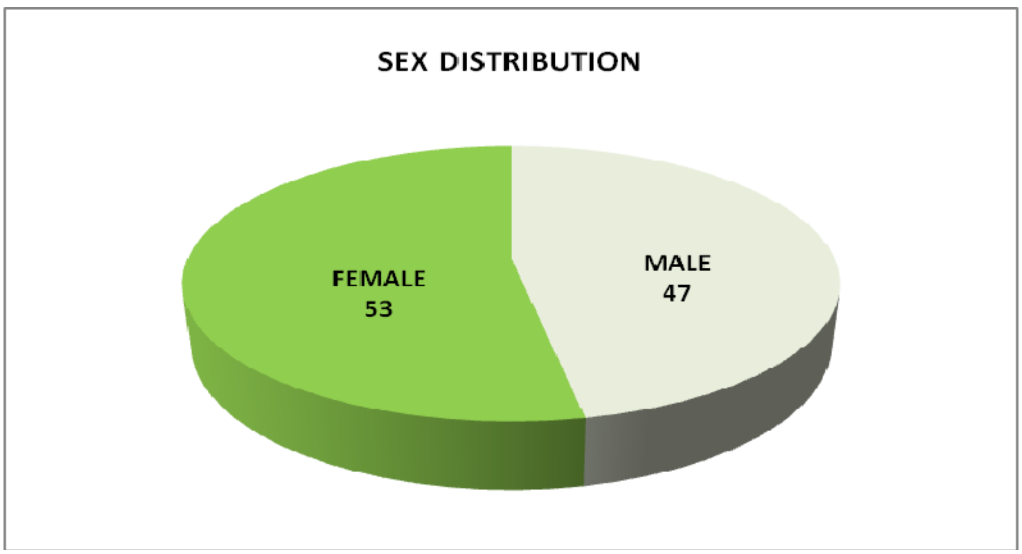

Fig.4 Sex Distribution

Anatomical and Electrophysiological Facial Nerve Preservation

Intraoperatively the facial nerve was anatomically preserved in 86 patients (86%). Electrophysiological responses were obtained from the root entry zone in only 77 patients (77%). In 9 patients the facial nerve was only anatomically preserved but no electrophysiological responses were obtained.

(Table 5)

Early facial nerve function in 75 patients according to tumor size

Size of tumor (cm)	House and Brackmann (Early postoperative period)						
	Grade I	Grade II	Grade III	Grade IV	Grade V	Grade VI	Total
< 3	2 (29%)	4 (57%)	1 (14%)	0	0	0	7
3 - 3.9	5 (22%)	10 (44%)	4 (17%)	4 (17%)	0	0	23
>/= 4	1 (2%)	18 (41%)	15 (33%)	9 (20%)	2 (4%)	0	45
Total	8 (10%)	32 (43%)	20 (27%)	13 (17%)	2 (3%)	0	75

1. Early Postoperative Facial Function

Of the 77 patients in whom the facial nerve was preserved both anatomically and electrophysiologically, size of the tumor was not available in 2 patients. Of the remaining 75 patients, good facial function was seen in the early postoperative period in 40 patients (53%) and poor in 35 (47%) Table 5.

Of the 75 patients, there were only 7 patients (9%) with tumor size less 3 cm and among them 6 patients (86%) had good and 1 patient had poor facial nerve function. There were 23 patients (31%) with tumor size ranging from 3 – 3.9 cm and among them 15 patients (66%) had good and, 8 patients (34%) had poor facial nerve function. In the remaining 45 patients (60%) tumor size was >/= 4 cm and among them 19 patients (43%) had good and 26 patients (57%) had poor facial nerve (Table 5).

In the 9 patients in whom the facial nerve was anatomically preserved but there were no electrophysiological responses, 1 patient (11 %) had good function and 8 patients (89 %) had poor function.

2. Long Term Facial Nerve Outcome

Of the 77 patients in whom the facial nerve was preserved anatomically and electro physiologically, 59 patients had long term follow up ranging from 3 months to 6 years. These 59 patients were analyzed separately. We noted 44 patients (75%) with good function and 15 patients (25 %) with a poor facial function. So the long term facial nerve functional preservation rate was 75 % (Table 6).

In the 9 patients in whom the facial nerve was anatomically preserved but there were no electrophysiological responses, 4 (44 %) had good and 4 patients (44 %) had poor long term facial function outcome and 1 patient had no follow up.

(Table 6)

Long term facial nerve functions in 59 patients according to tumor size

Size of tumor (cm)	House and Brackmann (Long term follow up)						Total
	Grade I	Grade II	Grade III	Grade IV	Grade V	Grade VI	
< 3	5 (83%)	1 (17%)	0	0	0	0	6 (10%)
3 - 3.9	9 (50%)	5 (28%)	1 (5%)	3 (17%)	0	0	18 (30%)
>/= 4	9 (26%)	15 (43%)	5 (14%)	6 (17%)	0	0	35 (60%)
Total	23 (40%)	21 (35%)	6 (10%)	9 (15%)	0	0	59

Significance of Immediate Facial Function

Immediate postoperative facial nerve function was significant in predicting final facial nerve outcomes in this study. If the immediate facial nerve function was Grade I to II, this had 68.18 % sensitivity, a 100 % specificity, a 100 % positive predictive value (PPV), and an 51.7 % negative predictive value in predicting long term facial function

(Table 7). In other words, a patient with poor facial function in the immediate postoperative period, had only a 49.3 % chance of good long term facial function.

(Table 7)

Final facial nerve outcome as it relates to immediate postoperative facial nerve function in 59 patients.

House and Brackmann	Final Facial Nerve Function (Grade I – II)	Final Facial Nerve Function (Grade III – VI)	Total
Initial Facial Nerve Function (Grade I – II)	30	0	30
Initial Facial Nerve Function (Grade III – VI)	14	15	29
Total	44	15	59

Significance of electrophysiological response to the long term facial function outcome :

As mentioned above, the facial nerve was anatomically preserved in 86 patients (86%) but the electrophysiological responses were obtained from the root entry zone in only 77 patients (77%). In 9 patients the facial nerve was only anatomically preserved but no electrophysiological responses were obtained. We had a total follow up of 67 patients (59 among electrophysiological response group and 8 among the later).

Analysis of these two groups showed that the presence of electrophysiological response in the root entry zone had 91.66 % sensitivity, 21.05 % specificity, 74.57 % positive predictive value, and 50 % negative predictive value in predicting long term facial function (Table 8). In other words, if a patient has electrophysiological response, there is 74.57 % chance that he or she will have a good long term facial function. In contrast, a patient with no electrophysiological response has a 50 % chance of having a good long term facial function if the seventh nerve was anatomically preserved.

(Table 8)

Electrophysiological response	House and Brackmann (Long term outcome)		Total
	Good	Poor	
Yes	44	15	59
No	4	4	8
Total	48	19	67

Compound Muscle Action Potential (CMAP) Amplitude vs Long term Facial Function Outcome

In the 51 patients in whom complete intraoperative stimulation parameters were available; the mean of CMAP amplitude after proximal stimulation (Root entry zone) was 136.28 mV for patients with good postoperative facial nerve function. These values decreased with increasing facial nerve damage, 119.96 mV in poor postoperative facial nerve function outcome patients, exhibiting a direct inverse correlation with facial nerve function assessed 1 week and more than three months after surgery (Table 9). But statistically, there was no correlation with p value of 0.33 (Logistic regression analysis).

(Table 9)

House & Brackmann	Mean CMAP Ampl (micro volts)	No. of patients	P value
I / II	136.28	38	0.33
III/IV/V/VI	119.96	13	

Proximal to distal amplitude ratio was analysed and we found no statistically significant correlation with the facial nerve outcome (p = 0.651 , Logistic regression analysis) Table 10.

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(Table 10)

Proximal (REZ) to distal (Porus) amplitude ratio vs long term facial nerve function outcome in 51 patients :

Sl. No.	Case No.	Amp REZ	Amp Porus	Proximal to Distal Amp Ratio (REZ/Porus)	7th HB grade Postop 1 week	7th HB grade Postop long term f/u	p value
1	1	56.4	53.8	1.05	4	4	0.651
2	2	81.1	36.2	2.24	2	2	
3	7	28.7	28.3	1.01	3	2	
4	10	77.1	92	0.84	3	2	
5	12	98.6	101.1	0.98	3	3	
6	15	154	198	0.78	2	1	
7	16	36.2	50.3	0.72	2	1	
8	18	81.3	21.3	3.82	2	1	
9	19	28.3	31.2	0.91	2	1	
10	24	36.3	112	0.66	4	3	
11	25	155	162	0.96	3	1	
12	26	464	498	0.93	1	1	
13	27	70.4	119	0.59	3	1	
14	29	186	196	0.95	2	1	
15	31	201	207	0.97	4	3	
16	34	85.6	278	0.31	2	1	
17	36	242	211	1.15	1	1	
18	38	253	162	1.56	2	1	
19	39	79.2	98.8	0.8	2	1	
20	42	157	213	0.74	2	2	
21	43	137	88.2	1.55	3	2	
22	44	17.5	15.8	1.11	2	1	
23	45	10.6	70.8	0.15	5	2	
24	48	86.7	210	0.41	2	2	
25	52	42.1	45.6	0.92	4	4	
26	54	95.9	122	0.79	4	4	
27	55	138	165	0.84	2	1	
28	57	227	241	0.94	2	2	
29	59	61.8	92.7	0.67	3	3	
30	60	50.2	48.2	1.04	4	4	
31	61	41.3	95.3	0.43	2	1	
32	65	110	363	0.3	2	1	
33	68	225	185	1.222	3	2	

34	74	83.6	102.1	0.82	4	4	
35	76	26.7	36.5	0.73	3	2	
36	77	67.5	91.7	0.74	3	2	
37	78	83.4	102.5	0.81	4	4	
38	80	208	195	1.07	2	1	
39	81	78.4	81.7	0.96	4	2	
40	83	80.6	84.7	0.95	2	1	
41	85	72.7	98.7	0.74	2	2	
42	86	28.5	29.1	0.98	2	1	
43	87	59.7	72.5	0.82	3	1	
44	88	81.6	88.7	0.92	3	2	
45	89	89.6	98.6	0.91	2	2	
46	90	72.4	92.7	0.78	2	2	
7	91	71.2	69.8	1.02	2	2	
48	93	57	78.8	0.72	5	4	
49	95	370	800	0.46	3	3	
50	97	52.5	64.4	0.82	3	2	
51	100	52.9	40.3	1.31	3	4	

Compound Muscle Action Potential (CMAP) Latencies vs Facial Outcome

The mean **v**alue of CMAP latency after proximal stimulation (Root entry zone) was 9.89 msec for patients with good postoperative facial nerve function and 9.90 msec in patients with poor postoperative facial nerve function (Table 11). Statistical analysis showed no significant correlation with the facial nerve outcome, p value of 0.77 (Logistic regression analysis) .

(Table 11)

House & Brackmann	Mean Latency (msec)	No. of patients	p value
I / II	9.89	38	0.77
III/IV/V/VI	9.90	13	

Proximal to distal latency ratio was analysed and we found no significant correlation with the facial nerve outcome (p = 0.715 , Logistic regression analysis) Table 12.

(Table 12)

Proximal (REZ) to distal (Porus) latency ratio vs long term facial nerve function outcome in 51 patients :

S.No	Case No.	Latency REZ	Latency Porus	Proximal to distal latency ratio (REZ/Porus)	7th HB grade Postop 1 week	7th HB grade Postop long term f/u	p value
1	1	7.2	6.5	1.11	4	4	0.715
2	2	20.4	16.2	1.26	2	2	
3	7	6.7	6.8	0.99	3	2	
4	10	14.1	9.8	1.44	3	2	
5	12	8.1	6.8	1.19	3	3	
6	15	9.2	6.4	1.44	2	1	
7	16	13.7	9.7	1.41	2	1	
8	18	7	6	1.67	2	1	
9	19	7.3	6.5	1.12	2	1	
10	24	13.5	11	1.23	4	3	
11	25	6.5	5.5	1.18	3	1	
12	26	11.2	9.3	1.2	1	1	
13	27	8.6	6.7	1.28	3	1	
14	29	6.8	5.6	1.21	2	1	
15	31	9.1	5.6	1.63	4	3	
16	34	8.7	6.8	1.28	2	1	
17	36	9.3	7.3	1.27	1	1	
18	38	9	6.7	1.34	2	1	
19	39	7.6	6.5	1.17	2	1	
20	42	6.2	5.2	1.19	2	2	
21	43	11	7.5	1.47	3	2	
22	44	10.8	8.9	1.21	2	1	
23	45	9.3	6.9	1.35	5	2	
24	48	9.2	5.7	1.61	2	2	
25	52	8.9	7.1	1.25	4	4	
26	54	8.7	6.3	1.38	4	4	
27	55	7.7	6.4	1.2	2	1	
28	57	9.7	7.5	1.29	2	2	

29	59	10.8	9.5	1.14	3	3	
30	60	8.2	6.2	1.32	4	4	
31	61	10.1	6.4	1.58	2	1	
32	65	9.4	6.1	1.54	2	1	
33	68	7.2	6.2	1.16	3	2	
34	74	8.9	5.1	1.75	4	4	
35	76	5.9	5.2	1.13	3	2	
36	77	9.1	5.7	1.6	3	2	
37	78	9.8	9.1	1.08	4	4	
38	80	6.5	5.7	1.14	2	1	
39	81	8.9	8.2	1.09	4	2	
40	83	7	6.2	1.13	2	1	
1	85	10.5	9	1.17	2	2	
42	86	8.7	7.9	1.1	2	1	
43	87	8.38	7.9	1.06	3	1	
44	88	9.2	8.1	1.14	3	2	
45	89	7.9	6.4	1.23	2	2	
46	90	8.1	7.2	1.13	2	2	
47	91	7.2	6.5	1.11	2	2	
48	93	12.6	7.5	1.68	5	4	
49	95	8.3	6.7	1.24	3	3	
50	97	8.5	8	1.06	3	2	
51	100	9.7	9.1	1.07	3	4	

1. TUMOR SIZE vs FACIAL NERVE FUNCTION OUTCOME

There were 59 patients in whom the tumor size and the long term facial nerve function outcomes were available. There were only 6 patients in whom the tumor size was less than 3 cm and all of them had good facial nerve function outcome. There were 18 patients whose tumor size were between 3 and < 4 cm and out of them 14 patients had good and 4 patients had poor facial nerve function outcome. There were 35 patients in whom the tumor size was equal to more than 4 cm (termed as “giant vestibular schwannomas”) and out of them 24 patients had good and 11 patients had poor facial nerve function outcome (Table 13and Fig.5). Statistically there was no significant correlation between the size of the tumor and the long term facial nerve function outcome (p = 0.822).

(Table 13)

Tumor size vs Postoperative long term facial nerve function outcome in 59 acoustic neurinoma patients.

House and Brackmann Grade	Tumor Size		
	Small (< 3 cm)	Medium (3 - 3.9 cm)	Giant (> / = 4 cm)
I / II	6 (100%)	14 (78%)	24 (69%)
III / IV /V / VI	0	4 (22%)	11 (31%)
Total	6	18	35

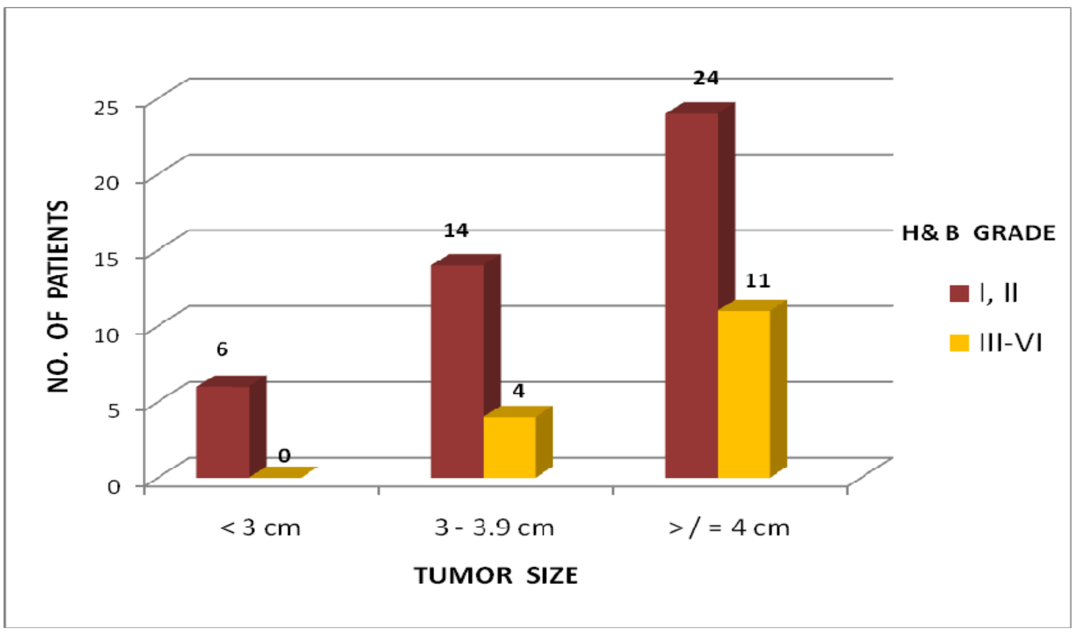


Fig.5 Tumor size vs Postoperative long term facial nerve function outcome in 59 acoustic neurinoma patients:).

2. BRAINSTEM DISTANCE vs FACIAL NERVE FUNCTION OUTCOME

There were 59 patients in whom the brainstem distance and long term facial nerve function outcomes were available. There were 13 patients in whom the brainstem distance was less than or equal to 2 cm and out of them 10 patients had good and 3 patients had poor facial nerve function outcome in the long term postoperative period.

There were 46 patients with the brainstem distance more than 2 cm and out of them 34 patients had good and 12 patients had poor facial nerve function outcome in the long term postoperative period (Table 14 & Fig. 6). Statistically there was no significant correlation between the brainstem distance and the long term facial nerve function outcome (p = 0.131, Logistic regression analysis).

(Table 14)

Brainstem distance vs postoperative facial nerve function outcome in 59 acoustic neuroma patients

House and Brackmann Grade	Brainstem Distance	
	< /= 2 cm	> 2 cm
I / II	10	34
III / IV / V / VI	3	12
Total	13	46

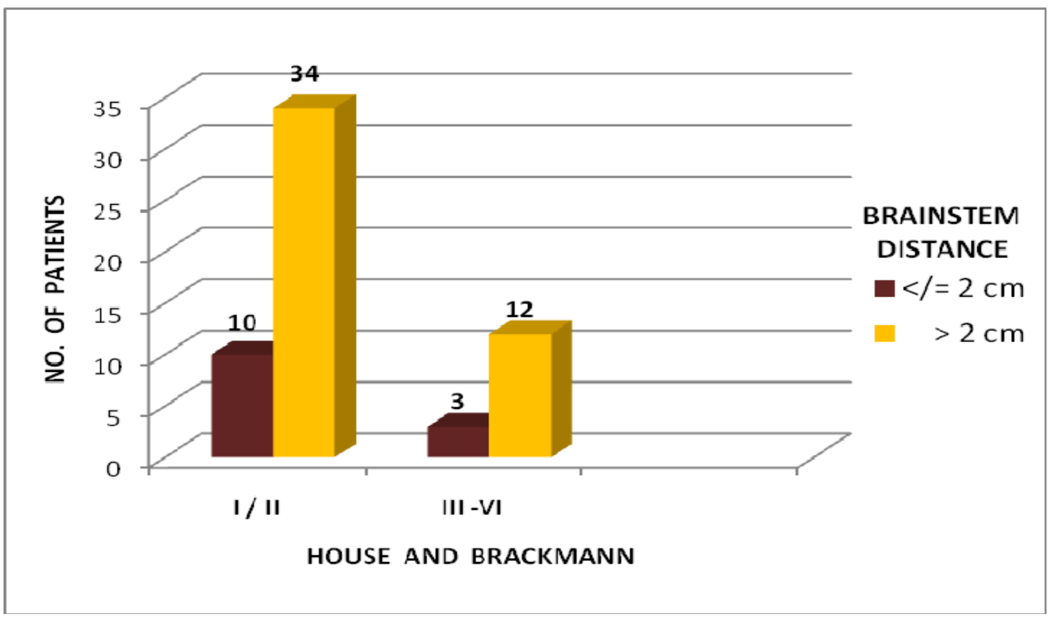


Fig. 6 Brainstem distance vs Postoperative facial nerve function outcome in 59 acoustic neuroma patients.

3. PORUS SIZE vs FACIAL NERVE FUNCTION OUTCOME

There were 59 patients in whom the porus size and long term facial nerve function outcomes were available. There were 23 patients in whom the porus size was less than 1 cm and out of them 18 patients had good and 5 patients poor facial nerve function outcome in the long term postoperative period. There were 36 patients with the porus size was more than or equal to 1 cm and out of them 26 patients had good and 10 patients had poor facial nerve function outcome in the long term postoperative period (Table 15 / Fig. 7). Statistically there was no significant correlation between the porus size and the long term facial nerve function outcome ($p = 0.220$, Logistic regression analysis).

(Table 15)

Porus size vs Postoperative facial nerve function outcome in 59 acoustic neurinoma patients.

House and Brackmann Grade	**Porus Size**	
	< 1 cm	**> / = 1 cm**
I / II	18	26
III / IV /V / VI	5	10
Total	23 (39%)	36 (61%)

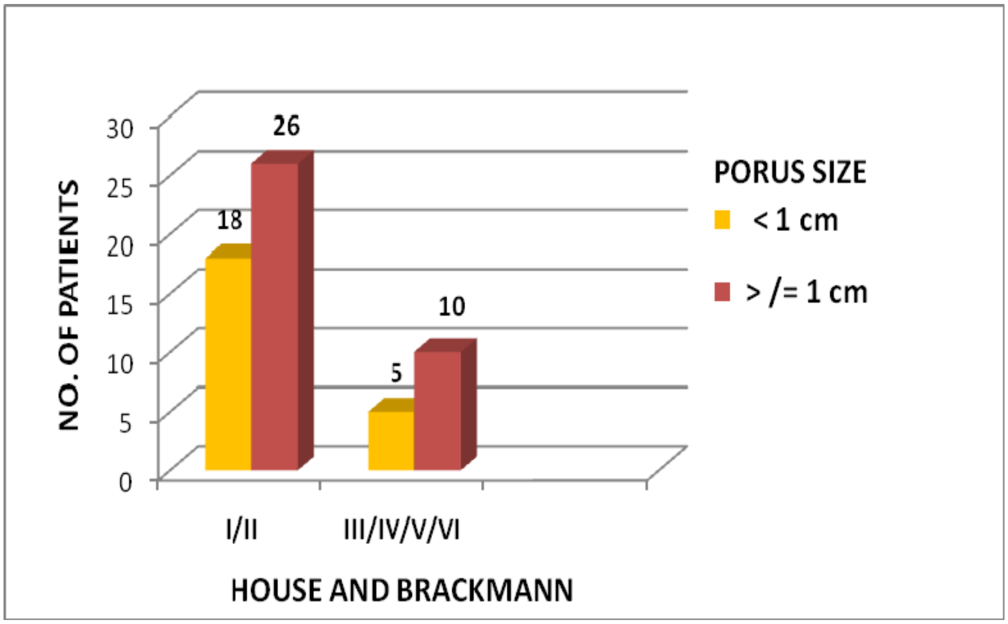


Fig. 7 Porus size vs Postoperative facial nerve function outcome in 59 acoustic neurinoma patients

4. FACIAL NERVE LENGTH vs FUNCTIONAL OUTCOME

Out of the total 58 patients with long term follow up, 53 patients had facial nerve length documented. So, we analyzed these 53 patients. There were 3 patients (5%) in whom the facial nerve length was less than or equal to 2 cm and out of them 2 patients had good and 1 patient had poor facial nerve function outcome in the long term postoperative period. There were 50 patients (95%) with the facial nerve length more than 2 cm and out of them 38 patients had good and 12 patients had poor facial nerve function in the long term postoperative period (Table 16/ Fig. 8). Statistically there was no significant correlation between the facial nerve length and the long term facial nerve function outcome (p= 0.641, Logistic regression analysis).

(Table 16)

Facial nerve length vs Postoperative facial nerve function outcome in 53 acoustic neurinoma patients.

House and Brackmann Grade	Facial Nerve Length	
	< / = 2 cm	> 2 cm
I / II	2	38
III / IV / V /VI	1	12
Total	3 (5%)	50 (95%)

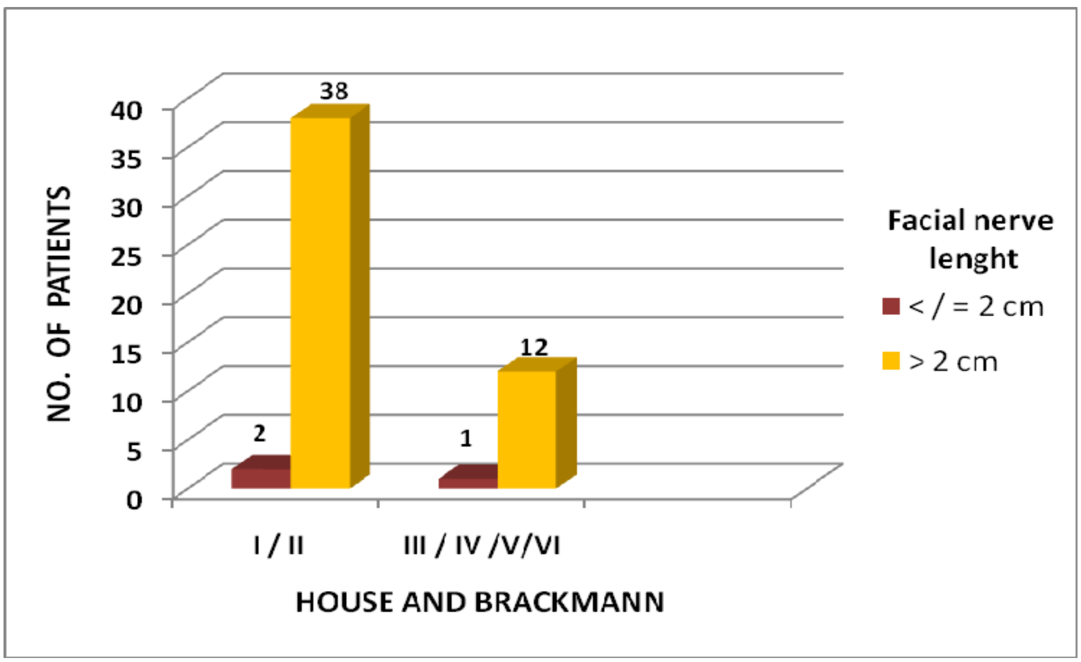


Fig. 8 Facial nerve length vs Postoperative facial nerve function outcome in 53 acoustic neurinoma patients.

5. SOLID / CYSTIC TUMORS vs FACIAL NERVE FUNCTION OUTCOME

Out of the total 59 patients with long term follow up, tumor was predominantly solid in 54 patients and out of them 40 patients had good and 14 patients had poor facial nerve function outcome in the long term postoperative period. There were 5 patients with tumor predominantly cystic and out of them 4 patients had good and only 1 patient had poor facial nerve function outcome in the long term postoperative period (Table 17 / Fig 9). Statistically there was no significant correlation between the solid and cystic nature of tumor with the long term facial nerve function outcome ($p = 0.518$, Logistic regression analysis).

Tumor consistency vs Postoperative facial nerve function outcome in 59 acoustic neurinoma patients. (Table 15).

House and Brackmann Grade	SOLID	CYSTIC
I / II	40	4
III / IV / V / VI	14	1
Total	54 (92%)	5 (8%)

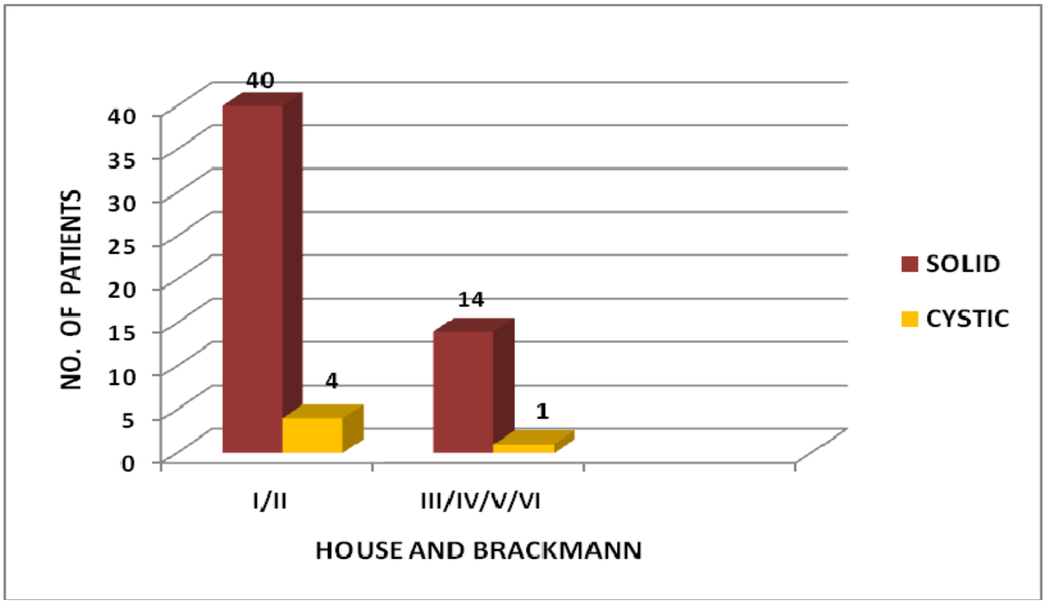
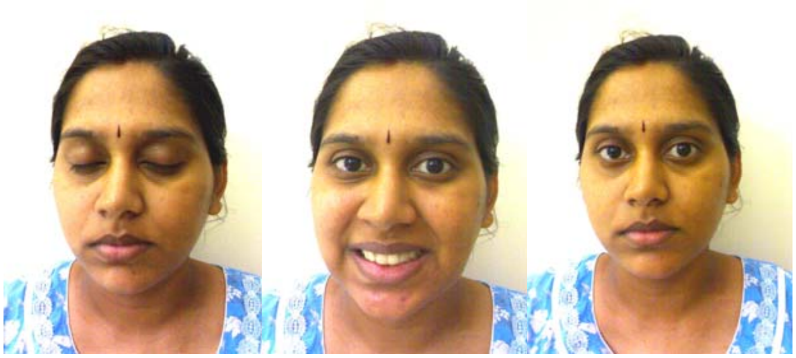
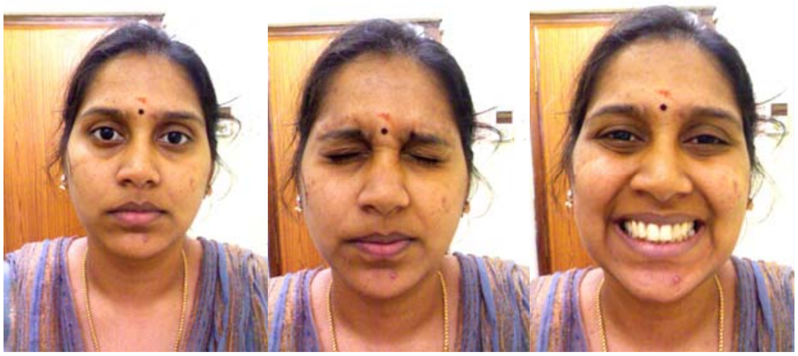


Fig. 9Tumor consistency vs Postoperative facial nerve function outcome in 59 acoustic neurinoma patients.

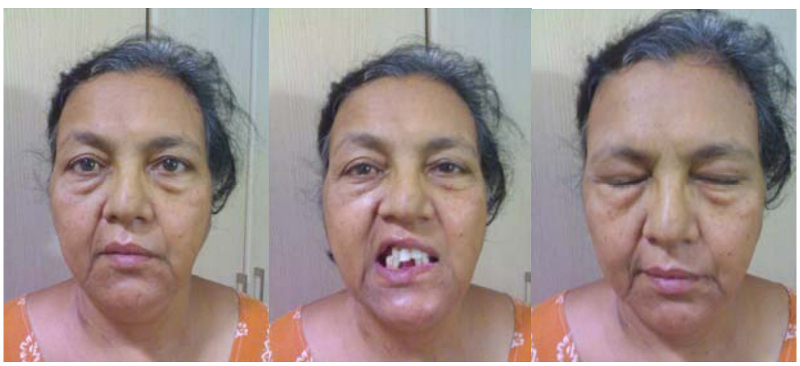


Grade II



Grade I

Fig.10 Patient with left-sided acoustic tumor 1wk after total excision and 1 year later.



Grade II

Grade I

Fig.11 Patient with left-sided acoustic tumor 1wk after total excision and a year later.

Grade II

Grade II

Fig.12 Patient with right-sided acoustic tumor 1wk after total excision and 7 months later.

Grade III

Grade III

Fig.13 Patient with right-sided acoustic tumor 1wk after total excision and 3 months later.


Grade III


Grade II

Fig.14 Patient with left-sided acoustic tumor 1wk after total excision and 4 months later.


Grade IV


Grade III

Fig.15 Patient with left-sided acoustic tumor 2wks after total excision and 1 year later.

Grade V

Grade V

Fig.16 Patients with right-sided acoustic tumors 8 months after total excision.

DISCUSSION

DISCUSSION

Intraoperative monitoring has greatly enhanced the surgeons ability to preserve both anatomic and functional integrity of cranial nerves. The morbidity of cerebellopontine angle surgery has significantly decreased (40, 41). With the introduction of intraoperative monitoring the functional preservation of the facial nerve has improved from 77% to 95% (48, 36). The immediate feedback offered by the use of intraoperative facial nerve monitoring greatly enhances the surgeon's ability to modify the dissection for maximal preservation of function.

An association between initial and final facial nerve function after the excision of acoustic neuromas has been established in the literature. In a study by Arriaga, et al. 1993 (44) in 515 patients showed 99% of patients with good initial facial nerve function had good final facial nerve function postoperatively. 73% of patients with fair initial function had good final facial nerve function, and in 28% final facial nerve function remained fair. 25% of patients with poor initial facial nerve function postoperatively had good, 52% had fair, and 23% had poor final facial nerve function.

Our results are similar (Table 16), 100% of the patients with good initial facial nerve function had good final facial nerve function postoperatively. 48% of patients with poor initial facial function postoperatively had good outcome and remaining 52% had poor final facial nerve function in the long term. So, based on the initial facial nerve function postoperatively, the surgeon can estimate final facial nerve function but cannot predict which patient will have facial nerve recovery to what degree.

(Table 16)

Final facial nerve outcome as it relates to initial postoperative facial nerve function in 59 patients.

Initial Facial NerveFunction (1week)		Final Facial Nerve Function (> 3 months)	
Good (I-II)	Poor (III-VI)	Good (I-II)	Poor (III-VI)
30	0	30 (100%)	0
0	29	14 (48%)	15 (52%)
30	29	44	15

Facial Nerve Preservation

The preservation of facial nerve has always been considered to be a primary concern in acoustic neuroma surgery, particularly in patients with a large tumor, in whom the nerve is usually adherent to the surface of the tumor. Table 4 summarizes the facial nerve functional preservation rate of tumors of various size ranges from a number of studies. Direct comparison between the studies should be made only with extreme caution, because the number of cases, experience of surgeons over the course of the reported series, methods used to measure tumor size, use of intraoperative monitoring, and criteria for choosing the approach are not necessarily equivalent across studies. The anatomical preservation of the facial nerve is not equivalent to functional preservation. For acoustic neuromas, the larger the tumor size, the more difficult it is to maintain the integrity of the facial nerve (73). Criteria for preservation of facial nerve function may differ from one study to another. Where possible we have presented the percentage of patients achieving a House and Brackmann Grade II or better as an acceptable functional outcome. Frequently, results were not reported for size categories. In addition, procedures performed before and after the advent of facial nerve monitoring were often combined. Thus, the comparisons between the listed studies must be made only with caution. The functional preservation rate was 80 -100% in tumor size less than 2 cm and 56 – 100% in tumor size between 2 to 4 cm. But there was a wide range 20 – 85 % in the rate of functional preservation in tumor size more than 4 cm. In our study we found 100%

functional preservation rate in tumor size less than 3 cm and 78% functional preservation rate in the tumor size range 3 to < 4cm and 69% in those with giant vestibular schwannomas (>/ = 4cm) (Table 13).

Predictive Value of Electrophysiological Studies

There have been several reports of utilizing intraoperative facial nerve monitoring parameters to predict facial nerve outcomes (Table 3). In our study we look into the absolute values of compound muscle action potential amplitudes and latencies at root entry zone, and proximal to distal amplitude and latency ratios. Review of literature of utility of intraoperative facial nerve monitoring parameters to predict facial nerve outcomes revealed that proximal to distal amplitude ratio was the most powerful parameter for intraoperative assessment of postoperative facial nerve function (40, 48, 56, 57, 53). However, in our study we could not establish any correlation between the compound muscle action potential amplitudes and latencies at root entry zone and proximal to distal amplitude and latency ratios to the initial and long term facial nerve function outcome. A few possibilities of not getting a correlation might be 1) Wrong identification of root entry zone, or 2) Interobserver variability in assessing House and Brackmann grading of facial function. But various studies has shown high inter-observer reliability (93%) of House and Brackmann grading system for facial function(76).

In our study we found that there was a tendency to get a higher CMAP amplitude (136.28 mV) in patients with good facial function outcome as compared to the poor outcome ones (119.96 mV). But there was no statistical correlation. It might be due to very few number of patients with poor facial function outcome (only 13 out of 51 patients) (Table 9).

Parameters other than intraoperative monitoring have also been analyzed in our study. Brainstem distance (horizontal distance from anterior lip of internal acoustic meatus to the brainstem on the MRI), consistency of the tumor (predominantly solid or cystic), size of the porus (distance between the medial and lateral lip of internal acoustic meatus) and facial nerve length (measured intraoperatively from the porus to the root entry zone) in relation to long term facial nerve function outcome. None of these parameters has been analysed before our study. Statistical analysis of these parameters failed to correlate to the initial and long term facial nerve function outcome.

There were 9 patients in whom the facial nerve was anatomically preserved but there were no electrophysiological responses. Functionally in the immediate and early postoperative period 1 patient (11 %) had good function and 8 patients (89 %) had poor function. In the long term follow up, out of these 9 patients, 4 (44 %) had good facial function and 4 patients (44 %) had poor facial function and 1 patient had no follow up. Perhaps this can be explained by neurapraxia or axonotomesis where neural conduction improves spontaneously or by regeneration after the injury. This shows that if the facial nerve is anatomically preserved but electro physiologically not preserved, there is still a very good chance (50%) of functional preservation of facial nerve in the long term follow up (Table 8).

CONCLUSION

CONCLUSION

While a positive response to facial nerve stimulation at the end of a vestibular schwannoma surgery is a good predictor of long term postoperative facial nerve function, the absence of responses did not mean that the function would be poor. Our functional preservation rate was 75%.

Proximal-to-distal amplitude and latency ratios did not correlate with the final facial nerve function.

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ANNEXURES

PROFORMA - (ANNEXURE I)

Unit:	1	

Serial Number:	Hospital Number :
Name:	Age: Gender:
Address:	

Phone Number/ Email:

Date of Surgery: ______ Size of Tumor (Largest dimension): ______

Duration of Symptoms: ______

Brain Stem Distance: ______
(Horizontal Length to the Brain Stem)

Predominantly cystic Yes / No	Porus Size=

Extent of excision:

Subtotal = 1
Total = 2
Partial = 3

7^{th} H & B Grade

Preop	Postop 1 Week	Postop followup

Tarsorrhaphy:

Y	N

Followup Duration ______

7^{th} saved Yes / No

Responses at REZ Yes / No

Responses at porus Yes / No

Facial nerve stimulation at end of surgery	Minimum Current (mA)	Amplitude (microV)	Latency (msec)
REZ			
Porus			

Facial Nerve length (cm) ______

HOUSE AND BRACKMANN GRADING OF FACIAL NERVE FUNCTION

Grade I - Normal.

Grade II - Mild dysfunction.

Gross: Slight weakness on close inspection.
May have slight synkinesis
At rest, normal tone and symmetry.

Motion : Forehead moderate to good function
Eye closure complete with minimal effort
Mouth slight asymmetry.

Grade III – Moderate dysfunction

Gross: Noticeable but not disfiguring difference between the two sides, noticeable but not severe synkinesis, hemi-facial spasm, contracture or both
Normal tone and symmetry at rest.

Motion: Moderate function of forehead
Eye closure complete with effort
Mouth, slightly weak with maximal effort

Grade IV – Moderately severe dysfunction

Gross: Obvious weakness/ disfiguring asymmetry at rest.
Normal tone and symmetry at rest.

Motion: Forehead none, eye closure incomplete with maximal effort, mouth asymmetric with maximal effort

Grade V – Severe dysfunction

Gross: Barely perceptible motion, asymmetry at rest.

Motion: Forehead none, eye closure incomplete mouth slight movement.

Grade VI – Total paralysis.

MASTER TABLE (ANNEXURE II)

Case No.	Age/ Gender	Largest diameter (cm)	Brainstem distance (cm)	Predominantly cystic	Porus size / cm	Extent of excision	7th HB grade Preop	7th HB grade Post op 1 week	7th HB grade Long term follow up	7th saved	Response at REZ	Response at porus	Facial nerve length / cm	Current strength REZ / mA	Amp1 REZ / micro V	Amp 2 REZ / micro V	Amp 3 REZ /micro V	Lat 1 REZ / m sec	Lat 2 REZ / m sec	Lat 3 REZ / m sec	Current strength Porus / mA	Amp 1 Porus / micro V	Amp 2 Porus / micro V	Amp 3 Porus / micro V	Lat 1 Porus / m sec	Lat 2 Porus / m sec	Lat 3 Porus / m sec
1	26M	3.2	2.1	No	0.4	T	I	IV	IV	Yes	Yes	Yes	2.7	0.1	56.4	38.6	81.7	8.4	7.8	7.2	0.1	53.8	49.6	123.5	8.1	7.2	6.5
2	40F	4.1	2.29	No	1.5	S	II	II	II	Yes	Yes	Yes	2.6	0.1	81.1	16.2	75.4	20.4	15.2	14.4	0.1	36.2	20.9	74.2	16.2	16.8	13.7
3	33F	4.2	2	No	0.5	T	II	II	No FU	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
4	50F	No film in PACS	#	No	#	S	II	IV	III	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	0.1	0.1	ND	ND	ND	ND	ND	ND
5	48M	4.2	3.4	No	1.2	T	II	IV	NO F/U	Yes	Yes	Yes	3.5	0.1	37.7	41.8	170.2	14.2	11.2	11.2	0.1	206	233	240	9.3	7.9	10.1
6	41M	4	2.9	No	1	T	II	II	NO F/U	Yes	Yes	Yes	3	0.1	228	57.3	53.2	7.3	6.5	6.6	0.1	238	60.1	139	6.1	5.5	5.2
7	41M	3.9	3.3	No	1	T	II	III	II	Yes	Yes	Yes	3	0.1	28.7	13.3	10.5	8.4	6.7	6.7	0.1	28.3	14.4	27.6	9.5	6.8	7.4
8	44M	4.6	3.1	No	0.8	T	II	II	NO F/U	Yes	Yes	Yes	1.5	0.1	220	68.4	24.2	10.7	8.3	7	0.1	164	62.2	33.5	10.3	7.8	6.8
9	24M	2.8	1.2	No	1	T	II	IV	IV	7th not seen	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
10	45F	4.2	1.6	No	0.8	T	II	III	II	Yes	Yes	Yes	2.8	0.1	80.2	77.1	28.5	14.9	15.1	14.1	0.1	234	92	94.8	10.5	12.5	9.8
11	41M	4.4	3	No	1.2	T	II	II	NO F/U	Yes	Yes	Yes	1.8	0.1	48.8	28.1	15.1	7.9	11	14.3	0.1	50.7	39.2	56.7	7.1	10.8	14
12	19M	6	2.6	No	0.6	T	I	III	III	Yes	Yes	Yes	3.5	0.1	47.9	10.5	98.6	10.4	7	8.1	0.1	61.5	45.1	101.1	10.1	6.5	6.8
13	45F	4	2.8	No	0.4	T	II	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
14	14M	3	1.5	No	0.4	T	I	III	II	Yes	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0

15	42F	3.7	2.9	Yes	1	T	I	II	I	Yes	Yes	Yes	3.5	0.1	62.5	22.8	154	7.5	9.2	7.7	0.1	137	41.7	198	6.8	6.4	6.1
16	42M	4.2	2.5	No	0.8	T	II	II	I	Yes	Yes	Yes	3	0.1	9.07	36.2	33.2	13.7	11.5	17.2	0.1	39	50.3	85	9.7	10.6	14
17	47F	3.2	2.2	No	0.9	T	I	III	NO F/U	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
18	36M	2.5	2.4	No	1.2	T	I	II	I	Yes	Yes	Yes	3.4	0.1	94.8	81.3	71.8	11	10.8	7	0.1	60.5	21.3	85.3	9.2	6.7	6
19	51F	4.3	2.6	Yes	1	T	II	II	I	Yes	Yes	Yes	2.4	0.1	28.3	31.7	95.2	8.6	8.2	7.3	0.1	31.2	48.6	116.2	8.2	7.9	6.5
20	33F	3.1	2.4	No	1.3	S	I	III	III	Yes	Yes	No	ND	0.1	68.5	72.6	206.8	7.6	8.2	6.9	0.1	0	0	0	0	0	0
21	37M	4.4	3.8	No	1.1	T	I	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
22	28F	4.5	2.8	No	1	P	III	III	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
23	49F	3	1.2	No	0.5	T	I	I	I	Yes	Yes	Yes	2.2	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
24	32M	5.3	2.7	No	1	T	I	IV	III	Yes	Yes	Yes	3	0.1	27.2	36.3	80.3	14.6	13.5	11	0.1	112	55.4	198	12.8	11	10.4
25	27M	4	3.2	No	1.1	T	II	III	I	Yes	Yes	Yes	2.6	0.1	155	110	234	7.3	6.6	6.5	0.1	162	253	298	6.8	5.9	5.5
26	36F	3.2	1.6	No	0.6	T	I	I	I	Yes	Yes	Yes	2.6	0.1	25.1	25.5	464	6.7	11.2	6.4	0.1	56.2	69.1	498	5.9	9.3	5.6
27	52M	2.5	1.25	No	0.4	T	I	III	I	Yes	Yes	Yes	2.7	0.1	120	123	70.4	8.6	10.3	11.4	0.1	234	244	119	6.7	9	10.3
28	53M	5.6	4	No	1.8	S	II	II	II	Yes	Yes	Yes	2.5	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
29	55F	3.2	1.8	No	0.7	T	II	II	I	Yes	Yes	Yes	2.5	0.1	174	22.1	186	7.7	11.2	6.8	0.1	245	28.5	196	7.1	10.5	5.6
30	40M	4	2.5	Yes	0.6	T	II	III	I	Yes	No	No	2.2	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
31	25F	4.6	3.4	No	1.1	T	II	IV	III	Yes	Yes	Yes	3.2	0.1	87.3	28.8	201	7	9.1	6.1	0.1	264	135	207	5.4	5.6	5.1
32	33F	5.3	1.8	No	1	T	II	IV	NO F/U	Yes	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
33	22M	5	3	No	1.2	T	I	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
34	35M	4.1	3.2	Yes	1	T	II	II	I	Yes	Yes	Yes	3	0.1	85.6	50.8	68.9	8.7	7.9	7.7	0.1	278	212	251	6.8	6.4	6.2
35	36M	4.8	2.4	No	0.4	T	II	III	NO F/U	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
36	48F	2.5	1.2	No	0.9	T	I	I	I	Yes	Yes	Yes	1.3	0.1	103	46.3	242	9.3	7.6	6.2	0.1	92.2	75.5	211	7.3	7.2	5.1
37	55M	5.6	4.4	No	1.6	T	II	II	NO F/U	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
38	25F	3.8	2.5	No	0.8	T	II	II	I	Yes	Yes	Yes	2.7	0.1	253	65	427	6.5	9	7.3	0.1	162	75.5	486	6.2	6.7	6.5
39	59M	3.2	2.6	No	0.8	T	II	II	I	Yes	Yes	Yes	2.5	0.1	79.2	58.9	116	9.5	8.2	7.6	0.1	98.8	76.4	254.1	8.6	7.4	6.5
40	41M	6.5	2.5	No	0.9	T	II	VI	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0

41	25F	3.6	3.1	No	1.5	T	II	I	NO F/U	Yes	Yes	Yes	2.9	0.1	93.1	39.1	350	9.8	8.5	6.3	0.1	198	54.5	402	8	7.3	6.1
42	44F	3.1	1.7	No	0.8	T	II	II	II	Yes	Yes	Yes	2.5	0.1	92.5	182	157	5.7	5.6	6.2	0.1	213	314	213	5.1	5.4	5.2
43	39F	4.4	3.3	No	1.9	T	II	III	II	Yes	Yes	Yes	2.8	0.1	109	137	95.4	11	9.4	8.3	0.1	158	88.2	220	7.5	7.4	6.5
44	58F	3.4	2.2	No	1.3	T	I	II	I	Yes	Yes	Yes	2.3	0.1	62.5	10.6	17.5	9.1	10.8	9.4	0.1	63.8	14.5	15.8	7.8	8.9	9.2
45	52M	4	2.3	No	0.5	T	II	V	II	Yes	Yes	Yes	2.6	0.1	0	0	10.6	0	0	9.3	0.1	95.2	61.6	70.8	7.5	7.7	6.9
46	27F	4	3.4	No	1.6	S	II	III	NO F/U	Yes	Yes	Yes	2.2	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
47	42M	4.7	3.3	No	0.8	T	III	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
48	22M	6.3	4	No	1.2	S	II	II	II	Yes	Yes	Yes	3.6	0.1	47.2		86.7	10.4	8.3	9.2	0.1	242	151	210	6.6	5.8	5.7
49	59M	4.4	1.9	No	0.5	T	I	I	I	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
50	57F	4	3	No	1.2	T	II	III	II	Yes	Yes	Yes	2.5	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
51	29M	NO SC ALE	#	No	#	S	II	IV	NO F/U	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
52	56F	4.4	3.2	No	1	T	I	IV	IV	Yes	Yes	Yes	3	0.1	62.3	42.1	10.2	8.9	8.1	8.6	0.1	93.7	45.6	18.8	7.1	7.5	7.3
53	45F	2.4	1.9	No	0.7	T	II	I	NO F/U	Yes	Yes	Yes	1.8	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
54	52M	4.6	4	No	1	T	I	IV	IV	Yes	Yes	Yes	2.6	0.1	39.8	39.8	95.9	8.7	7.9	8.6	0.1	88.6	101	122	6.3	7.9	6.7
55	50M	4.5	2.9	No	1.5	T	II	II	I	Yes	Yes	Yes	2.7	0.1	33.8	23.4	138	7.7	9	7.5	0.1	59.3	29.5	165	6.4	8	6.7
56	42F	2.5	1.3	No	0.4	T	I	II	I	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
57	32M	3.5	3	No	1.1	T	II	II	II	Yes	Yes	Yes	3	0.1	227	212	169	8.8	9.7	7.3	0.1	241	385	183	6.8	7.5	6.2
58	40F	4.5	3.4	No	0.6	T	II	III	NO F/U	Yes	Yes	Yes	3.5	0.1	19.1	25.8	10.2	9.6	8.9	7.3	0.1	35.4	33.2	14.6	9.4	8.6	7.1
59	16M	4.3	3.6	No	1.6	T	II	III	III	Yes	Yes	Yes	3.7	0.1	72.1	61.8	108. 5	10.8	10.6	8.2	0.1	121. 5	92.7	231. 8	9.5	9.8	8.1
60	45F	3.8	1.9	No	0.9	T	II	IV	IV	Yes	Yes	Yes	3.2	0.1	49.7	50.2	143	8.1	8.8	8.2	0.1	237	48.2	238	7.2	7	6.2
61	45F	3.5	3	No	0.6	T	II	II	I	Yes	Yes	Yes	4	0.1	41.3	31.2	27.3	8.4	9.8	10.1	0.1	95.3	81.7	110	6.9	8	6.4
62	24F	4	3.4	No	1.3	T	II	IV	NO F/U	Yes	No	Yes	2.8	0.1	0	0	11.3	0	0	9.8	0.1	150	157	94.3	13.4	11.9	9.8
63	64M	4	2.5	No	0.7	T	II	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
64	65M	4.3	2.5	No	0.8	T	II	II	II	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
65	49F	4.2	2.4	No	1	T	II	II	I	Yes	Yes	Yes	2.8	0.1	25.8	43.8	110	9.4	7.4	7.6	0.1	183	323	363	6.1	6.6	5.6

66	67F	4	1.5	No	1	T	III	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
67	23M	6	3.5	No	1	T	I	IV	III	YES	No	No	3.5	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
68	40M	3.6	2.8	No	1.5	T	II	III	II	Yes	Yes	Yes	3.3	0.1	194	225	178	7.2	5.8	6.2	0.1	241	185	215	6.2	8.5	6.5
69	32F	3.2	1.3	No	1.4	S	I	I	NO F/U	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
70	71M	3.6	2.4	No	0.6	T	I	IV	NO F/U	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
71	31M	5	2.3	No	1	T	I	IV	IV	Yes	No	No	3.5	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
72	57F	3.5	1.6	Yes	0.5	T	I	I	NO F/U	Yes	Yes	Yes	ND	0.1	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
73	45F	3	1.4	Yes	0.7	T	III	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
74	22F	4.7	3.1	No	0.8	T	II	IV	IV	Yes	Yes	Yes	2.8	0.1	83.6	92.6	75	8.9	7.9	7.8	0.1	102	228	344	5.1	5.8	5.6
75	38M	4.8	3.1	No	1.1	T	II	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
76	33M	5	2.8	No	1.2	T	II	III	II	Yes	Yes	Yes	3.2	0.1	26.7	28.4	52	6.8	7.3	5.9	0.1	36.5	61.4	102.7	6.1	6.5	5.2
77	31F	5.4	3.7	No	1.8	T	II	III	II	Yes	Yes	Yes	6.1	0.1	40.6	43.9	68	11	9.1	10	0.1	175	68.2	91.7	6.8	5.7	6.4
78	54F	3.8	3.2	No	1.4	T	II	IV	IV	Yes	Yes	Yes	4.5	0.1	83.4	56.5	93	9.8	8.4	7.2	0.1	103	92.7	121.6	9.1	8	6.8
79	38M	4	2.5	No	1	T	II	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
80	31F	2.4	2.2	Yes	1.7	S	II	II	I	Yes	Yes	Yes	2.5	0.1	147	185	208	6.5	6.8	6	0.1	217	205	195	5.7	6.1	5.5
81	65M	4.3	2.9	No	1	T	II	IV	II	Yes	Yes	Yes	2.5	0.1	78.4	86.5	112	8.9	8.6	7.2	0.1	81.7	92.5	182.6	8.2	8.1	6.9
82	46M	3	2.5	No	0.7	T	II	VI	V	Yes	No	Yes	2.2	0.1	0	0	0	0	0	0	0.1	56.5	47.1	83.2	10.2	9.6	9.1
83	27F	4.7	2.6	No	1	T	II	II	I	Yes	Yes	Yes	2.3	0.1	76.5	80.6	122	8.4	8.6	7	0.1	146	84.7	201.5	7.8	7.9	6.2
84	35F	4	2.3	No	0.8	T	III	V	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
85	41M	3.7	2.4	No	0.9	T	II	II	II	Yes	Yes	Yes	3	0.1	217	72.7	101	10	10.5	9.4	0.1	343	98.7	194.5	9.8	9	8.6
86	34F	3.2	2.4	No	1	T	II	II	I	Yes	Yes	Yes	2.3	0.1	53.2	28.5	61	9.7	8.8	8.7	0.1	57.5	29.1	72.5	9.1	8.5	7.9
87	57F	4	2.8	No	0.9	T	II	III	I	Yes	Yes	Yes	ND	0.1	59.7	66.4	59	9.8	7.5	8.4	0.1	72.5	88.4	92.7	9.5	7.1	7.9
88	20F	5.2	3.6	No	1.3	T	II	III	II	Yes	Yes	Yes	2.7	0.1	57.5	81.6	106	8.8	9.2	7.9	0.1	85.6	88.7	127.6	7.9	8.1	7
89	45M	4.2	2.7	No	1.1	T	II	II	II	Yes	Yes	Yes	3.8	0.1	98.5	89.6	122	8.8	8.2	7.9	0.1	157	98.6	225.7	8	7.4	6.4

90	58F	2.8	1.5	No	1	T	II	II	II	Yes	Yes	Yes	1.3	0.1	56.5	72.4	86	8.5	8.8	8.1	0.1	103	92.7	156.8	8.2	8.1	7.2
91	30F	5.8	2.4	No	0.8	T	II	II	II	Yes	Yes	Yes	2.6	0.1	63.5	71.2	90	8.7	8.9	7.2	0.1	74.6	69.8	128.7	8.2	8.1	6.5
92	44F	4	2	No	0.8	T	II	IV	IV	Yes	Yes	Yes	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
93	42M	5.1	3.9	No	1.6	T	II	V	IV	Yes	Yes	Yes	4	0.1	25.1	29	57	13	11.5	13	0.1	55	65.5	78.8	7.5	7.8	8.5
94	49F	4.2	2.5	No	1	T	II	VI	V	Yes	No	No	3	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
95	40F	4.5	3.5	No	0.9	T	II	III	III	Yes	Yes	Yes	3.5	0.1	370	120	388	8.3	7.2	7.5	0.1	800	356	900	6.7	6	7
96	67F	3.5	2.8	No	1	T	II	II	I	Yes	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
97	68F	4	3.3	No	1.1	T	II	III	II	Yes	Yes	Yes	3	0.1	52.5	92.7	218	8.8	8.5	7.2	0.1	64.4	117	327	8.6	8	6.8
98	47M	4.3	2.3	Yes	0.7	T	II	III	NO F/U	No	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
99	44F	2.8	2	No	0.4	T	II	III	II	Yes	No	No	ND	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
100	38F	4.5	2	Yes	1	T	II	III	IV	Yes	Yes	Yes	1.1	0.1	58.1	52.9	34	9.2	8.7	9.7	0.1	69.7	40.3	37.2	8.9	8.5	9.1

ND – Not documented, T – Total; S- Subtotal; P – Partial, F/U – Follow up