"Facial nerve monitoring and Diffusion Tensor Imaging in vestibular schwannoma surgery in low- and middle-income countries -A systematic review of financial consideration".

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KEYWORDS

Vestibular schwannoma - Intraoperative neuromonitoring – DTI - Facial nerve injury – Cost-Effectiveness

ABSTRACT

There are differences in surgical care comparing the nations with high, low, and moderate incomes. Vestibular Schwannoma surgery techniques have undergone lot of revolution in the last century. IONM are being widely used in developed countries and being propagated in LMICs with great enthusiasm. The goal of the current investigation was to systematically review the published literature and to find out the costs and utility of vestibular schwannoma surgery performed with the aid of IONM and DTI in resources poor countries.

Methods: -Direct basic costs for surgery and cost of IONM and DTI were calculated from previous studies. Cost of IONM and DTI is added to overall cost if they are used. To assess the impact of these modern technologies ,3 macro-scenarios were considered: (1) Vestibular schwannoma surgery without IONM (2) Vestibular schwannoma surgery with IONM (3) Vestibular schwannoma surgery with IONM and DTI. To calculate the average cost, probability model was used and it was assumed that 100 cases were operated in each scenario and average cost were calculated after including complications and their management.

Results: The average cost in the group without IONM was highest (91,699 USD) and in the IONM and DTI group was lowest (83,983 USD) and was 84,686 USD in IONM group. The additional cost of IONM and IONM with DTI cost was 0.414% and 0.558% of total cost respectively per case.

Discussion: - In the setting of vestibular schwannoma surgery, IONM with or without DTI is more cost-effective considering impact of facial nerve injury than surgery without IONM.

Conclusion: - This analysis shows that the cost-effectiveness of the vestibular schwannoma surgery with IONM and DTI for facial nerve injury and should be encouraged.

Introduction

There are differences in surgical care between nations with high income and those of low- and moderate-income countries (LMICs). According to the WHO Income level as defined by GNI per capita, Low-income countries have an income of $1045 or less per capita, middle-income countries have an income of $1046 to $12745 per capita and high-income countries have an income of $12745 per capita or more [1]. 75% of the world's population lives in middle-income countries and is home to 62% of the world's poor. At the same time, LMICs represent about one-third of the global GDP [2].

Vestibular schwannoma surgery techniques have undergone a lot of revolution in the last century. Intra-operative facial nerve monitoring is being widely used in developed countries for the surgical removal of vestibular schwannoma with improved nerve functioning outcomes, particularly in patients with large tumors. With tremendous excitement, these new technologies are currently being spread in LMICs [3,4]. The prevalence of significant facial nerve dysfunction after surgery decreased from 15- 59 % in the pre-monitoring period to 10-33% [5] after Delgado introduced facial nerve monitoring in 1979. In vestibular schwannoma surgery, the facial nerve's anatomical conservation rate has increased by up to 86-92 % [6-7]. The preservation of facial nerve function is now the primary goal of surgery. Poor quality of life and elevated levels of anxiety and despair are brought on by facial palsy [8]. Direct electrical stimulation (DES) and free-running EMG are the two most frequently employed techniques for facial nerve monitoring during CPA and skull base procedures (9). FMEPs or transcranial facial nerve motor-evoked potentials, have just lately been developed .

DTI is a more recent imaging experiment that combines numerous diffusion-weighted pictures created in various orientations to evaluate the direction of diffusion of water molecules. Maximum water molecule diffusion occurs along the direction of a nerve fiber.[10]. By this method, we can reconstruct a nerve fiber tract between two regions of interest. Three-dimensional (3D) diffusion tensor imaging can be used to determine the position of the facial nerve accurately in relation to the tumor. By knowing the position of the facial nerve preoperatively, chances of better preserving facial nerve function is presumed [11-12]. Different studies have reported a concordance of 80%to 100% between preoperative diffusion tensor imaging and intraoperative findings.

The objective of the present study was to systematically review the published literature and to find out the costs and utility of vestibular schwannoma surgery performed with the aid of intraoperative neural monitoring (IONM) and DTI in LMIC.

The current research uses a decision-tree model of vestibular schwannoma surgery to examine the cost-effectiveness of IONM from a societal standpoint. Surgeries with and without IONM and IONM with DTI are contrasted particularly, since patients require high-quality, economical treatment, this problem is relevant.

Materials and Methods: -

PRISMA criteria were followed in the systematic review (21).

Criteria for Selection and Eligibility employing the PICO (P-Population, I-Index test, C-Comparison, O-Outcome) worksheet, predetermined qualifying criteria. **(Table I)**

Table I: PICO Worksheet

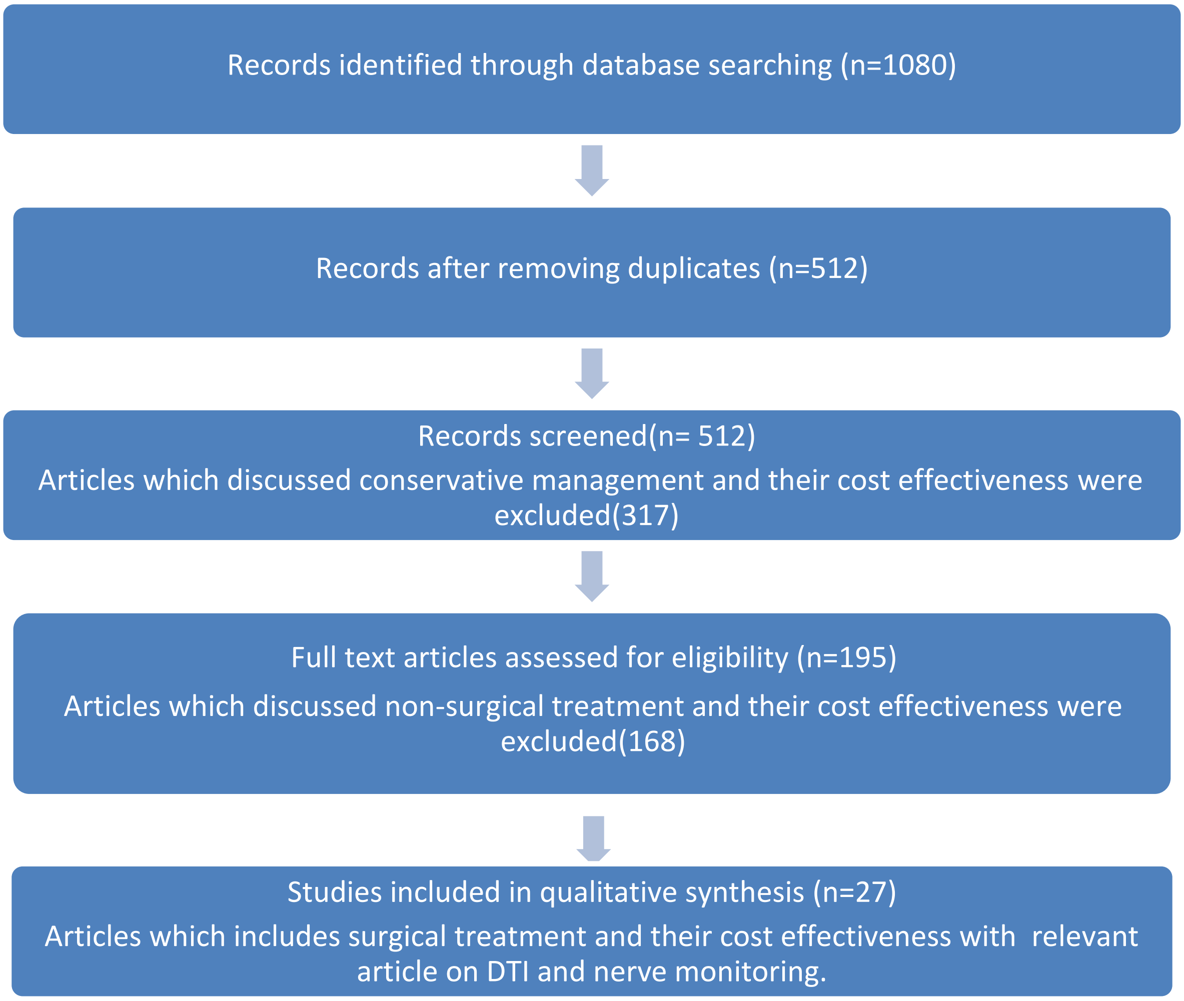
Population	Patient who underwent surgery for vestibular schwannoma.
Index test	Measuring the incidence of facial nerve injury with and without aid of different modalities and their cost.
Comparison	Average cost of surgery in different groups.
Outcome	Cost effectiveness of different modalities in facial nerve preservation and additional cost during facial nerve injury.

Studies evaluating facial nerve injury during CP angle surgery, vestibular schwannoma or in other surgery, IONM for CP angle surgery and DTI for facial nerve identification and cost-effectiveness of different modalities were included. Articles that discuss conservative management and their cost effectiveness were excluded. The majority of the articles that included material deemed relevant to the current research were those for facial nerve monitoring during otological, neurotological, and head and neck procedures. Articles published in languages other than English, opinion pieces, case studies, and reviews were also excluded.

Search Strategies -Studies were searched in PubMed databases from January 2003 to March 2023. Searches were performed using the MESH terms "cost vestibular schwannoma", "facial nerve intraoperative monitoring", "cerebellopontine angle" and "cost-effectiveness". Additionally, we used the terms for CP angle tumors or DTI and Facial nerve and Vestibular schwannomas. Authors were contacted to request the full text of articles where only abstracts were available. Relevant publications were found for the present study after carefully reviewing all the reference sections. The complete text of any articles whose abstracts seem to meet the criteria for inclusion was then read.

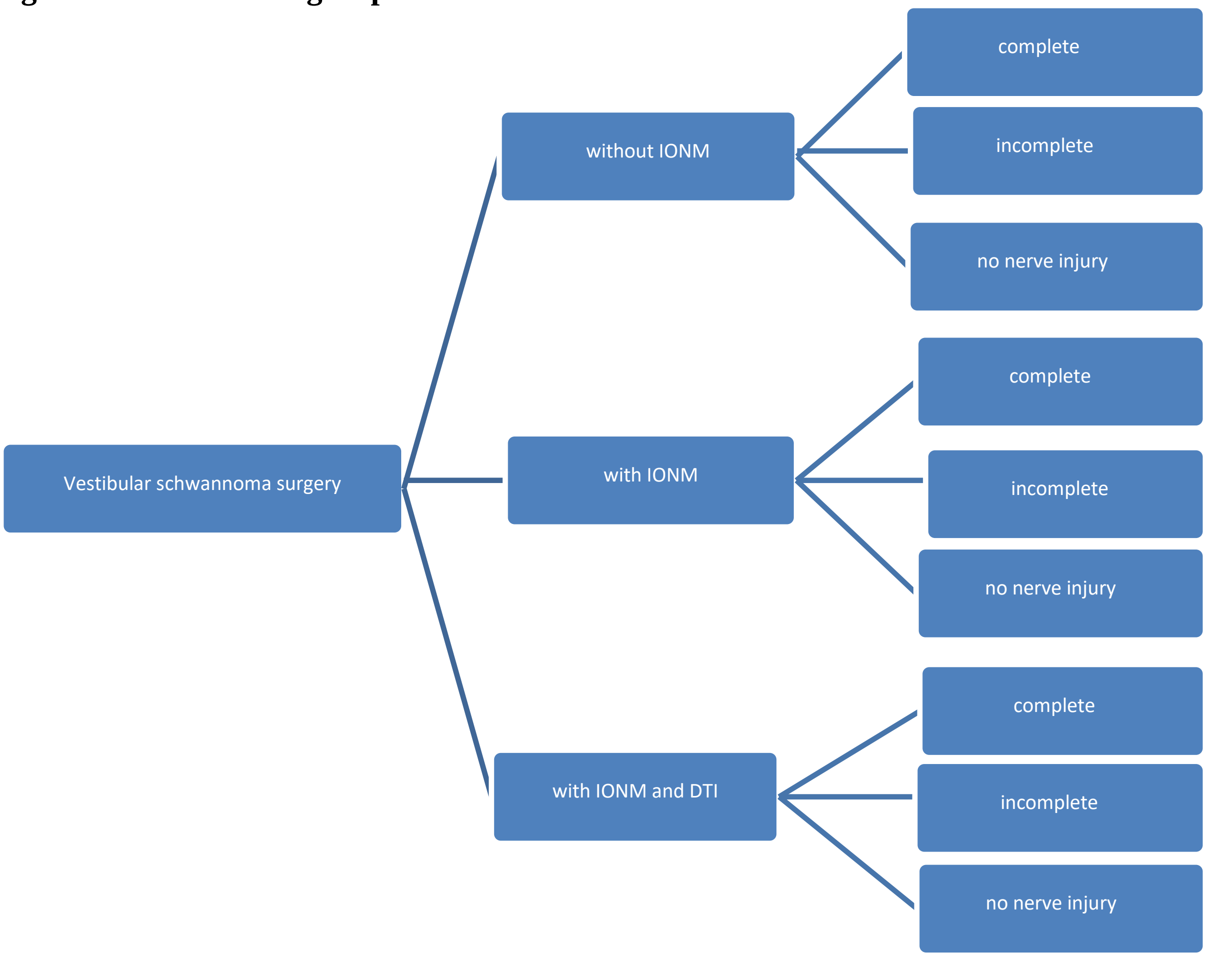
Information gathering and analysis was done to find the articles that satisfied the requirements, the whole text of those articles was collected and examined by two separate writers. The authors of research whose published data was insufficient for assessment were contacted and asked for further information. All suitable papers were included, and then they underwent a systematic review procedure. The research design, sample size, purpose of the investigation, sample collection schedule, clinical symptoms were examined, outcome measures, and findings were all included in a unified evidence table**. (figure 1)**

Figure 1 study design



Each reference section was thoroughly examined to identify relevant literature to the current study.168 articles were present for cost vestibular schwannoma among which 12 articles discussed the cost from a treatment point of view considering microsurgery were included. Articles that discussed conservative management and their cost effectiveness were excluded. Facial nerve monitoring articles for head and neck, ontological and neurotological procedures were the ones with the most information deemed relevant to the current research. Regarding our study, we found 2 useful articles, one for parotidectomy and another for middle ear and mastoid surgery. We also searched for DTI and facial nerve and Vestibular schwannoma or CP angle tumor and a total of 13 articles were found useful and we reviewed them. In our study we assessed the impact of these modern technologies and 3 macro-scenarios were considered: (1) Vestibular schwannoma surgery without IONM (2) Vestibular schwannoma surgery with IONM (3) Vestibular schwannoma surgery with IONM and DTI. **(figure 2)**

figure 2 different arm group and outcomes



Incidences of facial nerve injury without nerve monitoring and with nerve monitoring were derived from previous studies (13-16). The current analysis utilized the nerve damage rates from a prior study and it includes a study done by different approaches. The facial nerve preservation in different studies ranges from 70-91% when no monitoring is used, while it was 88-99% in different studies when facial nerve monitoring is used. The role of DTI tractography when considered for preserving facial nerves was 90.9%. (17) **(Table 2)**

Table 2 Incidence of nerve injuries in different group

1 Vestibular schwannoma surgery without IONM	likelihood that facial nerve won't be injured without IONM	70%-91 %
	likelihood of facial nerve injury without IONM	30%-9 %
2 Vestibular schwannoma surgery with IONM.	likelihood that facial nerve won't be injured with IONM	88%-99 %
	likelihood of facial nerve injury with IONM	12%-1 %
3 Vestibular schwannoma surgery with IONM with DTI	likelihood that facial nerve won't be injured with IONM and DTI	90%
	likelihood of facial nerve injury with IONM and DTI both	10%

Costs for surgery were derived from the literature and costs included the cost of surgery, cost of IONM equipment and the cost of the DTI sequence. The capital cost of an intra-operative nerve monitor and software for DTI sequencing was not factored in.

The price of a microsurgical excision of VS performed using one of the three main techniques was determined by Joe Saliba et al. in 2020. Total operating room time (minutes), operating room expense (US dollars), and surgical supply expense (US dollars) are among them and according to them, the cost of surgery is 68,417USD.They included the cost of the ultrasonic aspirator and nerve monitoring and all consumable items. (18) Using inflation rates, all cost parameters were raised to reflect current prices.

The DTI series had a mean total direct cost of $97 with a range of $73.22 to $115.65. The post-processing expenses incurred by the computer scientist and neurologist were $31.43 and $13.95, respectively, for a total of $45.38 were the bigger cost components. The creation of the 3-D tractography pictures is labor-intensive, taking 46 minutes on average, and radiologists' variable reporting costs were $25.00 on average. (19) Using inflation rates from the US Department of Labor's Bureau of Labor Statistics Consumer Price Index24 for healthcare, all cost parameters were raised to their current values. **(Table 3)**

Table 3 cost of surgery in different group

Scenario	Total hospitalization cost	IONM cost per procedure	DTI cost per procedure	Modern technique cost/ hospitalization cost
Vestibular schwannoma surgery without IONM	USD 79459	-	-	-
Vestibular schwannoma surgery with IONM	USD 79790	331 USD	-	0.414%
Vestibular schwannoma surgery with IONM and DTI	USD 79903	331 USD	113 USD	0.558%

The price of various facial nerve damage procedures along with the price of follow-up care were also included. Using inflation rates, all cost factors were adjusted to current values. All expenses were calculated using US dollars. (20) **(Table 4)**

Table 4 Final cost of surgery assuming facial nerve injury treatment and follow-up

1 Vestibular schwannoma surgery without IONM	Surgery without monitoring (without facial nerve injury)	79459USD
	Surgery without monitoring (with facial nerve injury)	Complete-79459+68264USD
		Incomplete-79459+13338USD
2 Vestibular schwannoma surgery with IONM.	Surgery with monitoring (without facial nerve injury)	
	Surgery with monitoring (with facial nerve injury)	Complete-79790+68264USD
		Incomplete-79790+13338USD
3 Vestibular schwannoma surgery with IONM and DTI	Surgery with monitoring and DTI (without facial nerve injury)	79903USD
	Surgery with monitoring and DTI (with facial nerve injury)	Complete-79903+68264 USD
		Incomplete-79903+13338 USD

For analyzing above data, we used probability model and assumed 100 cases were operated in each arm. The variables for our study included the costs of vestibular schwannoma surgery with and without monitoring aids (IONM and DTI) and the probabilities of facial nerve injury in different scenario. After reviewing the literature, we discovered that utilizing IONM generally improves facial nerves outcomes, particularly in cases of big tumors (22-25). Nevertheless, there has not yet been a controlled, prospective, randomized research. Such research is unlikely to be conducted in the difficult medicolegal climate of today as the majority of surgeons who have incorporated monitoring into their practices do so because they see a real benefit for their patients and are hesitant to stop using IONM. The range of values for facial nerve injuries were taken from published literature, and we included the arm with the greatest proportion of injuries in our likelihood model for each. We presumed that whether intraoperative facial nerve monitoring was employed after a facial nerve injury had already occurred had no effect on whether the injury would be complete or incomplete. We assumed that there is equal chance of complete and incomplete nerve injury because we could not find any literature regarding the chances of complete and incomplete nerve injury. All analyses were performed using probability and all possible scenarios in each arm. The model included several assumptions. **(Table 5)**

Table -5 Effective average cost assuming 100 cases in each group

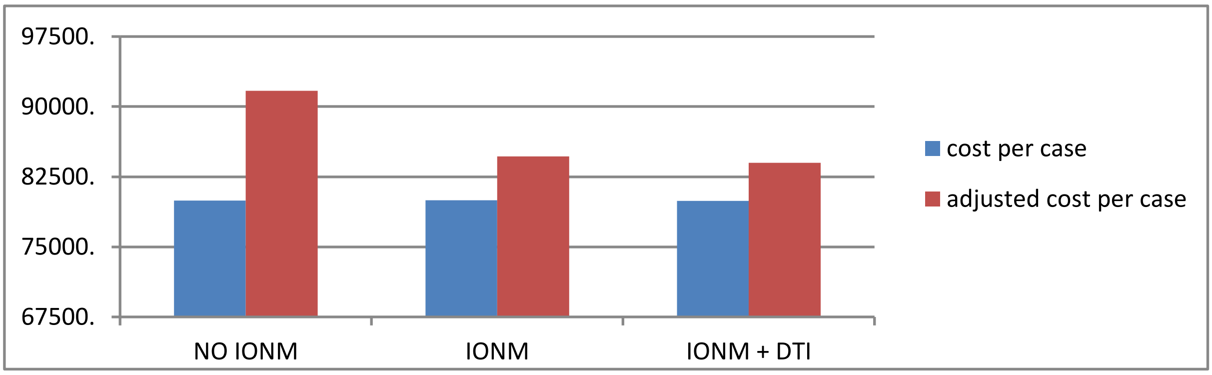
	Outcome	Probability	Cost(USD)
Vestibular schwannoma surgery without IONM	No injury	0.7	79459
	Incomplete nerve injury	0.15	92797
	Complete nerve injury	0.15	147723
Average cost			91699
Vestibular schwannoma surgery without IONM	No injury	0.88	79790
	Incomplete nerve injury	0.06	93128
	Complete nerve injury	0.06	148054
Average cost			84686.12
Vestibular schwannoma surgery without IONM	No injury	0.9	79903
	Incomplete nerve injury	0.05	93241
	Complete nerve injury	0.05	148167
Average cost			83983.1

Result-
The price of surgery in the first example was $79459 without an IONM arm. The prices for the IONM group were $79790, and for the IONM with DTI arms, they were $79903. Cost reductions per patient

for surgery without IONM arm were $331 over the IONM arm and $444 over the IONM and DTI arm. But if we assume a high-volume center and consider 100 cases of vestibular schwannoma surgery, after applying the probability of the facial nerve injury and cost of their management, the cost of surgery in the average cost in the group without IONM was highest 91,699 USD and in the IONM and DTI group was lowest 83,983 USD and was 84,686USD in IONM group. The additional cost of IONM and IONM with DTI costs around 0.414% and 0.558% of total cost respectively per case. But this additional cost has a significant impact on facial nerve preservation and later improving the quality of life of patient. Using IONM with or without DTI would offer benefit over surgeries without

IONM. As the rate of facial nerve injury decreased with the use of IONM and IONM with or without DTI, it is more cost-effective in treatment and follow-up in patients of vestibular schwannoma. **[figure-3]**

Figure -3 comparison of average cost in different group



Discussion-
Doctors and patients often get fascinated with new modes of treatment before understanding their merits and demerits. IONM and DTI requires high initial investment. Intraoperative facial

nerve injury that can occurs during vestibular schwannoma surgery have significant impact on patient’s life as it decreases the quality of life with disfigurement of face which has a psychological impact. Surgery with IONM and DTI reduce the chances of facial injury and improves the outcome. Although IONM is costly but use of this device with or without DTI is highly cost effective in the setting of vestibular schwannoma in patients of LMIC considering the impact of facial nerve injury as observed. Healthcare professionals of LMIC should be educated regarding the benefits and use of these newer technologies. and encouraged to use them.

Limitations-

We made no effort to estimate the value of IONM to a specific surgeon in terms of confidence in anatomical landmark-based facial nerve identification. Although it is hard to put a number on this, it is unquestionably a relevant factor. Furthermore, since most cost-effectiveness evaluations rely on estimates of probability and utility, the validity of the current study's conclusions depends on the accuracy of the estimations we used to build our model.

Conclusion –

Although facial nerve damage is a clinically relevant side effect of vestibular schwannoma surgery, IONM provides, at most a reduction in the incidence of facial nerve injury. This research reveals that the reduction in facial nerve damage makes sense from a financial standpoint. The additional cost per patient for these help on modalities in high volume facilities where many CP angle surgeries are done each year is not very substantial.

CONFLICT OF INTEREST STATEMENT - The writers affirm that they had no relationships with people or groups that may have influenced the article's content adversely or claimed authorship rights when it was written, either on a personal or professional level.

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