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Current trends of vestibular schwannoma management in a referral center in Indonesia: A retrospective cohort study

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ABSTRACT

Background: Vestibular schwannoma (VS) is the most common benign brain tumor of the cerebellopontine angle. Due to its location, this pathology can create both focal and global deficits. The registry system for VS in Indonesia is developing, including in the author's institution, which eventually shows a changing trend in managing VS.

Methods: We retrospectively collected data from all patients diagnosed with vestibular schwannoma, based on histological or radiological results. Treatments included craniotomy and/or Gamma Knife Radiosurgery (GKRS) in 2018-2023.

Results: Data from 88 patients were analyzed. The number of patients treated has increased annually. VS predominantly affects females (64%). The proportion between GKRS and craniotomy procedures also shifted throughout the year. Common symptoms included hearing loss (63.6%), disequilibrium (50%), and headaches (39.7%). The most common tumor size was medium (15-30 mm; n=37; 42%). Tumors that fell into the intrameatal and small (<15 mm) categories were all treated with GKRS, whereas the other groups were divided into GKRS and craniotomy. GKRS demonstrated high efficacy in tumor control and favorable hearing and facial nerve preservation, whereas craniotomy remained crucial for larger tumors.

Conclusion: The number of VS diagnosed each year has increased in our center, accompanied by a noticeable shift in preference from GKRS to craniotomy, which is influenced by the integration of intraoperative monitoring. Treatment preference was further determined based on the clinical profile and tumor size. In the future, there is a need to develop a national registry to better reflect the true incidence of VS within the Indonesian population.

Keywords: *vestibular schwannoma, gamma knife radiosurgery, craniotomy, intraoperative monitoring, national registry*

List of Abbreviations

VS	: vestibular schwannoma
GKRS	: gamma knife radiosurgery
CPA	: cerebellopontine angle
CSF	: cereberospinal fluid
IOM	: intraoperative monitoring
RSCM	: Dr. Cipto Mangunkusumo National General Hospital

MRI	: magnetic resonance imaging
ICP	: intracranial pressure
VP	: ventriculoperitoneal
SRS	: stereotactic radiosurgery
NF2	: neurofibromatosis type 2
COVID-19	: coronavirus disease 2019

BACKGROUND

Vestibular schwannoma (VS) is the most common benign tumor of the cerebellopontine angle (CPA). This pathology makes up 6-8% of all primary brain tumors. Despite its benign nature, the location, the relationship to adjacent structures, and the compression effect of the tumor may cause morbidity and mortality [1]. VS is often marked by hearing loss and disequilibrium, and is often associated with other cranial nerve deficits. Tumor size and direction of tumor growth also affect the progression of symptoms. More recently, VS cases are diagnosed when sizes are relatively small, likely due to better access to healthcare facilities [2].

Reports from different sources have shown that incidence rates vary in different geographical locations [2]. Despite its potential morbidity and mortality, epidemiological studies of VS are still lacking in Indonesia. The registry system is still under development, and the data from every center are separate. Therefore, the current management of VS in different areas of the country may not be the same. In rural areas, when cases of hydrocephalus appear, a cerebrospinal fluid (CSF) diversion procedure is performed; however, the management of the tumor itself is performed after being referred to a higher center.

VS management varies, and choices are made according to the severity of the disease, tumor size, and extent of tumor growth. Within the last few decades, less invasive modalities such as external beam radiotherapy and Gamma Knife radiosurgery (GKRS) have been widely used, especially for smaller tumors (diameter <3 cm) [3]. Larger tumors require surgical intervention, and the emerging, widely used now, intraoperative monitoring (IOM) has become increasingly prevalent. This technology aids neurosurgeons in preserving functional integrity during surgery.

This study presents a retrospective analysis of vestibular schwannoma cases treated at "Dr. Cipto Mangunkusumo" National General Hospital, Jakarta, from 2018 to 2023. As a national referral hospital in Indonesia, it plays a pivotal role in admitting VS cases from district hospitals in various parts of the country. The findings of this study provide valuable insight into the current landscape of VS management in Indonesia.

METHODS

A retrospective analysis was conducted from 2018 to 2023 at "Dr. Cipto Mangunkusumo" National General Hospital (Rumah Sakit Cipto Mangunkusumo/RSCM) in Jakarta, Indonesia. The data of patients diagnosed with vestibular schwannoma were systematically collected. The diagnosis of vestibular schwannoma was established through either histopathological examination or radiological assessment, primarily based on gadolinium-enhanced magnetic resonance imaging (MRI). All data were meticulously extracted from the hospital medical records.

The collected data were analyzed and methodically presented through structured tables and charts. All the individuals included in this study were aged > 18 years. Therapeutic interventions included GKRS, craniotomy, and CSF diversion procedures.

This study also systematically evaluated various variables to explore the management of vestibular schwannomas in RSCM comprehensively. The evaluated key variables included sex,

age group, size, and lateralization of tumors, offering insights into the demographic and anatomical dimensions of VS. This study also meticulously dissected other variables explored, including clinical presentations and symptomatology, types of referring physicians, surgical decisions regarding GKRS and craniotomy, clinical course of the disease, and postoperative outcomes. These variables were chosen to provide a comprehensive perspective of VS in a national referral center in Indonesia, which encompasses demographic, anatomical, clinical, and procedural dimensions of VS management.

RESULTS

From 2018 to 2023, 88 patients with RSCM were diagnosed with vestibular schwannoma on the basis of histopathological or brain MRI findings. All patients were included in this study, as they fulfilled the inclusion criteria. The number of treated cases increased throughout the year, and the proportion between GKRS and craniotomy also shifted (Table 1).

Year	Craniotomy (n)	GKRS (n)	Treated Cases (n)
2018	1	7	8
2019	1	14	15
2020	2	13	15
2021	4	16	20
2022	5	6	11
2023	12	8	20

Table 1. Distribution of treated vestibular schwannoma cases based on craniotomy and GKRS procedures.

Demographics	Number (n=88)	Percentage (%)
Sex		
Female	56	64
Male	32	36
Age (median)	**43**	
<40 years	29	33
40-49 years	18	21
50-59 years	28	32
60-69 years	11	12,5
>69 years	2	2,3
By size		
Intrameatal	7	8
Small	1	1.1
Medium	37	42
Large	19	21.5
Giant	24	27.2

Koos grading		
I	11	12.5
II	5	5.7
III	10	11.4
IV	62	70.5
Median volume (cm^3)	11.3 (0.027– 165)	
Lateralization		
Right	37	42
Left	47	53.4
Bilateral	4	4.5
Types of referring physicians		
Neurosurgeons in RSCM	25	28.4
Neurosurgeons outside RSCM	31	35.2
Other specialties in RSCM	16	18.2
Other specialties outside RSCM	17	19.3
General physicians	0	0

Table 2. Demographic characteristics of vestibular schwannoma patients in RSCM

According to the results in table 2, there were 56 (64%) female and 32 (36%) male patients with a median age 48.5 for all cases. The median age was 43 years, with cases more often found in the < 40 years age group (n = 29; 33%). Based on tumor size, the authors classified them into four groups: intrameatal, small (diameter <15 mm), medium (diameter 15-30 mm), large (diameter 30-40 mm), and giant (>40 mm). According to the Koos grading scale, the majority of the tumors were classified as Grade IV, comprising 70.5% of the cases. Koos Grade I held a 12.5% share and Grade III represented 11.4% of the cases, while Koos Grade II has the smallest percentage of 5.7%. The median volume of all vestibular schwannoma (VS) patients treated at RSCM from 2018 to 2023 Is 11.3 cm^3, ranging from 0.027 cm^3 to 165 cm^3.

In the analysis of tumor lateralization, tumor distribution showed a slight left-sided predominance (53.4%) compared to the right (42%). Bilateral occurrences were observed in 4.5% of the cases. These findings underscore the lateralization tendency in VS, highlighting the relevance of considering the tumor side in diagnostics and treatment, particularly for bilateral VS, which requires further evaluation for other plausible conditions.

Table 2 also provides a breakdown of the types of physicians involved in referring patients with VS to the Neurooncology division within the Department of Neurosurgery at RSCM, where both the GKRS and surgical approaches are performed. Notably, neurosurgeons play a central role in the referral system, both within the RSCM (28.4%) and external to the RSCM (35.2%), indicating reliance on neurosurgical expertise in the referral system. Other specialties, both internal and external to the RSCM, play a comparatively smaller role. Moreover, there is an absence of direct referrals from general physicians to the neuro-oncology division of the neurosurgery department in RSCM.

Symptoms	**Number (n=88)**	**Percentage (%)**
Hearing loss	63	71.5

Tinnitus	22	25
Disequilibrium	44	50
Facial nerve palsy	22	25
Trigeminal nerve deficits	18	20.4
Dysarthria	10	11.3
Dysphagia	10	11.3
Headache	33	39.7
Visual impairments	11	12.5
Cerebellar signs	4	4.5
Hemiparesis	3	3.4
Hemihipesthesia	1	1.1

Table 3. Signs and symptoms of vestibular schwannoma

In terms of symptomatology (Table 3), the majority of patients who visited our center presented with symptoms of hearing loss (71.5%). This underscores the significant auditory impact of tumors. Tinnitus affected 25% of patients, while disequilibrium was notable in 50% of the cases. Facial nerve palsy and trigeminal deficits were observed in 25% and 20.4% of the patients, respectively. Dysarthria and dysphagia were present in approximately 11% of cases. In addition to the primary symptoms, 39.7% reported headaches and 12.5% experienced visual impairments. Less frequently, cerebellar signs, hemiparesis, and hemihypesthesia were observed. This reveals the diverse manifestations associated with vestibular schwannomas, which can give rise to auditory, neurological, and other secondary symptoms.

Variables	**Number (n=88)**	**Percentage (%)**
Types of intervention		
GKRS	60	68.2
Craniotomy	28	31.8
Mean duration from initial symptoms to intervention	25 months (1-161)	
GKRS (n=60)		
Median volume	8 cm^3 (0.027-40.9)	
Median maximum diameter	2.6 cm (0.2-6.2)	
Median dose	15.20 Gy (8-52)	
Median isodose line	50 ± 2.6%	
Indications for GKRS		
Maximum tumors diameter <3cm	46	76.7
Hearing and facial nerve preservation	9	15
Surgeons' preference	5	8.3
Craniotomy (n=28)		
Indications for surgery		

Large and giant tumors (>3cm)	*27*	*96.4*
Severe neurological deficit	*1*	*3.6*
Extent of surgical resection		
Gross total resection	*8*	*28.6*
Near total resection	*11*	*39.3*
Subtotal resection	*9*	*32.1*

Table 4. Intervention-related variables of vestibular schwannoma patients in RSCM

Based on the results in table 4, sixty patients underwent GKRS, and 28 underwent craniotomy. One patient underwent two re-craniotomy procedures and one patient underwent two GKRS procedures. The mean duration from initial symptoms to interventions was reported to be 25 months, with a wide range of 1 to 161 months.

Various parameters are highlighted for the GKRS cases. The median volume of tumors treated is 8 cm3 (0.027- 40.9). The median maximum diameter is 2.6 cm (0.2-6.2). The radiation dose administered shows a median of 15.20 Gy (8-52). The median isodose line was 50 ± 2.6%. Most patients who underwent GKRS were in the intracanalicular, small, and medium tumor groups, which contributed to 76.7% of the patients who underwent GKRS.

Ten patients (16.7%) with large tumors and four patients (6.7%) with giant tumors underwent GKRS procedures. These interventions were chosen for reasons other than tumor size, including preservation of hearing and facial nerves (15%) and based on surgeons' preference (8.3%).

In contrast, patients who underwent craniotomy had medium (1, 3.6%), large (9, 32.1%), and giant (16, 57.1%) tumors. Medium-sized tumors were considered for craniotomy due to the severe neurological deficits experienced by the patient. IOM was used in most craniotomy procedures and all procedures were performed using the retrosigmoid approach. Further analysis of craniotomy cases revealed the extent of surgical resection. Gross total resection was achieved in 28.6% of the cases, near-total resection in 39.3%, and subtotal resection in 32.1%.

The most prevalent immediate symptom after the intervention was hearing loss, reported by 65 individuals, which decreased to 42 after a year (Table 5). Tinnitus, disequilibrium, and facial nerve palsy were also common initially but exhibited a decline over the follow-up period. Notably, dizziness and trigeminal deficits were reported in a small proportion of individuals and remained relatively stable. Other symptoms, such as dysarthria, dysphagia, headache, visual impairments, cerebellar signs, hemiparesis, hemihypesthesia, ptosis, and death, demonstrated varying degrees of occurrence and persistence across different time points. These data indicate the dynamic nature of post-event symptoms, with some resolution, while others persist or emerge during the follow-up period. Loss to follow-up occurred in a small number of cases (n=5, 5%), introducing a potential source of bias in the reported outcomes.

Symptoms (n=88)	**Immediate**	**3 months**	**6 months**	**12 months**
Hearing loss	65	61	52	42
Tinnitus	21	21	18	12
Disequilibrium	39	31	30	26
Dizziness	8	3	2	2

Facial nerve palsy	30	23	20	15
Trigeminal deficits	20	16	14	12
Dysarthria	12	6	4	3
Dysphagia	12	6	4	3
Headache	17	15	11	9
Visual impairments	11	10	8	6
Cerebellar signs	13	6	5	3
Hemiparesis	4	2	2	1
Hemihypesthesia	1	1	1	1
Ptosis	1	1	1	1
Death	-	2	-	-
Loss to follow up	-	4	-	1

Table 5. Symptoms during follow-up in vestibular schwannoma patients in RSCM

According to the results in table 6, hearing preservation emerged as a notable achievement in this study, with 92% of the patients experiencing successful preservation of hearing. Similarly, facial nerve preservation was achieved in 67.2% of cases, demonstrating a considerable success rate in maintaining facial nerve function.

Variables	**Number**	**Percentage (%)**
Hearing preservation	23	92
Facial nerve preservation	39	67.2
Median length of hospital stay	5 (2-17) days	
GKRS		
Mean follow-up duration	11.3 ± 2.3 months	
Mean length of hospital stay	4.9 ± 2.1 days	
Tumor control	57	95.5
Mean relative volume reduction	34 ± 6.7 %	
Hearing preservation		
Hearing preservation	18/20	90
No hearing preservation	2/20	10
Hearing improvement	17/28	60.7
No hearing improvement	11/28	39.3
Facial nerve preservation		
Facial nerve preservation	36/38	94.7
No facial nerve preservation	2/38	5.3
Facial nerve improvement	4/8	50
No facial nerve improvement	4/8	50
Mortality	0	0
Craniotomy		

Mean follow-up duration	11.5 ± 1.6 months	
Mean length of hospital stay	6.3 ± 3.6 days	
Hearing preservation		
Hearing preservation	3/5	60
No hearing preservation	2/5	40
Hearing improvement	8/39	20.5
No hearing improvement	31/39	79.5
Facial nerve preservation		
Facial nerve preservation	18/28	64.3
No facial nerve preservation	10/28	35.7
Facial nerve improvement	3/14	21.4
No facial nerve improvement	11/14	78.6
Recurrence	2	7.2
Mean time interval after intervention to recurrence	9.5 ± 1.5 months	
Mortality	2	7.1

Table 6. Post-operative outcomes of vestibular schwannoma patients in RSCM

The mean follow-up duration for patients undergoing GKRS was 11.3 ± 2.3 months. The GKRS procedures exhibited favorable tumor control, with 95.5% of cases achieving successful tumor control. Additionally, a mean relative volume reduction of 34 ± 6.7% underscores the effectiveness of GKRS in reducing tumor size. The length of hospital stay for GKRS patients was relatively short, averaging 4.9 ± 2.1 days. In the context of hearing preservation following GKRS, 90% of patients maintained their hearing, whereas hearing improvement was observed in 60.7% of cases. Facial nerve preservation following GKRS was successful in 94.7% of the patients, with a notable 50% improvement in facial nerve function.

In contrast, craniotomy procedures are associated with a mean follow-up duration of 11.5 ± 1.6 months and a longer mean hospital stay of 6.3 ± 3.6 days. Hearing preservation in craniotomy cases was achieved in 60% of patients, with hearing improvement observed in 20.5% of cases. Facial nerve preservation was successful in 64.3% of the craniotomy patients, and 21.4% experienced improvement in facial nerve function. The study also reported recurrence in 7.2% of cases after craniotomy, with a mean time interval of 9.5 ± 1.5 months. Owing to VS's benign nature of VS, the overall mortality rate for both GKRS and craniotomy is low, with 0% and 7.1% mortality, respectively.

DISCUSSION

Incidence and demographic trends

VS is one of the most prevalent benign primary brain tumors with an incidence rate of 2.2 per 100,000 person-years [2]. A study by Fernández-Méndez et al. found that the incidence rate of VS tends to increase each year due to improved access to diagnostic facilities and referral systems, leading to earlier diagnosis of smaller tumors. Similarly, Evans et al. reported an annual increase in VS patients, and Goldbrunner et al. attributed this to improved screening protocols for asymmetrical hearing loss, better access to advanced imaging, and improved resolution of MRI, resulting in an increased number of VS diagnoses and a smaller average tumor size at the time of

diagnosis [2-4].Consistent with previous studies, this study found that the number of VS patient admissions increased annually [3,4].The majority of patients with VS in this study were female, consistent with a report by Boari et al. that VS is more common in younger individuals (<40 years of age) [5]. Similarly, Gupta et al. reported that VS patients typically present between the ages of 20-40, which is consistent with the findings of this study, in which 64% (n=56) of the patients were female and 33% (n=29) belonged to the same age group [6].

Clinical presentations and symptomatology

The most common symptom observed in this study was hearing loss (71,5%), followed by disequilibrium (50%), headache (39,7%), and tinnitus (25%). This finding is consistent with other studies published before [2,4,7]. Hearing loss, tinnitus, and disequilibrium were the hallmark symptom of VS that often develops gradually, due to the slow growth of the tumor compressing and irritating the vestibulocochlear nerve [8].

Headache and visual impairment are indicators of elevated intracranial pressure (ICP) due to space-occupying lesions in the brain. Other symptoms related to increased ICP, including nausea, vomiting, confusion, and decreased level of consciousness, may also be present in patients with VS, particularly in large and giant VS. In some cases where compression occur to the fourth ventricle, hydrocephalus may occur and require prompt CSF diversion procedures [2,9].

Compression of the facial nerve, leading to facial weakness or paralysis, reveals that the facial nerve travels in close proximity to the vestibulocochlear nerve. Growth of VS may also affect the trigeminal nerve, which manifests as numbness or a tingling sensation in the face. Less frequent symptoms, including cerebellar signs, may manifest because of the proximity of the tumor to the cerebellum. One of the main functions of cerebellum is to coordinate movement [8].

Based on the data analyzed, the authors determined that there is a trend towards admitting medium-to-large tumors to their institution. Specifically, in four cases, CSF diversion procedures were conducted prior to GKRS or craniotomy when symptoms of elevated ICP imaging findings supported this decision. In a separate study, Shin et al. reported that ventriculoperitoneal (VP) shunting was typically performed in patients with large ventricles and communicating hydrocephalus [10].

Treatment modalities

In our institution, the availability of the GKRS provided treatment options and treatment combinations. This explains why the proportion of cases treated with radiosurgery or craniotomy tends to change every year. Patients with serviceable hearing and tumors with a diameter <30 mm would be recommended GKRS [11-13]. In special cases, however, giant tumors undergo GKRS, such as those aged > 70 years or those not willing to undergo surgery. Age is a relative reason for patients not undergoing surgery, and good outcomes can still be achieved [14]. According to a study by Tosi et al. on the outcomes of Stereotactic Radiosurgery (SRS) for large VS, all treatment modalities demonstrated high tumor control rates and a decline in pretreatment hearing. However, no significant facial nerve impairment was reported [15].

Despite the aforementioned reasons, the authors still recommend surgery as the first-line treatment for large and giant tumors for a better control rate [11].With the availability of IOM, the trend of VS treatment has changed toward tumor resection, especially for medium to giant tumors. It is a crucial method for detecting facial nerve function intraoperatively while guiding the surgeon more safely for total resection [16,17].The retrosigmoid approach was used in all patients who

underwent surgery and presented with unserviceable hearing loss. The decision for choosing retrosigmoid approach reflects the prioritization of life-threatening conditions over functional preservation and surgeon's preference [18]. In their review, You et al indicated that the retrosigmoid approach appears to be the most adaptable pathway for facial nerve preservation in the majority of tumor sizes, although it is accompanied by a high likelihood of postoperative pain and CSF fistula [19]. Concurrently, Lin et al suggested that subtotal resection followed by observation or SRS, particularly for a large VS, can achieve long-term tumor control with improved CN preservation [20].

Lateralization of tumor

In our study, the observed lateralization tendency was to the left side (53.4%). Bilateral presentation of VS was found in 4.5% of the patients. Bilateral VS is a hallmark presentation of Neurofibromatosis type 2 (NF2). NF2 needs to be diagnosed using genetic testing, however it is still not available in our institution during this study period [21].

Types of referring physicians

Our institution is one of the largest referral centers in Indonesia, which maybe the reason more than half of the treated cases were referred from outside the RSCM. Currently, not all centers in Indonesia have GKRS facilities within the hospital. For this reason, the number of cases treated with GKRS was also higher than that of those who underwent surgical treatment especially for small size tumors.

This study also showed the central role of neurosurgeons in the referral system, which highlights the specialized expertise required for VS management. A direct referral process from the general practitioner may expedite the patient's process of intervention, thereby improving the prognosis.

Surgical decisions

The decision-making process for managing vestibular schwannomas involves a comprehensive evaluation of tumor characteristics and clinical considerations. GKRS is preferred for smaller tumors (<3 cm), constituting 76.7% of cases, with a median volume of 8 cm^3 and a precise dose of 15.20 Gy. Preservation of hearing and facial nerves guides 15% of the GKRS decisions. Surgeon's preference influenced 8.3% of cases, highlighting the individualized nature of clinical judgment. This finding is also supported by previous study which stated that GKRS is superior for smaller VS [22].

In contrast, craniotomy was reserved for larger tumors (>3 cm), which comprised 96.4% of the cases. The extent of surgical resection varied, with 28.6% of patients achieving gross total resection, emphasizing the surgical goal of complete resection. The decision-making landscape is shaped by a careful balance between tumor size, preservation objectives, and individual clinical judgment, reflecting the tailored approach in vestibular schwannoma management [14]. According to Kleijwegt et al., tumor location, a short duration of hearing loss, and balance disorders are considered to be the most effective predictors for adjusting an initial conservative treatment approach [23].

Clinical course

The overall symptoms of patients' post-intervention declined over the course of immediately after intervention and at 3-, 6-, and 12-month follow-up after intervention, indicating

the effectiveness of both the GKRS and craniotomy. Despite the overall positive clinical course, there were 2 deaths in the craniotomy group. Patient death was due to coronavirus disease 2019 (COVID-19) infection during the pandemic and was not related to surgical complications. In contrast, no deaths were observed in the GKRS group.

Post-operative outcomes

GKRS demonstrated efficacy with a high degree of tumor control (95.5%) and favorable hearing (90%) and facial nerve (94.7%) preservation outcomes. This study is consistent with previous studies reported [13,24]. Berkovitz et al. reported 104 (29.7%) participants who reported that they currently maintain useful hearing in the GKRS treated tumor ear [13]. Similarly, in their study Smith et al found that most patient who underwent GKRS for mildly to moderately symptomatic vestibular schwannomas experienced effective symptomatic relief from prior tinnitus (83.7%), vertigo, dizziness and disequilibrium (62.7%), functional neurological disorder (90.0%), transient neurological deficits (79.2%), and lateralize headache (94.7%) following GKRS, but not existing hearing loss (1.0%) [24]. The shorter hospital stay and lower recurrence rates further highlight the benefits of GKRS. Craniotomy, which is associated with longer hospital stay and lower rates of hearing and facial nerve preservation, remains a crucial intervention for larger tumors and cases with severe neurological deficits.

Limitations and future directions

Our study is limited because we could not compare the incidence rates of vestibular schwannomas in Indonesia's population or other centers. To capture a more accurate picture of the incidence of vestibular Schwannomas in Indonesia, a national registry should be established. Such a registry would enable us to investigate the relationship between tumor size and presenting symptoms, and also consider the possibility that cases may be more prevalent than those that have been referred to our center because of the limitations of the current referral system. A national registry could also serve as a foundation for evidence-based guidelines, targeted interventions, and the facilitation of multidisciplinary collaborations between medical specialists in Indonesia. Multidisciplinary collaborations between neurosurgeons, neurologists, otolaryngologists, and radiation oncologists ensure better comprehensive care for individuals affected by VS [25].

In considering future directions, the establishment of a national registry has emerged as a crucial step in facilitating evidence-based medicine tailored to Indonesian demographics. Collaborative efforts involving multiple institutions would provide a more comprehensive dataset, enabling a better understanding of vestibular schwannoma epidemiology, clinical course, and outcomes in Indonesia. Additionally, fostering international collaboration would facilitate the exchange of knowledge and expertise, contributing to advancements in both research and clinical practice.

The transition from GKRS to craniotomy, influenced by the implementation of IOM, exemplifies the developing nature of the neurosurgical techniques. Future research should explore the implications of advancements in neurosurgical technology that may lead to improved patient outcomes.

CONCLUSION

This study examines the demographic trends, clinical presentations, treatment modalities, and outcomes of vestibular schwannoma at one of the largest national referral centers in Indonesia, which also serves as a reflection of the general Indonesian population. The number of VS cases in

our center has increased annually, which indicates better detection and diagnosis of VS. Notably, hearing loss, disequilibrium, and headache are the most common symptoms of VS, along with various other clinical manifestations. The treatment options for VS vary, and the selection of treatment options is based on the presenting symptoms and tumor size. GKRS demonstrated efficacy in tumor control, hearing, and facial nerve preservation, with shorter hospital stays, whereas craniotomy is preferable for larger tumors and cases with severe deficits. In recent years, there has been a transition from GKRS to craniotomy, which is influenced by the implementation of IOM.

This study also highlights the need for a national registry in Indonesia to better understand the epidemiology of VS. This registry can serve as a foundation for evidence-based guidelines tailored to Indonesian demographic characteristics. Multidisciplinary collaboration and international partnerships are essential for improving patient prognosis.

Ethical approval

The ethical review and approval were conducted by the Research Ethical Committee of the Faculty of Medicine, Universitas Indonesia/"Dr. Cipto Mangunkusumo" Hospital, with the following reference number: KET-1634/UN2.F1/ETIK/PPM.00.02/2023.

Consent for publication

All authors listed in this manuscript have reviewed and approved the final version of the manuscript for publication.

Availability of data and material

All data analyzed in this study are included in this article and its supplementary file.

Competing interests

The authors declare no competing interests.

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Authors' contributions

RAA conceptualized the research. All authors were responsible for the collection, analysis, and interpretation of patient data. NZ and NC drafted the original manuscript. RAA, FD, and BAW reviewed and edited the manuscript. All authors have read and approved the final version of the manuscript.

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