



Original Article

The start-up of a neurosurgical service in an East Indonesian archipelagic province: The first 2-year experience of North Maluku Database in Neurosurgery (NOMADEN)

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ABSTRACT

Background: Despite encouraging developments after its initial founding in Indonesia more than seven decades ago, inequity in access and availability of neurosurgical services throughout the country continues to pose a challenge. We aimed to elaborate on the start-up of a previously inactive neurosurgical service in North Maluku, an archipelagic province in East Indonesia, and describe cases managed within the first two years of service.

Methods: In the North Maluku Database in the Neurosurgery register, demographic and clinical information of neurosurgical patients admitted to Chasan Boesoirie General Hospital, Ternate, from January 2021 to December 2022, were analyzed. Surgically managed patients were rendered visually according to their decades of life and districts of events.

Results: There were 998 new patients (mean age \pm standard deviation [SD]: 34.7 ± 19.6 years, 60.3% male) managed and 216 neurosurgical procedures (mean age \pm SD: 33 ± 20.4 years, 67.1% male) performed. The majority of patients operated were within the 1st decade of life (18.5%), presented to the emergency room (56.5%), covered by national health insurance (69.4%), from outside Ternate (62.5%), diagnosed with neurotrauma (40.7%), and discharged alive (80.1%). Ternate was the only district where all seven types of neurological diseases were encountered. No surgeries were performed for patients from Taliabu, the farthest district from Ternate.

Conclusion: A large portion of neurosurgical patients in North Maluku were those young and at productive age who were transported from outside Ternate with acute neurological disease (particularly neurotrauma). Distance and geographical circumstances may have a profound effect on access to neurosurgical services.

Keywords: Access, Archipelago, Equity, Neurosurgery, Register

INTRODUCTION

Neurosurgery has always been an indispensable subspecialty of medicine that is demanding not only to its practitioners – neurosurgeons – but also to the whole health and education systems, ensuring its sustainability. It is therefore unsurprising that difficulties in assuring the quality of, availability, and access to neurosurgical services will often be encountered by low- to middle-income countries (LMICs), where the greatest burden of global mortality (78.5%) and disability-adjusted life years (77.3%) due to neurological disorders lie.^[25] It is estimated that more than 5 million essential neurosurgical cases in LMICs were left untreated due to an inadequate

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neurosurgical workforce and poor access to neurosurgical facilities.^[5] Compared to Eastern Europe and Central Asia, LMICs in East Asia and the Pacific have an extremely smaller population with access to neurosurgical services within a 2-h window (respectively, 93.3% and 29.6%).^[25] In addition, the tendency to surmise non-clinical elements in making clinical decisions regarding neurosurgical diseases and procedures among people living in LMICs may affect their health-seeking behavior and consequently complicate expeditious management.^[14]

Indonesia, as one of the LMIC countries, has benefited from neurosurgical care for 75 years after its conception in 1948 by Lenshoek, an Indonesian-born Dutch neurosurgeon.^[19] The dissemination of service and education that were propagated afterward resulted in the establishment of eight neurosurgical training centers located across the country, from which around 493 neurosurgeons have been trained until the time this article was written.^[15] However, despite this, equity in the access to and the availability of neurosurgical services has not yet been attained. In 2021, it was found that of 38 provinces, only 28 have practicing neurosurgeons.^[13] The neurosurgeon-to-population ratio disparity between provinces is staggering, with roughly 1:110,000 in the capital city Jakarta, to virtually non-existent in several East Indonesia regions. Moreover, only 68% of Indonesians were within two hours of at least a level 1 of the World Federation of Neurosurgical Society facility type (able to manage trauma neurosurgery cases),^[25] meaning that around 88 million people had absolutely no prompt access to basic neurosurgical care. Furthermore, the unavailability of a detailed provincial neurosurgery register is alarming, considering tailored solutions may be necessary for each area in this archipelagic country comprising more than 17,000 islands.

The shortage of basic neurosurgical accouterment, the lack of guarantee of welfare and well-being for neurosurgeons, and the complicated bureaucratic access and protocols may dishearten any attempts to establish neurosurgical service in areas devoid of it. Far from braggadocio, any accounts that apprise the inception of such a framework may inspire and embolden fellow neurosurgeons dealing with similar challenges. Herewith, the author sought to elaborate on the start-up of a previously inactive neurosurgical service in North Maluku, an archipelagic rural province in East Indonesia, and to describe all cases managed within two years of service. The population/intervention/comparison/outcome statement is shown in Table 1.

MATERIALS AND METHODS

Regional information

North Maluku, formerly renowned as the powerhouse of world spice trade in the 14th–16th century, has a total area of

Table 1: The PICO statement for the present study.

PICO facets	Considerations
Population (P)	Neurosurgical patients living in North Maluku province, Indonesia
Intervention (I)	Neurosurgical service and registry for patients managed from January 2021 to December 2022
Comparison (C)	Other national and international studies pertaining the establishment of neurosurgical service
Outcome (O)	Information on patients' age, sex, point of entry, methods of payment, classification of disease, district of event, and in-hospital mortality
PICO: Population/intervention/comparison/outcome	

31,982.50 km², consisting of 30.9% land and 69.1% sea. Of 1474 islands, only 10% are inhabited. The total population in 2022 is estimated to be 1,319,338 people. There are 147 primary healthcare centers unequally distributed among the islands, with ten public hospitals in each ten districts. Dr. Chasan Boesoirie General Hospital, the only public hospital with neurosurgical capability, is located in Ternate Island, a district with a total area of 162.17 km² and an estimated population in 2022 of 206,475 people. The other nine districts, with their respective capital, approximate distance to Ternate (in the ascending order), and estimated population in 2022, are Tidore Islands (Tidore; 14.2 km; 118,247), West Halmahera (Jailolo; 36.1 km; 137,541), Central Halmahera (Weda; 73.9 km; 59,096), East Halmahera (Maba; 102.6 km; 94,510), North Halmahera (Tobelo; 125.2 km; 202,755), South Halmahera (Labuha; 157.5 km; 255,795), Morotai Islands (Morotai; 178.7 km; 76,102), Sula Islands (Sanana; 350.9 km; 105,293), and Taliabu Islands (Taliabu; 449.3 km; 58,744). As Ternate is completely separated from other districts by the Molucca Sea, passage thither must be undertaken by boats or ferries. Because a dedicated water ambulance is unavailable, transportation of neurosurgical patients is always delayed, having to conform to the public transportation schedule.

History of establishment

The first step of neurosurgery in the area can be traced back to the year 1993, when Professor R.M. Padmosantjojo performed reconstructive surgery on a 2-year-old anterior meningoencephalocele patient at the invitation of Chasan Boesoirie General Hospital, Ternate. As the public interest in the relatively new and unknown medical condition was high, the event was broadcast live by the local television station [Figure 1]. Professor R.M. Padmosantjojo returned in 1995 to perform a surgery on a 1.5-year-old occipital meningoencephalocele patient. These feats, however, were not followed through appropriately by the government, resulting in no further neurosurgical service for the next 26 years. At the end of 2020, the author, freshly graduated from the

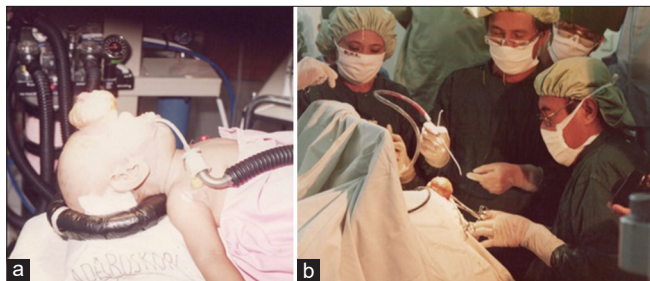


Figure 1: The first neurosurgical case managed in North Maluku, Indonesia. (a) A 2-year-old patient who suffered from anterior meningoencephalocele. (b) Professor R.M. Padmosantjojo (sitting) performed surgery with the assistance of Dr. Petonengan, the attending general surgeon (Source: Chasan Boesoerie General Hospital Archive).

neurosurgical residency at the University of Indonesia, was posted here to restart the service single-handedly.

Current activity

Because the nature of neurosurgery and its paraphernalia was relatively unknown to everyone in the region, during the 1st year, the author tried to build a good rapport with the hospital management (particularly staff in charge of daily medical service, billing, and procurement), contacted necessary instruments and medical consumables suppliers, and provided public information on neurological diseases and its management (e.g., the importance of wearing helmets and obeying the traffic rule to prevent traumatic brain injury (TBI), the importance of antenatal care and folic acid supplementation to detect congenital disease, e.g., hydrocephalus and dysraphism) through university lectures, local social events, on-air radio shows, etc.

The outpatient clinic is scheduled three times a week, and elective procedures are scheduled two days a week due to the limited capacity of the operating theater. Pre- and post-operative patients are admitted to a shared ward (30 beds) with other surgical specialties. Basic laboratory work-ups (e.g., blood count, electrolyte, and coagulation function) are available, but not cerebrospinal fluid analysis, blood serum culture, gas analysis, or inflammatory marker tests. Histopathological analyses must be done overseas since no in-house pathologist is present. The computed tomography scan was operational until February 2023, after which it malfunctioned due to technical issues. Magnetic resonance imaging is unavailable. All radiological images during the 1st year of service were self-analyzed by the neurosurgeon due to the absence of a radiologist.

Operating theater appurtenances

Three “mock-up” operating theaters are available for all types of general surgeries. These rooms, being originally

designed to be admission wards, lacked the essential features of operating theaters, for example, proper surgical lighting, controlled heating-ventilation-air conditioning systems, monitored water sources, and high-efficiency particulate air filters, increasing the risk of bacterial contamination. The lack of basic neurosurgical instruments has caused the author to use self-owned Hudson drills, Gigli wires, Penfield dissectors, shunt passers, and other necessary instruments. No microscope, microsurgical sets, endoscope, head fixation set, or C-arm were procured, and the plight remained until the time this article was written. The intensive care unit is occupied by three anesthesiologists, seven beds, and three ventilator machines that were often inoperable due to technical reasons. Central oxygen supply was unreliable, mobile X-ray was nonexistent, and power outage was a common event. No surgical nursing team had undergone specific neurosurgical nursing experience.

Patients database

The North Maluku Database in Neurosurgery (NOMADEN) is an effort to build a neurosurgical registry in North Maluku, Indonesia, encompassing all types of neurological disorders encountered. Information on age, sex, point of entry, methods of payment, classification of diseases, district of event, and in-hospital mortality from patients managed in Chasan Boesoerie General Hospital, Ternate, from January 2021 to December 2022 were prospectively recorded and cross-matched with the operating room procedure log book and the hospital medical record daily. The point of entry was divided into emergency department, ward (inpatient consultation), and outpatient. Methods of payment consisted of the National Health Insurance (NHI), out-of-pocket, and others (private insurance, social donation, etc.) Classification of diseases was based on the Japan Neurosurgical Database (JND) classifications, that is brain tumor, cerebrovascular diseases, functional, hydrocephalus/developmental anomalies, encephalitis/infection/inflammatory and miscellaneous diseases, neurotrauma, and spinal and peripheral nerve disorders.^[11] One appointed main diagnosis can be accompanied by one subsidiary diagnosis or more. All cases and procedures were thoroughly registered with consent.

Statistical analysis

Descriptive analyses were performed on two main groups: (i) the overall cohort group, consisting of new patients and their main diagnoses, and (ii) the neurosurgical subgroup, comprising patients who had undergone at least one neurosurgical procedure related to the main diagnosis, with additional procedures related to the subsidiary diagnoses if any. Continuous variables were presented as mean \pm standard deviation (SD), and categorical variables as count and percentages. Within each year of service, means of age

were compared using the Student's *t*-test, while differences between frequencies of categorical variables were examined through the Chi-square test or Fisher's exact test, whenever appropriate, to test for statistical significance. All analyses were done using IBM Statistical Package for the Social Sciences version 25 software.

RESULTS

The overall cohort group: Basic characteristics

Within the research period, 998 new patients were registered, with a mean age \pm SD of 34.7 ± 19.6 years [Table 2]. The majority of them were male (60.3%), referred from within Ternate Island (54.2%), presented to the emergency department (59.6%), and suffered from neurotrauma (54.9%). NHI was the main payment type (53.9%). Neurotrauma was the most prevalent disease managed in the 1st and 2nd years. The overall in-hospital mortality was 7.9%. Compared to the 1st year, in the 2nd year, a significant increase in the number of inpatient consultations (9.7% vs. 15.1%), brain tumors (7.4% vs. 10.2%), and patients referred from outside Ternate Island (43% vs. 47.8%) were observed.

The neurosurgical subgroup: Basic characteristics

In total, 216 procedures were performed [Table 3], the majority of which were emergency cases (56.5%), diagnosed with neurotrauma (40.7%), and referred from outside Ternate Island (62.5%). Most health expenses were paid for by the NHI (69.4%). The overall post-surgical in-hospital mortality was 19.9%. In contrast to the 1st year, there were fewer emergency cases (65.6% vs. 50.4%), fewer neurotrauma-related diseases (47.1% vs. 36.4%), fewer hydrocephalus/developmental anomalies cases (26.4% vs. 15.5%), and fewer referral from outside Ternate (69% vs. 58.1%) in the 2nd year.

The neurosurgical subgroup: Distribution across age decades and districts

Surgery was mostly performed on patients in their 1st decade of life (18.5%), in which group hydrocephalus/developmental anomalies was the most prevalent disease operated [Table 4]. Neurotrauma was the most common indication for surgery among patients in the 2nd–8th decades of life, particularly in the 4th decade of life (62.5%). No surgeries were done among patients in their 9th decade of life. Figure 2 presents the distribution of surgically managed neurological disease across districts. Ternate was the only district where all seven types of neurological diseases were encountered and operated on. Neurotrauma was the topmost disease operated in all except Morotai and South Halmahera districts, where hydrocephalus/developmental anomalies were the case.

Table 2: Basic characteristics of the overall cohort group ($n=998$).

	Total $n=998$	2021 $n=421$	2022 $n=577$	<i>P</i>
Age, mean years \pm SD	34.7 \pm 19.6	34.2 \pm 20.1	35.1 \pm 19.2	0.45
Sex, <i>n</i> (%)				
Male	602 (60.3)	242 (57.5)	360 (62.4)	0.1
Female	396 (39.7)	179 (42.5)	217 (37.6)	
Point of entry, <i>n</i> (%)				
Emergency department	595 (59.6)	260 (61.8)	335 (58.1)	0.04
Ward (inpatient)	128 (12.8)	41 (9.7)	87 (15.1)	
Outpatient	275 (27.6)	120 (28.5)	155 (26.9)	
Methods of payment, <i>n</i> (%)				
National health insurance	538 (53.9)	224 (53.2)	314 (54.4)	0.68
Out-of-pocket	347 (34.8)	145 (34.4)	202 (35)	
Others	113 (11.3)	52 (12.4)	61 (10.6)	
Classification of diseases, <i>n</i> (%)				
Brain tumor	90 (9)	31 (7.4)	59 (10.2)	0.05
Cerebrovascular disease	58 (5.8)	24 (5.7)	34 (5.9)	
Functional	39 (3.9)	16 (3.8)	23 (4)	
Hydrocephalus/developmental	60 (6)	36 (8.6)	24 (4.2)	
Encephalitis/infection/misc.	12 (1.2)	6 (1.4)	6 (1)	
Neurotrauma	544 (54.5)	232 (55.1)	312 (54.1)	
Spine and peripheral nerve	195 (19.5)	76 (18.1)	119 (20.6)	
District of event, <i>n</i> (%)				
Within Ternate	541 (54.2)	240 (57)	301 (52.2)	0.05
Tidore	83 (8.3)	39 (9.3)	44 (7.6)	
Halmahera, West	63 (6.3)	30 (7.1)	33 (5.7)	
Halmahera, South	48 (4.8)	23 (5.5)	25 (4.3)	
Halmahera, Central	151 (15.1)	47 (11.2)	104 (18)	
Halmahera, East	44 (4.4)	18 (4.3)	26 (4.5)	
Halmahera, North	31 (3.1)	8 (1.9)	23 (4)	
Morotai	17 (1.7)	7 (1.7)	10 (1.7)	
Sula Islands	18 (1.8)	7 (1.7)	11 (1.9)	
Taliabu Islands	2 (0.2)	2 (0.5)	0 (0)	
In-hospital mortality, <i>n</i> (%)	79 (7.9)	41 (9.7)	38 (6.6)	0.08

SD: Standard deviation

No surgeries were performed for patients from the Taliabu district.

DISCUSSION

The NOMADEN register

In the era of evidence-based medicine, a patient registry is crucial for the evaluation and sustainment of good medical-surgical practice, educative public information, and effective healthcare policy-making. The NOMADEN register was

Table 3: Basic characteristics of the neurosurgical subgroup (*n*=216).

	Total	2021	2022	<i>P</i>
	<i>n</i> =216	<i>n</i> =87	<i>n</i> =129	
Age, mean years±SD	33±20.4	29.2±20.8	35.6±19.8	0.02
Sex, <i>n</i> (%)				
Male	145 (67.1)	61 (70.1)	84 (65.1)	0.4
Female	71 (32.9)	26 (29.9)	45 (34.9)	
Point of entry, <i>n</i> (%)				
Emergency department	122 (56.5)	57 (65.5)	65 (50.4)	0.04
Ward (inpatient)	34 (15.7)	8 (9.2)	26 (20.2)	
Outpatient	60 (27.8)	22 (25.3)	38 (29.5)	
Methods of payment, <i>n</i> (%)				
National health insurance	150 (69.4)	54 (62.1)	96 (74.4)	0.03
Out-of-pocket	33 (15.3)	13 (14.9)	20 (15.5)	
Others	33 (15.3)	20 (23)	13 (10.1)	
Classification of diseases, <i>n</i> (%)				
Brain tumor	21 (9.7)	8 (9.2)	13 (10.1)	0.005
Cerebrovascular disease	15 (6.9)	5 (5.7)	10 (7.8)	
Functional	7 (3.2)	0 (0)	7 (5.4)	
Hydrocephalus/developmental	43 (19.9)	23 (26.4)	20 (15.5)	
Encephalitis/infection/misc.	8 (3.7)	4 (4.6)	4 (3.1)	
Neurotrauma	88 (40.7)	41 (47.1)	47 (36.4)	
Spine and peripheral nerve	34 (15.7)	6 (6.9)	28 (21.7)	
District of event, <i>n</i> (%)				
Within Ternate	81 (37.5)	27 (31)	54 (41.9)	0.006
Tidore	31 (14.4)	16 (18.4)	15 (11.6)	
Halmahera, West	17 (7.9)	10 (11.5)	7 (5.4)	
Halmahera, South	17 (7.9)	7 (8)	10 (7.8)	
Halmahera, Central	29 (13.4)	5 (5.7)	24 (18.6)	
Halmahera, East	21 (9.7)	13 (14.9)	8 (6.2)	
Halmahera, North	11 (5.1)	3 (3.4)	8 (6.2)	
Morotai	5 (2.3)	4 (4.6)	1 (0.8)	
Sula Islands	4 (1.9)	2 (2.3)	2 (1.6)	
Taliabu Islands	0 (0)	0 (0)	0 (0)	
In-hospital mortality, <i>n</i> (%)	43 (19.9)	20 (23)	23 (17.8)	0.3

SD: Standard deviation

founded for such purposes. Since the 3rd year of service is currently ongoing, only the first 2-year journey was depicted. To the best of our knowledge, no study from Indonesia has attempted to provide a comparable overview on a provincial level.

Within two years, nearly a thousand new patients were taken care of, with almost a quarter of them experiencing neurosurgical procedures. These were accomplished amid sociodemographic, sociocultural, geographical, and clinical

circumstances that might potentially beset the care provision. As a society living in the eastern part of Indonesia, the North Maluku people have different traditional perceptions and beliefs toward disease and procedures from their counterparts in the West.^[33] Many still believe that diseases exist due to supernatural causes and, consequently, must be dealt with equally supernatural actions, for example, magic water, sacred leaves, and enchantments. This is complicated by the indecorous role of the extended family, especially in scenarios where important medical actions need to be made swiftly. Oftentimes, informed consent can be obtained only after all members of the extended family have made their approval, resulting in delayed time to treatment or, more severely, death of the patient. The geographic affair of North Maluku also offers a unique situation for any medical provider aspiring to improve the health care quality herein. The author believes that by understanding the uniqueness of each society, progress will eventually be accomplished by every neurosurgeon coping with alike challenges in remote areas. Several findings below are important to be raised and made as stepping stones for future improvements.

Point of entry and methods of payment

The majority of patients were presented to the emergency department, indicating acute conditions necessitating prompt diagnosis and management, conservatively and surgically. Although the state of affairs was manageable at that moment by a single neurosurgeon, who was constantly on alert for 24 hours for two years, this is far from ideal. It is known that there has to be at least one neurosurgeon per 212,000 people to provide neurotrauma management, while in North Maluku, one neurosurgeon was responsible for 1.3 million people.^[4] More neurosurgeons are needed to balance the striking neurosurgeon-to-population ratio and, hopefully, improve the quality of care. On another note, a notable increase in intrahospital patient referrals by other specialists was evident in the 2nd year of service, likely denoting elevated medical recognition from other specialists toward neurosurgery.^[9] This may improve the opportunity of exposure for patients needing neurosurgical management.

In this paper, NHI was identified as the payment method of choice, particularly by those who underwent surgery. This optimal usage of one of the world's largest single-payer health insurance is in line with the aim stated by the Indonesian government in its introduction in 2014: To achieve Universal Health Coverage for all citizens.^[1] However, membership in the scheme is not always equivalent to the actual attainment of healthcare needs, which is the case in areas with poor access and availability to healthcare. With the founding of the previously inactive neurosurgical service in North Maluku, one of several provinces with the highest health needs,^[24] this issue can be ameliorated, overcoming the scarcity and

Table 4: The frequency of surgically managed neurological disease within decades ($n=216$).

Age (years)	The Japan Neurosurgical Database disease classification, n (%)						
	Brain tumor	Cerebrovascular disease	Functional	Hydrocephalus and developmental	Infection and misc.	Neurotrauma	Spinal and peripheral
0–9	2 (5)	0 (0)	0 (0)	23 (57.5)	2 (5)	13 (32.5)	0 (0)
10–19	2 (9.5)	0 (0)	0 (0)	5 (23.8)	0 (0)	13 (61.9)	1 (4.8)
20–29	1 (3.2)	0 (0)	1 (3.2)	4 (12.9)	0 (0)	16 (51.6)	9 (29)
30–39	3 (9.4)	0 (0)	1 (3.1)	3 (9.4)	0 (0)	20 (62.5)	5 (15.6)
40–49	7 (18.4)	4 (10.5)	0 (0)	2 (5.3)	2 (5.3)	13 (34.2)	10 (26.3)
50–59	5 (15.6)	6 (18.8)	5 (15.6)	3 (9.4)	3 (9.4)	6 (18.8)	4 (12.5)
60–69	1 (5.6)	2 (11.1)	0 (0)	2 (11.1)	1 (5.6)	7 (38.9)	5 (27.8)
70–79	0 (0)	3 (7.5)	0 (0)	1 (2.5)	0 (0)	0 (0)	0 (0)

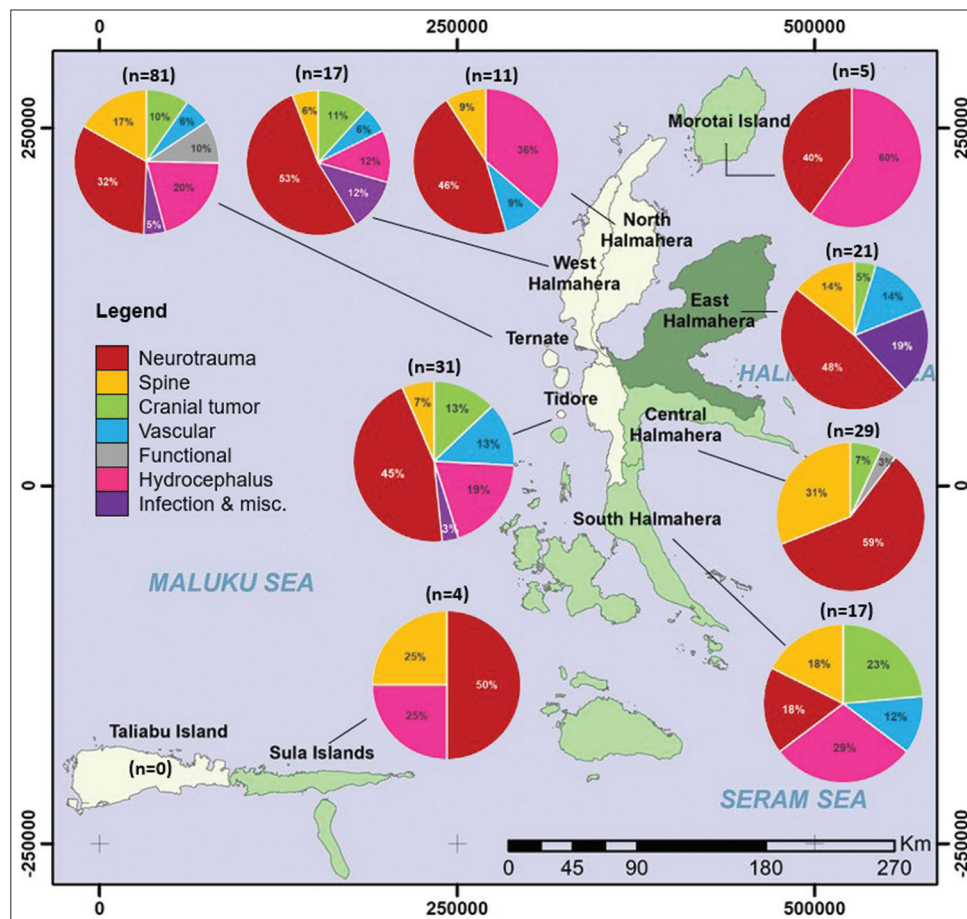


Figure 2: he distribution of surgically managed neurological disease in each district in North Maluku, year 2021-2022.

reducing the burden of impoverishing and catastrophic expenditures by patients and their families.^[21] In addition, the increased NHI utilization in the 2nd year of the service may indicate the growing conviction of the North Maluku people to engage in the national scheme, a fact that must be responded to by equitable improvements in the quality of care.

The neurological disease classification

The JND major classification of diseases was utilized for its generality.^[11] The easiness of categorizing main diagnoses of neurological disease makes registration simple and feasible, ideal for use in areas where the neurosurgeon has to juggle between clinical and research work by themselves. Since the

JND represents the real-life distribution of neurosurgical disease in a developed country, the author noticed several points that may provide hints about the demographic and epidemiological differences by comparing it with the NOMADEN. In the former, (i) the majority of patients in both cohort and neurosurgical subgroup were in the 8th decade of life, (ii) cerebrovascular diseases were the top disease in the overall cohort group (53.1%) and neurosurgical subgroup (41%), and (iii) octo-, nona-, and centenarian composed 28.8% and 24.5% of total patients in the overall cohort group and neurosurgical subgroup, respectively. Meanwhile, in the NOMADEN, (i) the majority of patients were in the 5th decade (cohort group) and 1st decade (neurosurgical subgroup) of life; (ii) neurotrauma was the top case in both cohort and neurosurgical subgroup; and (iii) octogenarian composed only 0.4% of all patients in the overall cohort group, none were identified in the neurosurgery subgroup. The high prevalence of cerebrovascular disease and elderly populations in the JND survey may represent the distinct healthcare burden in developed countries. In contrast, the occurrence of neurotrauma within the young and productive age group in the NOMADEN may express the main challenge to overcome in the developing country.

Neurotrauma: A multifaceted disease

Neurotrauma/TBI was identified as the most prevalent pathology encountered and managed operatively. We postulated that this is most likely related to motorcycle-related road traffic injury (RTI), which is responsible for 72.7% of trauma cases in Indonesia.^[26] As one of the significant contributors to the total global disease burden, 69 million new TBI cases are estimated to arise annually worldwide, and 49.9 million will take place in LMICs. In addition, 26.5% of these cases are predicted to occur in the South East Asian region, where Indonesia is located.^[10] Other than falls, assault/violence, or other causes, motorcycle-related RTI is known to be a major cause of TBI in LMICs^[8], wherein motorcycles become the primary means of daily commute to work, school, and other social activities.^[2] Indeed, the high volume of motorcycle units, combined with poor compliance with traffic laws and driving rules, are known to be directly connected to the poor outcome of TBI.^[3] In North Maluku, the Indonesian National Police in 2022 reported that the number of motorcycles reached 308,597 units, which is equal to one unit per four people.^[16] The substandard safety habit is also evident in the National Basic Health Research report in 2018, which divulged that 50.3% of motorcyclists and pillion riders in this province never wore any helmet.^[25] Road quality is another issue that may be related to the high prevalence of TBI. The Indonesian Central Bureau of Statistics in 2021 stated that 56.4% of the road outside Ternate Island is in a poor state, potentially increasing the risk of RTI.^[12] Considering these facts, it is clear that neurosurgeons must

assume a role outside the operating theater and hospital as advocates to assist in neurotrauma-related policy proposals and decision-making together with policymakers and law enforcement.

The burden of an archipelagic region

Distance, duration, and mode of transportation are innate issues that arise with North Maluku being a rural archipelagic province. It is suggested that the ideal neurosurgery center is accessible within four hours of disease onset, a goal that those factors may hinder. In this research, it is evident that the number of patients decreased as the distance to the neurosurgery center increased, even reaching zero in the case of Taliabu district. However, with the majority of patients who underwent surgery being referred from outside Ternate (62.5%), expeditious solutions must be found to elevate the quality of care. To objectively identify weaknesses in neurosurgical care accessibility and equity and to provide hard evidence to the government for improvement and support, the author suggests the utilization of geographic information systems and spatial analyses of population, public facilities, and roads in the future, such as one performed in the Maluku province.^[20]

Comparison with similar neurosurgical initiative

Despite its existence in Indonesia for more than seven decades, details about the establishment of neurosurgical enterprises nationally, especially in rural areas, are rarely chronicled and scientifically published. One report by Wicaksono *et al.*, however, provided an exemplary story of how neurosurgery consultants and trainees from Dr. Sardjito General Hospital, Yogyakarta, were able to provide support for three general hospitals located outside Java Island, all devoid of any neurosurgical service, from September 2017 to September 2019.^[32] During that time, a total of 600 neurosurgical cases were treated. Furthermore, while specific accounts of the initiatives of these hospitals were not presented, they proposed a model of collaboration between the neurosurgery division, government, health office, and stakeholders for the improvement of neurosurgical care in underdeveloped areas, one that may potentially be implemented in North Maluku in the future.

Overseas, a study by Farhan *et al.* about the newly founded neurosurgical service in Gilgit-Baltistan, a remote area in northern Pakistan populated by almost two million people, described nearly parallel circumstances with our study: With limited diagnostic and operative tools, the neurosurgeon single-handedly managed to handle 223 neurosurgical cases in its first two years of service, the majority of which was neurotrauma (46.6%).^[7] Similar geographic difficulty was encountered, with the area being dominated by mountainous and rocky terrains, interfering with safe patient transfer.

Other Indonesian neurosurgery registries

There are a handful of publications of note from Indonesia that focus on particular neurological diseases managed neurosurgically. Thohar Arifin *et al.* reported their experience with 589 surgically managed epilepsy patients from 1999 to 2017 in two neurosurgical centers in Semarang, Central Java.^[30] Prasetya *et al.* reported the characteristics of 100 surgically-managed trigeminal patients from 2014 to 2021 in a national referral hospital in Jakarta.^[23] Wahyuhadi *et al.* reported a register of 1540 patients who underwent surgery for brain tumors during 2012–2018 in a single general academic hospital in Surabaya, East Java.^[31] Tandian *et al.* made a specific report on the characteristics, management, and outcome of 44 medulloblastoma patients surgically managed from 2011 to 2018 in one national referral hospital in Jakarta.^[29] Rosyidi *et al.* registered the characteristics and clinical outcomes of 209 TBI patients managed from 2015 to 2017 in West Nusa Tenggara.^[27] Faried *et al.* reported the characteristics and outcomes of 407 motorcyclists admitted for moderate/severe TBI from 2013 to 2014 in Bandung, West Java.^[6] Sobana *et al.* reported the incidence of pre-shunt seizure in 334 hydrocephalus patients in Bandung, West Java.^[28] Although interpretations were limited due to differences in study population and diseases, together with this paper, they offered profound clinical insight and regional peculiarities that have the potential to be combined into one national Indonesian neurosurgical database, which, despite its importance in the national healthcare system, is still practically absent.

Future directions and sustainability

Of all neurosurgical cases left unattended globally due to the care deficit, half of which are identified in Southeast Asian countries.^[5] LMICs are especially in dire need of additional neurosurgical services. There is an urgent global need for essential neurosurgical procedures, of which neurotrauma and hydrocephalus are included.^[22] Both were also the two most common indications for surgery in this study. The Lancet Global Health Commission in 2018 proposed a high-quality health-system framework to achieve an equitable, resilient, and efficient health system.^[17] The foundations of the framework consist of five components: Population (with their specific character, health needs, attitudes, and preferences), governance (law- and policymakers regulating the health system), platforms (all types of healthcare facilities and their internal cooperation), workforce (human resources essential for care provision), and tools (health supplies, equipment, and human mindset). The NOMADEN study has identified issues in four of five of these components: The unique characteristics and traditional perspective of the North Maluku people toward neurosurgery (population), the deficit of high-quality neurosurgical facilities (platforms),

the lack of neurosurgeons and supporting specialties (workforce), and the scarceness of essential instruments, and commitment by the hospital management, and poor road and infrastructure (tools). Since these components are interrelated, the problem solution in a single component is inseparable from the others. To maintain service sustainability in North Maluku, the author suggests several actions be taken: initiation of health education to the people through social media (population); improvement of local and national government cooperation by the dissemination of the achievements and the obstacles encountered by the ongoing service (governance); optimization of remote primary health-care centers to expedite patient transportation (platform); the introduction of appropriate incentives for neurosurgeons interested working in the area, and the dispatch of local general practitioners to training centers to be educated as future local neurosurgeons (workforce); and prioritized procurement of equipment according to budget and health need. Moreover, we believe that the model of collaboration proposed by Wicaksono *et al.* may help to address issues in each component aforementioned.^[32]

Limitation and strength

Some notable limitations are identified. This study is a snapshot of the neurosurgical service in North Maluku in the year 2021–2022, the situation of which might have changed by the time the article was published. The study population consisted of patients residing in an archipelagic area in a developing country whose distinct characteristics cannot be generalized to other populations. Selection bias was unavoidable since only those presented to the neurosurgery center were registered, decreasing the study's representativeness. The actual onset-to-admission or onset-to-surgery time, a factor that influences patients' outcomes, was not included due to poor information reliability, either verbal (from witnesses or family relatives) or in writing (medical records). Human error might be introduced in the data registration since the author was the one performing clinical and research works altogether, where exhaustion is an inevitable issue. Nonetheless, because no other neurosurgical center exists in the area, this pilot research may be perceived as the only picture of the real-world situation of the neurosurgical service in North Maluku.

CONCLUSION

A large portion of neurosurgery patients in North Maluku were those young and at productive age who were transported from outside Ternate with acute neurological disease (particularly neurotrauma). Distance and geographical circumstances may have a profound effect on access to neurosurgical services. Although barely initiated and laden with problems, great strides have been made in the history

of neurosurgery in Indonesia by the presence of this service. The start-up journey may be viewed as a walkthrough for other neurosurgeons facing the same difficulties. Undoubtedly, the education of native neurosurgeons, support from experienced neurosurgeons, national and international medical associations, and, more importantly, the local and central government in forms of clinical and surgical works, knowledge transfers, surgical equipment provision, and funding for patient care are critical for ensuring sustainable service.^[18] Finally, young neurosurgeons in both developed and developing countries must be courageous enough to carry the wind of change and achieve health justice.

Ethical approval

The Institutional Review Board has waived the ethical approval for this study.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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