

Occurrence of stroke in children and young adults in Indonesia: a multicenter private hospital study

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Background: Most studies that estimate the occurrence of childhood stroke use heterogeneous methods and rely on International Classification of Diseases codes, a strategy that may be unreliable.

Purpose: This study aimed to estimate the occurrence of childhood stroke in Indonesia using imaging and clinical data from a private hospital network.

Methods: This cross-sectional study used consecutive retrospective multicenter data samples collected in 2019–2023. The study cohort included children aged >28 days to young adults aged 24 years with confirmed ischemic or hemorrhagic stroke on computed tomography (CT) or magnetic resonance imaging (MRI). The 1-year occurrence was calculated, and the data analysis was performed using IBM SPSS Statistics ver. 26.0.

Results: Over 5 years, the performance of 8,987 CT and 6,133 MRI scans resulted in the identification of 1,074 stroke cases. The average patient age was 14.8±7.0 years. Stroke occurrence was highest in 2021 (9.08%) and lowest in 2022 (5.91%). Male patients accounted for 67.9% of cases, with hemorrhagic strokes accounting for 83.4% of the total, primarily resulting from accidents (73.2%) and predominantly occurring in the frontal region (37.1%). A significant majority of cases (66.7%) were reported in Java. Males had a relative risk of 1.93 (95% confidence interval, 1.48–2.52; $P<0.001$) for hemorrhagic stroke versus females.

Conclusion: The incidence of childhood stroke revealed critical epidemiological trends and disparities, emphasizing the need for targeted public health interventions and enhanced stroke prevention strategies in Indonesia.

Key words: Stroke, Indonesia, Occurrence, Radiography, Child

Key message

Question: What is the occurrence of pediatric stroke in Indonesia?

Finding: This multicenter study identified 1,074 stroke cases, predominantly hemorrhagic (83.4%), with males and older children at higher risk. Accidents were the primary cause (73.2%).

Meaning: Pediatric stroke in Indonesia shows critical epidemiological trends, highlighting the need for targeted prevention efforts, particularly for high-risk groups like males and accident victims.

Introduction

Despite being one of the top contributors to disabilities among children, there is a significant lack of epidemiological data on pediatric stroke in Indonesia. Stroke was identified as the second leading cause of death and the third leading cause of disability globally.¹⁾ In Indonesia, stroke is the leading cause of death. According to the 2018 Indonesian Basic Health Research (Riskesdas) report, stroke in Indonesia increased from 7 per 1,000 people in 2013 to 10.9 per 1,000 in 2018. Financially, stroke is one of the most costly catastrophic diseases, with expenditures reaching 3.23 trillion rupiah (\$218.92 million) in 2022, making it the third highest after heart disease and cancer. This represents a significant increase from 2021, when the spending was 1.91 trillion rupiah (\$134.51 million).²⁾ Indonesia has one of the highest rates of stroke burden and mortality rates among other Southeast Asian (SEA) countries.³⁾

Pediatric stroke is distinct from adult stroke as it is not predominantly influenced by typical adult risk factors

such as hypertension and smoking.^{3,4)} Pediatric stroke results in substantial morbidity and mortality. Approximately 10%–25% of children who suffer a stroke will die, up to 25% will experience a recurrence, and up to 66% will have lasting neurological deficits or develop subsequent seizure disorders, learning difficulties, cerebral palsy,⁵⁾ or developmental issues. The early onset of these impairments along with their profound impact on the quality of life for both the child and family, substantially increases the economic and emotional burden on society.⁶⁾ Therefore, early detection and management are crucial in mitigating the impacts of pediatric stroke.

Epidemiological data provides clinicians with an estimate of disease occurrence in their local area. This occurrence information is critical for predicting patient diagnoses, as it affects the accuracy and reliability of diagnostic tests, ultimately helping to confirm or rule out specific conditions.⁷⁾ Current data on stroke burden and risk factors is inadequate, underscoring the urgent need for high-quality data collection at both hospital and population levels, particularly in the SEA region.⁸⁾ Diagnosing childhood stroke based solely on clinical criteria is especially challenging compared to adults. Among children presenting with sudden onset of focal deficits, nonstroke conditions are identified in 21%–90% of cases, including migraine (28%), seizures (15%), Bell's palsy (10%), and conversion disorders (6%).⁹⁾ Therefore, imaging confirmation is essential for diagnosing pediatric stroke, unlike adult stroke where the clinical diagnosis (not pathological diagnosis of stroke types) often follows the World Health Organization criteria. Additionally, using International Classification of Diseases (ICD) codes for identifying pediatric stroke is less reliable compared to their use in adult stroke cases.¹⁰⁾ A national study in the United States also discovered that research relying solely on ICD codes may underestimate the rates of childhood ischemic stroke, particularly among neonates.¹¹⁾

There are few studies dedicated solely to examining the occurrence of childhood stroke in Indonesia; the majority of research tends to focus on adults and the elderly.^{12–14)} A review of the Global Burden of Disease Study 2019 data found that the occurrence rate of stroke in children under 5 years old was 23.1 per 100,000, while in children aged 5–14 years, it was 20.4 per 100,000.¹⁵⁾ There are also limited studies estimating the occurrence of childhood stroke in Indonesia using imaging data.

Therefore, this study aims to analyze the characteristics of childhood and adolescent stroke cases in Indonesia using imaging data, confirmed by clinical data from a multicenter network private hospital in Indonesia.

Methods

1. Ethical approval

The proposal for this study was approved by the Ethics Committee of Pelita Harapan University, Tangerang, Indonesia, under number 220/K-LKJ/ETIK/VI/2024.

2. Sampling and study population

This cross-sectional study utilizes consecutive sampling from multicenter data. This hospital, part of a privately owned network with over 41 branches across 20 provinces in Indonesia, has been interconnected through the same Picture Archiving and Communication System (PACS) since 2019. These hospitals serve as secondary and tertiary network centers with more than four million patients annually. This connectivity allowed us to retrospectively analyze patients with all stroke subtypes from various provinces in Indonesia. Radiographic and clinical data were obtained from our PACS using the keyword "stroke." Potential candidates were consecutively included from January 2019 to December 2023. In this manuscript, stroke is broadly defined as "a sudden neurological sign or symptom caused by localized brain infarction or hemorrhage."¹⁶⁾ In this study, case ascertainment was determined by the final diagnosis provided by the clinicians, while the classifications of traumatic versus nontraumatic were based on the information recorded in the medical records.

The study includes children aged over 28 days up to young adults (24 years old) diagnosed with ischemic or hemorrhagic stroke confirmed by computed tomography (CT) or magnetic resonance imaging (MRI). Eligible participants exhibit sudden onset focal neurological deficits, altered consciousness, seizures, or headaches. Stroke subtypes considered encompass subdural hemorrhage, epidural hemorrhage, subarachnoid hemorrhage (SAH), and intracranial hemorrhage, attributable to both traumatic and nontraumatic origins. In this study, ischemic stroke is characterized by localized damage to brain tissue in a specific vascular region caused by a reduction in blood flow or oxygen supply. In contrast, hemorrhagic stroke encompasses spontaneous bleeding within the brain's parenchyma (intraparenchymal hemorrhage) and spontaneous (nontraumatic) SAH occurring just beneath the brain's surface.¹⁷⁾ Patients who underwent follow-up imaging during the study period were classified as single stroke cases.

The imaging protocol involved scans in the axial, sagittal, and coronal planes. Acquired images included T1-weighted turbo spin echo (repetition time [TR] = 250 msec, echo time [TE] = 2 msec), T2-weighted turbo spin echo (TR = 3,000 msec, TE = 80 msec), and fluid-attenuated inversion recovery (TR = 11,000 msec, TE = 125 msec). Cross-sectional

diffusion-weighted imaging was performed using a single-shot spin-echo echo-planar imaging sequence with NEX = 1, SPIR + SSGR fat suppression, and a b-value of 0 and 800 s/mm².¹⁸⁾ Each image was reviewed by radiology residents, who cross-checked it with the radiologists' final report. In cases where the residents disagreed with the report, a pediatric radiologist (JL) was consulted to resolve the discrepancy.

The exclusion criteria encompassed patients without any vascular insults attributable to stroke upon imaging, despite strong clinical indications suggesting otherwise. This manuscript also excluded infarctions or hemorrhages resulting from other causes such as infections or tumors. Additionally, hypoxic-ischemic encephalopathy, old infarctions, postoperative scans, and chronic small vessel ischemia were also excluded from the study.

3. Statistical analysis

The normality of all numerical values was assessed using the Kolmogorov-Smirnov test. If the data exhibited a normal distribution, descriptive statistics including mean and standard deviation were reported. For skewed data, the median and range were presented. The 1-year occurrence was calculated using the number of total scans as the denominator for the period occurrence proportions over 1 year. The numerator included all patients who had experienced an illness episode within that specific year.¹⁹⁾ The analysis of relative risk (RR) was carried out using IBM SPSS Statistics ver. 26.0 (IBM Co., Armonk, NY, USA).

Results

The hospital data reveals 8,987 CT scans and 6,133 MRI scans over the 5 years, identifying a total of 1,074 stroke cases. The number of scans increased annually, with 2023 showing the highest number compared to previous years. However, in 2021, MRI detected the highest number of stroke cases (n=44), which was consistently lower in other years (around 13-16 cases) whereas in 2023, CT scans

Table 1. Descriptive characteristics of study population (n=1,074)

Variable	No. (%)
Age group (yr)	
<1	51 (4.7)
1–4	74 (6.9)
5–9	147 (13.7)
10–14	163 (15.2)
15–19	295 (27.5)
20–24	344 (32)
Sex	
Male	729 (67.9)
Female	345 (32.1)
Types of stroke	
Ischemic	178 (16.6)
Hemorrhagic	896 (83.4)
Types of hemorrhagic stroke	
EDH	299 (33.4)
ICH	221 (24.7)
SAH	131 (14.6)
SDH	245 (27.3)
Laterality	
Right-sided	364 (33.9)
Left-sided	383 (35.6)
Bilateral	327 (30.5)
Stroke location	
Frontal	398 (37.1)
Temporal	200 (18.6)
Occipital	55 (5.1)
Parietal	151 (14.1)
Others	270 (25.1)
Geographical location	
Sumatra	124 (11.5)
Java	716 (66.7)
Kalimantan	150 (14)
Sulawesi	84 (7.8)
Modality of imaging	
CT	971 (90.4)
MRI	103 (9.6)
Accident	
Yes	786 (73.2)
No	288 (26.8)

EDH, epidural hemorrhage; ICH, intracranial hemorrhage; SAH, subarachnoid hemorrhage; SDH, subdural hemorrhage; CT, computed tomography; MRI, magnetic resonance imaging.

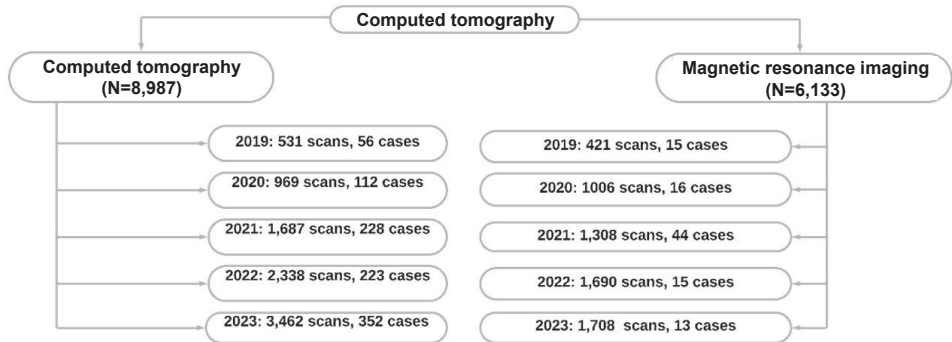


Fig. 1. CONSORT (Consolidated Standards of Reporting Trials) diagram for study enrollment.

identified the greatest number of stroke cases (N=352) (Fig. 1).

The mean age of the children is 14.8±7.0 years. The largest age group is 20–24 years (32%), followed by 15–19 years (27.5%) and 10–14 years (15.2%) (Table 1). Males constitute the majority at 67.9%, and most children and young adults experience hemorrhagic strokes (83.4%) typically due to accidents (73.2%), predominantly affecting the frontal region (37.1%). The brain injury's laterality is nearly balanced, with a slight left-sided predominance at 35.6%. Java Island accounts for the majority of cases (66.7%), followed by Kalimantan (14%) and Sumatra (11.5%) (Table 1).

More stroke cases were identified by CT scans as compared to MRI, with the occurrence of stroke cases by CT scans ranging from 9.54% in 2022 to 13.52% in 2021. In contrast, stroke occurrence detected by MRI ranged from 0.76% in 2023 to 3.56% in 2019. There was an increasing trend of detected stroke from 2019 to 2021, followed by a subsequent decrease from 2021 to 2023. The stroke occurrence ranges from 5.91% in 2022 to 9.08% in 2021 (Fig. 2).

Males have a RR of 1.93 times more likely (95% confidence interval [CI], 1.48–2.52; $P<0.001$) to suffer from hemorrhagic stroke compared to females. Children and young adults in Kalimantan are 50% less likely to experience hemorrhagic stroke (95% CI, 0.3–0.84; $P=0.004$) compared to the population in the Java region. Involvement in an accident increases the RR of hemorrhagic stroke by 7.46 times (95% CI, 6.28–8.86; $P<0.001$). Compared to 2019, only 2021 shows no significant difference in hemorrhagic stroke cases, while 2020 (RR, 0.86; 95% CI, 0.75–1.00; $P=0.028$), 2022 (RR, 0.88; 95% CI, 0.76–1.00; $P=0.04$), and 2023 (RR, 0.87; 95% CI, 0.76–1.00; $P=0.026$) indicate significantly reduced risk (Table 2).

Table 2. Analytic results of each variable by stroke subtype

Variable	Ischemic	Hemorrhagic	Relative risk (95% CI)	P value
Location				
Sumatra	17 (9.6)	107 (11.9)	1.05 (0.98–1.12)	0.21
Java	134 (75.2)	582 (65)	Reference	
Kalimantan	14 (7.9)	136 (15.2)	0.5 (0.3–0.84)	0.004
Sulawesi	13 (7.3)	71 (7.9)	0.8 (0.46–1.43)	0.55
Sex				
Male	93 (52.3)	636 (71)	1.93 (1.48–2.52)	<0.001
Female	85 (47.7)	260 (29)		
Age group				
28 day–<1 yr	9 (5.1)	42 (4.7)	Reference	
1–4 yr	12 (6.7)	62 (6.9)	0.96 (0.64–1.43)	1.000
5–9 yr	22 (12.4)	125 (14)	0.95 (0.75–1.21)	0.66
10–14 yr	25 (14)	138 (15.4)	0.96 (0.77–1.19)	0.67
15–19 yr	44 (24.7)	251 (28)	0.97 (0.85–1.1)	0.67
20–24 yr	66 (37.1)	278 (31)	1.01 (0.92–1.11)	1.000
Lateral				
Left	61 (34.3)	303 (33.8)	0.99 (0.8–1.23)	1.000
Right	63 (35.4)	320 (35.7)	1 (0.81–1.24)	1.000
Bilateral	54 (30.3)	273 (30.5)	Reference	
Accident				
Accident	6 (3.4)	780 (87)		
Not accident	172 (96.6)	116 (13)	7.46 (6.28–8.86)	<0.001
Year				
2019	17 (9.6)	54 (6)	Reference	
2020	15 (8.4)	113 (12.5)	0.86 (0.75–1)	0.028
2021	67 (38)	205 (23)	1 (0.87–1.17)	1.000
2022	32 (18)	206 (23)	0.88 (0.76–1)	0.04
2023	47 (26)	318 (35.5)	0.87 (0.76–1)	0.026

Values are presented as number (%) unless otherwise indicated.

CI, confidence interval.

Boldface indicates a statistically significant difference with $P<0.05$.

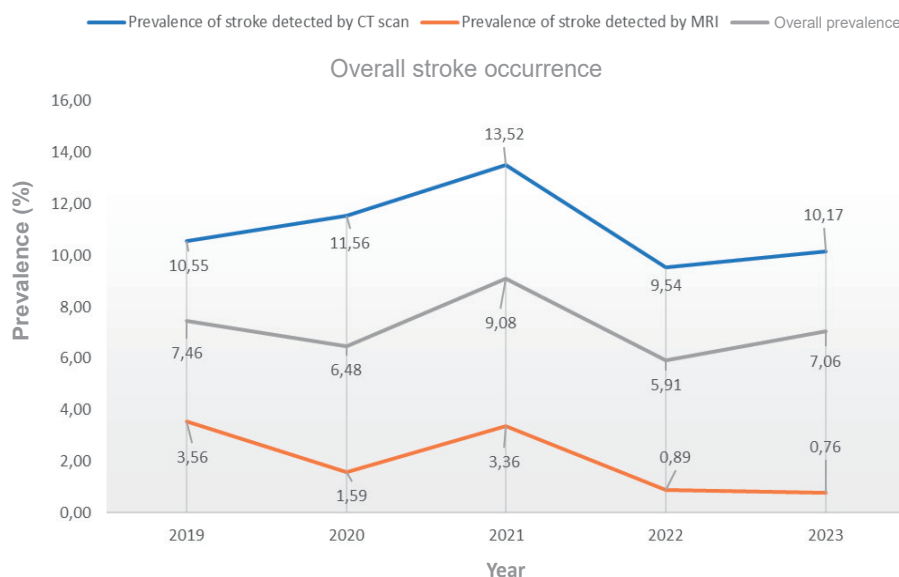


Fig. 2. Overall stroke occurrence detected by computed tomography (CT) and magnetic resonance imaging (MRI).

Discussion

The stroke occurrence ranges from 5.91% in 2022 to 9.08% in 2021. Out of 15,120 total neuroradiology scans performed in five years, there are 1074 cases detected. Males predominate with a predominance of hemorrhagic stroke, especially in the densest island in Indonesia, the Java Island. Males have a greater risk of hemorrhagic stroke, while children in Kalimantan are less likely to suffer from hemorrhagic stroke.

Direct comparison of these numbers is challenging because different studies use varying sampling methods and inclusion/exclusion criteria. The number of pediatric strokes in this population is quite low. This finding is in contrast with other literature which states that the incidence of childhood stroke is higher than hemorrhagic stroke, with an estimated 1 to 2 in 100,000 children for ischemic stroke as compared to ~1 to 1.7 in 100,000 children for hemorrhagic stroke.¹⁶⁾ One plausible explanation for this is that our cohort is dominated by accident cases, which inflates the hemorrhagic stroke cases. Another plausible explanation is also because the stroke protocol across different hospitals still utilizes CT scans as the first-line imaging modality. The recommended literature suggests the use of MRI for acute ischemic stroke (AIS) while CT scan is recommended for hemorrhagic stroke.²⁰⁾ Therefore, the imaging modality may preferentially bias towards the detection of hemorrhagic stroke.

Even when the criteria are similar, the statistical methods used to calculate the results can differ. One nationwide population-based study in Taiwan looked at the occurrence of stroke in children aged 1 month to 18 years between 2010 and 2011 and found a period occurrence of 14.3 per 100,000 individuals. Children aged <2 years old display the largest period occurrence of 29.1 per 100,000 individuals, the lowest occurrence occurs in children aged 6–9 years old with a period occurrence of 7.9 per 100,000 individuals, before rising back to 11.5 per 100,000 individuals in 14–18-year-old children, displaying a J-shaped occurrence curve.²¹⁾ Our data diverges from the conventional J-shaped curve pattern, showing an increase in occurrence rates with advancing age groups. Several factors may explain this finding. Firstly, there remains uncertainty and limited public awareness regarding childhood stroke. Given the low level of stroke awareness among Indonesians, childhood stroke may mistakenly be perceived as "impossible" among the general population.²²⁾ Secondly, the J-shaped curve is observed because the prevalence of perinatal stroke is high in several countries, though these findings vary due to the differing methodologies used in the studies.²³⁾ Thirdly, there was a decrease in stroke occurrence in 2020, coin-

ciding with coronavirus disease 2019 (COVID-19). Parents are more hesitant to bring their children to the hospitals, which results in lesser hospital detection for stroke cases. This trend has been observed worldwide and causes the J-shaped curve to be violated in our cohort.^{24,25)} Lastly, the J-shaped curve reflects an intriguing trend in pediatric ischemic stroke risk, where children under 1 year of age face the highest risk, followed by a significant decline after the first year.²⁶⁾ This risk stays low until mid-adolescence when it starts to rise again. Hence, differing children populations in Indonesia, which portends a different racial profile and comorbidity may not adhere to this curve.

Therefore, it is possible that children who suffered from stroke either passed away before reaching the hospital or their symptoms became too nonspecific to be recognized as stroke, resulting in a low detected occurrence among those under ten years old. This assertion is supported by stroke being the leading cause of death among individuals over five years old, accounting for 15.4% of all deaths in 2006.²⁷⁾ Secondly, the number of hemorrhagic strokes due to accidental causes is very high in this sample population, which is a risk factor for both ischemic and hemorrhagic stroke.⁶⁾

Indonesia mandates that only individuals over 18 years old with a valid driving license can legally drive. However, in practice, many underage individuals ride motorcycles recklessly, often while intoxicated or under the influence of illegal drugs, and without using any protective gear.²⁸⁾ Thus, the differing curve shapes observed in this study can be attributed to the underreporting of very young children and the overreporting of adolescents involved in trauma. These same reasons can also explain why hemorrhagic stroke is more prevalent in this study, as compared to the widely accepted theory of ischemic stroke being more prevalent in childhood cases.^{23,26)} This trend could also explain the reduced stroke risk in 2020 and 2022, as COVID-19 restrictions during these periods likely resulted in fewer children being involved in traffic, leading to a lower risk of stroke.

In pediatric patients presenting with stroke-like symptoms, MRI is the preferred imaging modality. However, obtaining high-quality scans in children can be challenging due to movement artifacts caused by restlessness in MRI scanners, often necessitating sedation.²⁶⁾ Furthermore, not all centers in Indonesia have CT scans, especially in the rural areas, let alone an MRI machine.¹²⁾ The uneven distribution of medical equipment persists in Indonesia,²⁹⁾ which may help explain why most cases are detected on Java Island. Java, being the most densely populated island in Indonesia, has some of the most advanced medical equipment and imaging facilities. However, the hospitals in our network are also mostly based in Java, which

creates a sampling bias, skewing the data population towards a predominance in Java Island.

Males are at an increased risk for hemorrhagic stroke which has been confirmed previously, although ethnic and gender differences in stroke incidence may have contributed to this finding. In the same study, the authors find that trauma does not account for the higher occurrence of hemorrhagic stroke in boys,²³⁾ although our studies suggest otherwise. This phenomenon may be explained by underreporting of ischemic stroke and more cases of hemorrhagic stroke being found due to the acuteness of the trauma.

As the world needs better epidemiological data for estimating the disease burden of childhood stroke, imaging plays an even more central role.³⁰⁾ Most studies do not utilize neuroradiological data when determining the occurrence of childhood stroke. It is baffling when most guidelines recommend immediate neuroimaging to either confirm or exclude stroke but most epidemiological studies only consider ICD-coded diagnosis.³¹⁾

There are several limitations to our study. Firstly, there is a significant gap in clinical data for our patients, as we rely solely on imaging data with case ascertainment based on clinicians' final diagnoses. Consequently, we are unable to assess acknowledged risk factors for childhood stroke such as sickle cell disease, congenital heart diseases, arteriopathy, infections, or prothrombotic conditions.^{10,32,33)} This also means that some stroke mimics, especially those that cannot be excluded only by imaging, could be included as well. However, this is mitigated partially by ascertaining the case clinically via the final diagnosis made by the clinicians.³⁴⁾ Second, this study only included hospital admissions, so children with stroke who were not hospitalized would have been overlooked. This limitation is obvious when no data is available from Papua Island. Third, this study also excluded perinatal stroke (children with stroke before 28 days of age), as the authors could not ascertain the temporality of the presentation and the onset, which may cause the skewness of our data. The authors initially tried to collect perinatal stroke but the data was too heterogeneous, with perinatal stroke being the least common type of stroke, contradicting the consensus. Hence, the authors believed that excluding perinatal stroke is better than including this heterogeneous and biased finding. Fourth, we could not ascertain some data such as mortality rate and ethnicity disparities as this data is not readily available through our system. Fifth, most patients are still diagnosed by CT scans. Initial CT imaging often fails to detect evidence necessary for diagnosing AIS in 40% to 80% of cases.³⁵⁾ Thus, the stroke occurrence may be higher than it is, especially in AIS. The sixth limitation is that, due

to the retrospective nature of the study and the use of data from multiple hospitals, some variability and systematic errors may have been introduced, potentially leading to an overestimation or underestimation of the occurrence rates. Finally, occurrence represents a balance between incidence and mortality. High occurrence can result from either high incidence, low mortality, or both. Nonetheless, occurrence still indicates the state of the disease within the community, highlighting the need for healthcare services to actively manage chronic diseases.³⁾

Despite its limitations, our study represents one of the first—if not the first—to exclusively report on the occurrence of childhood stroke cases in Indonesia. Moreover, it is the first study to utilize radiographical data, which provides more accurate estimates of stroke cases. Moving forward, national studies integrating clinical and radiographical data are essential to determine risk factors, etiology, incidence and occurrence, mortality rates, and the financial and socioeconomic impact of childhood stroke cases in Indonesia.

In conclusion, our study represents a pioneering effort to estimate the occurrence of childhood stroke in Indonesia using both clinical and radiographical data from a multi-center network of private hospitals. The occurrence of childhood stroke observed in our study highlights significant epidemiological trends and disparities. Hemorrhagic strokes, predominantly due to accidents, were more common than ischemic strokes, with a notable occurrence in males and older children. This finding could spur the government and other child protective agencies to reinforcing traffic laws. Geographic disparities were also evident, with the majority of cases occurring in Java, while regions like Papua Island had no reported cases, likely due to limited data availability.

Further research should aim to address the identified gaps, including the inclusion of comprehensive clinical data, the assessment of risk factors like sickle cell disease and congenital heart diseases, and the evaluation of socioeconomic impacts. Collaboration across healthcare facilities and the implementation of standardized diagnostic protocols are essential steps toward achieving a more comprehensive understanding of childhood stroke and improving outcomes for affected children and their families.

Footnotes

Conflicts of interest: No potential conflict of interest relevant to this article was reported.

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Author contribution: Conceptualization: JL and GSO; Formal analysis: VS; Investigation: YTH, MAM, DLR, CBHS, GSO; Methodology: GSO and VS; Project Administration: JL; Writing - Original Draft: YTH, MAM, DLR, CBHS, GSO; Writing - Review & Editing: All authors

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