

## Analysis of Equity in Access to Cataract Surgery Services Among *BPJS Kesehatan* Participants

<sup>a</sup> M Ikhsan; <sup>b</sup> Syarif Rahman Hasibuan; <sup>c</sup> Nisrina Widayanti; <sup>d</sup> Wahyudi Utomo; <sup>e</sup> Taufik Akbar

<sup>ad</sup> Business Administration, Politeknik Negeri Jakarta, Depok, West Java, Indonesia; <sup>b</sup> Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jakarta, South Jakarta, Jakarta, Indonesia; <sup>c</sup> Center for Health Administration and Policy Studies, Faculty of Public Health, Universitas Indonesia, Depok, West Java, Indonesia

### ABSTRAK

Katarak merupakan penyebab utama kebutaan yang dapat dicegah di dunia, namun kesetaraan akses terhadap operasi masih menjadi tantangan meskipun telah diterapkan jaminan kesehatan universal. Penelitian ini menganalisis kesetaraan pemanfaatan operasi katarak pada peserta Jaminan Kesehatan Nasional (JKN) di Indonesia menggunakan regresi logistik dan model multilayer perceptron (MLP). Hasil menunjukkan bahwa usia, jenis kelamin, status perkawinan, wilayah tempat tinggal, dan segmen kepesertaan berhubungan dengan pemanfaatan operasi katarak. Individu yang lebih tua, laki-laki, dan peserta dari beberapa segmen kepesertaan tertentu memiliki kemungkinan lebih tinggi untuk menjalani operasi. Temuan ini menunjukkan adanya pengaruh faktor struktural dalam sistem pelayanan kesehatan, sehingga perlu penguatan mekanisme rujukan lintas wilayah, pengurangan hambatan akses layanan, serta perbaikan kebijakan manajemen layanan publik dalam program JKN untuk mewujudkan prinsip ekuitas dalam pelayanan kesehatan mata.

### ABSTRACT

Cataract is the leading cause of avoidable blindness worldwide, yet equitable access to surgery remains a challenge despite universal health coverage. This study examines equity in cataract surgery utilization among participants of Indonesia's national health insurance program using logistic regression and a multilayer perceptron (MLP) model. Findings show that age, sex, marital status, place of residence, and insurance segment are significantly associated with surgery utilization. Male participants, older age groups, and certain insurance segments are more likely to undergo surgery, indicating structural inequities in access. These findings underscore the need to strengthen referral mechanisms, reduce access barriers, and improve public service management policies within JKN to advance equity in essential eye care services.

### INTRODUCTION

Cataract is the leading cause of blindness worldwide. According to the Global Burden of Disease Study, cataract accounted for approximately 45% of global blindness in 2020, affecting an estimated 15.2 million people, and remained the second leading cause of moderate and severe vision impairment, with 78.8 million cases (Lin et al., 2025; Song et al., 2018; Wan et al., 2025). Older adults, women, and populations in low socio-demographic index (SDI) regions bear a greater burden, largely due to limited access to surgical treatment (Fang et al., 2022; Lin et al., 2025). Visual impairment from cataract reduces quality of life and contributes to high disability-adjusted life years (DALYs) globally (Cicinelli et al., 2022; Jiang et al., 2023; M. Li et al., 2025). Surgical advancements have lowered age-standardized disability in high-income settings. However, the overall burden continues to rise in low-SDI countries, reflecting persistent inequities in access and outcomes (Lee & Afshari, 2017; Zou et al., 2023).

Despite the technical availability of effective surgical treatment, equitable access to cataract

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surgery remains elusive, even in countries with universal health coverage (UHC). In high-income settings, gender disparities in surgical access manifest differently but remain present: studies from Sweden and Poland document longer waiting times and lower surgery rates for women (Jute & Stålhammar, 2025; Lange et al., 2023), while racial disparities in surgical timelines have been documented in the United States (Fernandez et al., 2025). At the health system level, blindness correlates with the density of ophthalmologists, which in turn correlates strongly with national income: high-income countries average 76.2 ophthalmologists per million inhabitants, compared to just 3.7 per million in low-income countries ((Mailu et al., 2020). These structural patterns suggest that formal coverage expansion alone cannot guarantee equitable utilization of surgical services.

Indonesia introduced the National Health Insurance (*Jaminan Kesehatan Nasional*, JKN) in 2014 as a major policy reform to achieve universal health coverage and ensure equitable access to health services. However, progress toward universal health coverage in the substantive sense, access to needed services, when and where they are needed, without financial hardship, has been hindered by financing deficits and operational challenges faced by healthcare providers (Susilo et al., 2025). Achieving equity in service utilization remains a persistent challenge, as disparities in health system capacity, facility distribution, and referral pathways can influence how benefits are accessed across population groups. Studies on public service governance also emphasize that effective implementation of national social policies requires adequate institutional capacity and equitable service delivery mechanisms to ensure that policy goals translate into real access for citizens (Sururi, 2023). Therefore, examining disparities in cataract surgery utilization within the JKN system is essential to evaluate whether universal health coverage has translated into equitable access to essential eye care services.

From a public administration perspective, this gap reflects a persistent challenge in social policy implementation: that institutional expansion does not automatically translate into equitable service delivery outcomes. As Tudor Hart observed in his foundational formulation of the Inverse Care Law, the availability of good medical care tends to vary inversely with the need of the population served — a principle that remains relevant to publicly financed health systems, including those operating under universal coverage frameworks. Since 1971, little global progress has been made in tackling this inverse care law, and it continues to manifest across health systems of varying income levels, describing the double injustice in which socially disadvantaged populations not only face greater disease burden but also receive less care (Cookson et al., 2021). Applied to the JKN context, this framework raises a critical policy question: has the formal extension of insurance coverage to the Indonesian population translated into equitable access to essential surgical services such as cataract surgery?

Research on cataract surgery in Indonesia has primarily examined clinical outcomes, demographic profiles, and local barriers rather than equity in access. Studies in Bali and East Java indicate that most patients are elderly and experience phacoemulsification with favorable visual outcomes (K. Salsabila & Unari, 2025; Wetarini et al., 2020). Financial constraints, limited access to facilities, and fear of surgery become major barriers in regions such as South Timor Tengah and West Java (Ratnaningsih et al., 2016; Suryathi et al., 2019). Gender-based differences have also been documented: men are more likely to receive earlier treatment than women (Simanjuntak et al., 2018). National rapid assessments confirm that untreated cataract is still the leading cause of blindness, with wide provincial variation in surgical coverage (Rif'Ati et al., 2021). At the system level, evidence from the JKN framework confirms that full population coverage does not guarantee equal healthcare utilization for equal need, a finding with direct implications for evaluating equity in specialized surgical services (Cheng et al., 2025). Yet no prior study has systematically analyzed disparities in cataract surgery access at the national level using

BPJS Kesehatan administrative data, leaving a critical gap in the evidence base for health policy accountability.

As of December 31, 2024, JKN coverage had reached 98.45%, yet disparities persist across socioeconomic groups and geographic regions, contributing to unequal service quality, low utilization, and financial burdens among lower-income households (Nabila et al., 2026), underscoring the need to shift JKN's policy focus from coverage expansion to equitable service access. Examining whether cataract surgery, a high-need, cost-effective, and fully covered intervention under JKN, is equitably distributed across population groups is therefore directly relevant to the governance and accountability of Indonesia's public health system.

This study addresses that gap. The central research question is: *Has access to cataract surgery under JKN been equitably distributed across geographic regions, sex, and insurance membership segments?* The study analyzes national BPJS Kesehatan claims data from 2017 to 2024, applying logistic regression and machine learning to identify structural determinants of surgical utilization inequality. The aim is to generate national-level evidence that supports policy reform and improved public service management within Indonesia's universal health coverage system.

### Literature Review

Two theoretical frameworks ground the analysis in this study. First, Andersen's Behavioral Model of Health Services Use (Alkhalaf et al., 2023) distinguishes three categories of determinants shaping healthcare utilization: predisposing characteristics (age, sex, social structure), enabling resources (income, insurance, geographic access), and need factors (perceived and professionally evaluated health status). Among its key strengths from a social epidemiology standpoint is its capacity to systematize equity and inequity in access to health services by specifying need versus predisposing and enabling factors, making it particularly suitable for analyzing utilization disparities within insurance-based systems like JKN. This framework implies that equitable utilization is achieved when enabling resources, including insurance coverage, geographic proximity, and referral pathway access, are sufficient to translate need into actual service use, regardless of predisposing characteristics such as sex or socioeconomic status.

Second, Tudor Hart's Inverse Care Law posits that the availability of good medical care tends to vary inversely with the need for it in the population served. First articulated in 1971 to describe inequalities in primary care delivery in the UK, the Inverse Care Law has since been widely adopted to describe social disparities in healthcare of all kinds, with researchers identifying its manifestation across health systems of varying income levels and governance structures (Cookson et al., 2021). Tudor Hart recognized that even universal coverage systems cannot deliver perfectly equitable care without evidence-based redistributive approaches, a warning directly applicable to evaluating JKN's equity performance in specialized surgical services. Together, these frameworks suggest that achieving equitable cataract surgery access under JKN requires not only financial protection but active governance mechanisms to reduce structural barriers to utilization across population subgroups.

The JKN program was established as a structural reform to ensure equitable access to health services for all Indonesians, regardless of economic status. Under JKN, participants are stratified into distinct segments: nationally subsidized (PBI APBN), regionally subsidized (PBI APBD), self-enrolled informal sector workers (PBPU), and formal workers (PPU), each with different contribution structures and, potentially, different patterns of health-seeking behavior and service access.

Evidence from the JKN framework confirms that full population coverage does not guarantee equal healthcare utilization for equal need, and that factors affecting utilization, including geographic location, insurance segment, and socioeconomic status, produce persistent inequities even among the insured population (Cheng et al., 2025). Nationally representative analysis of JKN underutilization confirms that even among insured individuals, 48.3% do not use their JKN coverage for outpatient care, with rural residents, self-employed workers, and those at higher income levels being more likely to forego their entitlement (Sujarwoto et al., 2026). This coverage-utilization gap is a governance problem as much as a service delivery challenge: it indicates that administrative enrollment has not translated into behavioral integration of JKN-covered services into health-seeking patterns.

Operational challenges, including reimbursement delays to hospitals, insufficient capitation rates in primary care, and the difficulty of maintaining regular membership among informal workers due to unstable incomes, further undermine the program's capacity to deliver equitable service access across segments (Susilo et al., 2025). These structural features of JKN's financing and governance architecture shape which populations can effectively convert formal insurance entitlement into actual surgical utilization — the central analytical question this study examines for cataract surgery. No prior study has addressed this question using national BPJS Kesehatan administrative data, constituting the primary research gap this work fills.

## RESEARCH METHODS

### Study Design and Data Source

This study employed a cross-sectional design using secondary data from the BPJS Kesehatan Regular Sample Data (RSD) 2017–2024. The RSD is a nationally representative administrative claims sample covering approximately 1% of JKN participants, containing de-identified information on demographic characteristics, service utilization, and insurance financing classifications. The BPJS Kesehatan sample data broadly represents the Indonesian insured population and has been used in prior longitudinal and cross-sectional health policy research, though known limitations in the quality of diagnostic information and socioeconomic variables should be considered in the interpretation of findings. The dataset is publicly accessible upon request at <http://data.bpjs-kesehatan.go.id/>.

### Sample Weight and Selection Process

The RSD employs a stratified two-stage cluster sampling design. Sampling weights were assigned to ensure representativeness of Indonesia's insured population (BPJS Kesehatan, 2024). In the first stage, primary healthcare facilities (*Fasilitas Kesehatan Tingkat Pertama*, FKTP) served as primary sampling units, stratified by facility type and participant category. In the second stage, households registered under each selected facility were randomly sampled. Each household was assigned a sampling weight equal to the inverse of its selection probability — for example, a household drawn from a stratum of 6,200 families received a weight of 6,200, indicating that it represents 6,200 families in the population. Individual-level weights were derived by distributing household weights across all registered members.

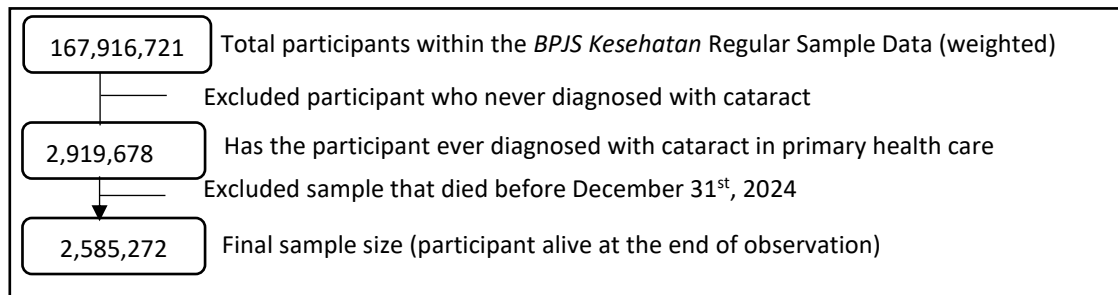
Post-stratification adjustment was applied to align the analytical sample with the national population distribution by sex, age group, and insurance segment. All analyses applied these sampling weights to produce population-level estimates that account for unequal selection probabilities and reduce sampling bias inherent in complex survey designs (Mansournia & Altman, 2016). Weighting also improves estimation efficiency by aligning the analytical sample

with actual population distribution (Atasever et al., 2025; Bhoj & Chandra, 2024). This weighting procedure ensures that all descriptive statistics and regression estimates reflect the characteristics of Indonesia's insured population rather than the raw, unweighted sample.

### Sample Selection

The study population consisted of all *BPJS Kesehatan* participants recorded in the RSD dataset ( $n = 167,916,721$ , weighted). Participants without any cataract diagnosis in primary healthcare were excluded. This step resulted in 2,919,678 individuals with at least one recorded cataract diagnosis (ICD-10 code H25–H26). Those who died before December 31, 2024, were then excluded to ensure comparability in follow-up duration. The final analytic sample comprised 2,585,272 participants who were alive at the end of the observation period (Figure 1). These criteria identified individuals who had ever been diagnosed with cataract in primary care.

**Figure 1.**  
**Sample Selection Criteria**



Source: Processed by the authors

### Variables and Measures

The dependent variable was the cataract surgery status, categorized as “underwent surgery” or “did not undergo surgery,” based on secondary and tertiary care claims. This study utilized variables from referral care data fields FKL30 (ICD-9-CM procedure or treatment code) and FKL19A (claim description). Cases containing the keyword “Cataract” in FKL30 or “Katarak” in FKL19A were classified as having undergone surgery.

Independent variables included: (1) age (continuous); (2) sex (male/female); (3) residential location (city/ regency); (4) region (Jakarta, Sumatra, Java–Bali, Kalimantan, Sulawesi, Nusa Tenggara–Maluku–Papua); (5) marital status (single, married, divorced/widowed, undefined); and (6) participant segment (non-worker, subsidized group [PBI-APBN or subsidized by state budget and PBI-APBD or subsidized by regional budget], sell-enroll participant [PBPU], and formal worker [PPU]) as defined by *BPJS Kesehatan* participant segmentation.

### Statistical Analysis

Descriptive statistics were used to characterize the distribution of cataract surgery across sociodemographic subgroups. Binary logistic regression was performed to estimate adjusted odds ratios (aORs) with 95% confidence intervals (CIs), using “did not undergo surgery” as the reference category. All regression models were weighted using individual sampling weights to produce population-representative estimates. The Sumatra region was not statistically significant ( $p = 0.07$ ) and is reported accordingly.

A Multilayer Perceptron (MLP) neural network was additionally developed to examine non-linear relationships among predictors — associations that logistic regression may not fully

capture. While logistic regression identifies the direction and significance of individual predictors, the MLP provides normalized importance scores reflecting each variable's relative contribution to the outcome. The dataset was split into training (70%) and testing (30%) subsets using random assignment. Model performance was evaluated using overall accuracy, incorrect prediction rate, and area under the receiver operating characteristic curve (AUC). The two methods serve complementary functions: logistic regression supports hypothesis testing about determinants of inequity, while MLP provides a data-driven ranking of variables that is informative for prioritizing policy intervention. Importantly, model performance metrics should be interpreted in the context of administrative data limitations — the absence of clinical severity indicators constrains predictive precision and is discussed accordingly.

All analyses were conducted using IBM SPSS Statistics version 29, employing the Neural Network module for MLP modeling and standard logistic regression procedures for comparative analysis.

**Ethical Considerations**

The use of this dataset is supported by an official statement from *BPJS Kesehatan* (Letter No. 17028/I.2/0925), confirming that the data sample is open for public and research purposes as part of *BPJS Kesehatan*'s collaboration initiative to support evidence-based policy development in the JKN program. In accordance with this statement, the study complies with *BPJS Kesehatan*'s data usage policy and national ethical standards for research using secondary data. Therefore, separate ethical approval was not required, as the dataset is authorized for research and policy analysis by *BPJS Kesehatan* under the conditions specified in the official letter.

**RESULTS AND DISCUSSIONS**

**Sample Characteristics**

**Table 1.**  
**Sample Characteristic**

Variable	Percent (%) n=2,585,272
Status of Cataract Surgery	
Did not undergo surgery	49.2
Undergo surgery	50.8
Residential Location	
Rural / Regency Area	66.4
Urban / City Area	33.6
Region	
Jakarta	5.9
Sumatera	21.2
Jawa dan Bali	54.9
Kalimantan	4.6
Sulawesi	9.7
Nusa Tenggara, Maluku dan Papua	3.7
Sex	
Male	44.8
Female	55.2
Marital Status	
Single / Never Married	8
Married	74 .1
Divorced / Widowed	14 .7
Undefined	3 .2
Participant Segment	

Variable	Percent (%) n=2,585,272
Non-Worker	13.1
<i>PBI APBN</i> (Central Government Subsidized)	32.5
<i>PBI APBD</i> (Regional Government Subsidized)	15.4
PBPU (Self-enrolled)	25.8
PPU (Formal Worker)	13.2
Age (years) – mean (SD)	63 (11)

Source: Processed by the authors with reference by BPJS Kesehatan

In this study, a total of 2,585,272 National Health Insurance participants who were diagnosed with cataract at primary healthcare facilities were included. Table 1 presents the demographic and regional characteristics of the study population. Approximately 50.8% of participants underwent cataract surgery, while 49.2% did not. Most of the participants resided in rural or regency areas (66.4%), with the remaining 33.6% living in urban areas. Regionally, more than half of the participants were located in Java and Bali (54.9%), followed by Sumatra (21.2%), Sulawesi (9.7%), Jakarta (5.9%), Kalimantan (4.6%), and Nusa Tenggara, Maluku, and Papua (3.7%). In terms of sex distribution, 55.2% were female, and 44.8% were male. Most participants were married (74.1%), with 8.0% single, 14.7% divorced or widowed, and 3.2% undefined. Regarding participant segmentation, *PBI APBN* (government-subsidized) participants comprised 32.5% of the total, followed by PBPU (self-enrolled) at 25.8%, *PBI APBD* (regionally subsidized) at 15.4%, PPU (formal workers) at 13.2%, and non-workers at 13.1%. The mean age at diagnosis was 63 years (SD = 11).

### Equity in Access to Cataract Surgery Services

**Table 2.**  
**Distribution of Undergoing Surgery by Sample Characteristics**

Variable	% Undergo surgery
Residential Location	
Rural / Regency Area	49.6
Urban / City Area	53.0
Region	
Jakarta	60.2
Sumatera	45.5
Jawa dan Bali	51.6
Kalimantan	47.4
Sulawesi	56.6
Nusa Tenggara, Maluku dan Papua	43.1
Sex	
Male	53.2
Female	48.9
Marital Status	
Single / Never Married	49.3
Married	51.0
Divorced / Widowed	53.3
Undefined	37.7
Participant Segment	
Non-Worker	52.9

Variable	% Undergo surgery
PBI APBN (Government-Subsidized)	48.5
PBI APBD (Regionally-Subsidized)	51.4
PBPU (Self-Employed)	58.6
PPU (Formal Worker)	38.9

Source: Processed by the authors with reference by BPJS Kesehatan

Table 2 shows the distribution of cataract surgery across participant characteristics. Participants living in urban areas had a higher surgery proportion (53.0%) than those in rural or regency areas (49.6%). Jakarta recorded the highest regional proportion (60.2%), followed by Sulawesi (56.6%) and Java–Bali (51.6%). Nusa Tenggara, Maluku, and Papua had the lowest (43.1%).

Surgery rates were higher among males (53.2%) than among females (48.9%). By marital status, divorced or widowed participants had the highest proportion (53.3%), whereas married participants reached 51.0%, and those never married reached 49.3%.

Participant segmentation revealed notable differences. PBPU members had the highest surgery proportion (58.6%), followed by non-workers (52.9%) and PBI APBD (51.4%). PPU members had the lowest (38.9%).

**Table 3.**  
**Determinants of Access to Cataract Surgery**

Variable	Sig. (p-value)	Adjusted Odds Ratio (aOR)	95% CI
Age (in years)	0.00*	1.03	1.03–1.03
Regency (ref: city)	0.00*	0.95	0.94–0.95
Male (ref: female)	0.00*	1.21	1.20–1.21
Marital status			
Single	ref		
Married	0.00*	0.87	0.86–0.88
Divorced/Widowed	0.00*	0.83	0.82–0.84
Undefined	0.00*	0.51	0.50–0.52
Participant Segment			
PPU	ref		
Non-Worker	0.00*	1.12	1.11–1.13
PBI APBN	0.00*	1.27	1.26–1.28
PBI APBD	0.00*	1.31	1.29–1.32
PBPU	0.00*	1.75	1.73–1.76
Region			
Nusa Tenggara, Maluku, Papua	Ref		
Jakarta	0.00*	1.65	1.62–1.68
Sumatra	0.07	1.01	1.00–1.03
Java and Bali	0.00*	1.24	1.23–1.26
Kalimantan	0.00*	1.10	1.09–1.12
Sulawesi	0.00*	1.57	1.54–1.59

\* statistically significant

Source: Processed by the authors with reference by BPJS Kesehatan

Table 3 presents the results of the multivariate logistic regression identifying independent predictors of undergoing cataract surgery.

**Individual Characteristics (Sex, Age, and Marital Status)**

Each additional year of age was associated with modestly but significantly increased odds of surgery (aOR = 1.03; 95% CI: 1.03–1.03), consistent with the rising surgical need among older populations. This association reflects an age-appropriate pattern of service use and is consistent with epidemiological evidence that cataract incidence rises sharply after age 60 (Ben-Eli et al., 2025).

Male participants had 1.21 times higher odds of surgery than females (aOR = 1.21; 95% CI: 1.20–1.21). This finding is consistent with gender-based patterns documented across low- and middle-income country contexts, where men are more likely to receive surgical care due to structural advantages in health-seeking behavior and household decision-making (Cai et al., 2022; Geiger et al., 2024; Gupta et al., 2024). In high-income countries, the pattern is reversed—women typically have higher cataract surgery rates, partly due to longer life expectancy and greater engagement with preventive care (Hagström et al., 2024; Hambisa et al., 2022; Hugosson & Ekström, 2020). The male predominance observed in this study is therefore unlikely to reflect greater disease burden and more plausibly indicates structural barriers limiting women's access within the JKN framework, barriers that formal insurance coverage does not automatically remove.

From a public service management perspective, this gender disparity represents an accountability challenge. JKN's constitutional mandate to ensure equitable access (Article 28H, 1945 Constitution) requires that formal entitlement translates into utilization. Despite significant increases in JKN coverage, inequality remains particularly pronounced for vulnerable groups, including women and those in lower socioeconomic categories (Novita Listyaningrum et al., 2025). Targeted health promotion, community-based outreach, and gender-responsive referral pathways are therefore policy levers that BPJS Kesehatan and the Ministry of Health should consider to reduce this disparity.

Regarding marital status, single participants (reference) had higher odds of surgery than married (aOR = 0.87) or divorced/widowed (aOR = 0.83) participants, with those of undefined status least likely to undergo surgery (aOR = 0.51). These associations are interpreted cautiously given the cross-sectional design: they indicate that marital status is an independent correlate of surgical utilization, rather than a causal determinant. In many low- and middle-income countries, widowed or divorced women face higher rates of cataract-related blindness but have lower surgery uptake due to limited financial and social support (Ramke et al., 2019). Research in other settings indicates that single individuals are more likely to seek surgery, possibly due to greater autonomy, fewer family responsibilities, and more proactive health behavior (Wale et al., 2021).

Married individuals may delay surgery due to caregiving roles or household decision-making constraints. Single persons, especially those with stable income or living in urban areas, may have greater flexibility to seek care (Olaïdé Adoukê et al., 2024). From a service governance standpoint, marital status functions as a proxy for social vulnerability, and community-based case-finding strategies should account for socially isolated individuals who may face the greatest barriers to completing the referral pathway. Marital status should therefore be considered a social determinant of healthcare access rather than a simple demographic characteristic. Cataract programs should adopt community-based strategies that identify and assist individuals at risk of exclusion, particularly widowed or socially isolated persons. Incorporating social context into service design can improve equity in eye health coverage.

### **Socioeconomic Characteristics (Participant Segments)**

Disparities were observed across participant segments. Compared to formal workers (PPU), all other segments had higher odds of undergoing cataract surgery: non-workers (aOR = 1.12; 95%

CI: 1.11–1.13), nationally subsidized participants (PBI APBN; aOR = 1.27; 95% CI: 1.26–1.28), regionally subsidized participants (PBI APBD; aOR = 1.31; 95% CI: 1.29–1.32), and self-employed (PBPU; aOR = 1.75; 95% CI: 1.73–1.76). PBPU and subsidized participants (PBI) exhibited higher surgery odds than PPU. This pattern contradicts national and global evidence indicating that poorer or informal groups generally have lower healthcare access and utilization (Awidi et al., 2023; Darmawan et al., 2025b, 2025a; Endradita et al., 2020; Mailu et al., 2020).

This unexpected finding is best interpreted through the lens of the Inverse Care Law (Hart, 1971), which posits that healthcare availability tends to vary inversely with the need of the population served. Applied to the JKN context, the low utilization among PPU members — who are formally employed and contribute premiums through payroll deduction — may reflect a different set of structural barriers than those affecting subsidized groups. Specifically, formal workers may face opportunity costs associated with surgical absence from work, greater reliance on private care alternatives, or administrative friction within the JKN tiered referral system that discourages uptake of publicly financed services.

Recent nationally representative evidence from Indonesia confirms that insurance underutilization is higher among self-employed, casual, and higher-income workers, with outpatient non-use increasing with income quartile (highest vs. lowest quartile: aOR 1.34) suggesting that formal and higher-income workers systematically underuse their JKN entitlements relative to lower-income groups (Sujarwoto et al., 2026). This dynamic may partly explain the lower surgical uptake among PPU members in the present study.

Within BPJS Kesehatan's class-based structure, Class 1 participants, who overlap substantially with the PPU segment, tend to have better access to specialists and shorter waiting times, but this does not necessarily translate into higher utilization of elective surgical services like cataract surgery. Conversely, subsidized participants (PBI) who face greater financial barriers in the absence of coverage may exhibit higher relative utilization precisely because JKN represents their primary or sole pathway to surgical care (Hakiki, 2025).

It must be acknowledged that this finding may also reflect data quality limitations. Surgery classification relied on keyword matching in administrative claim fields, and differential completeness of claims records across segments could introduce systematic misclassification (Fatimah et al., 2025). BPJS Kesehatan sample data carries known limitations in diagnostic information quality and socioeconomic variables, which should be considered when interpreting utilization patterns across membership types. BPJS Kesehatan and the Ministry of Health are therefore encouraged to conduct field-level audits of surgical claims by segment to distinguish genuine utilization differences from administrative artifacts. This is both a data governance and a service accountability issue with direct implications for program monitoring.

### **Geography Characteristics (Residential and Regional)**

Urban residents had significantly higher odds of surgery than rural residents (aOR = 0.95 for regency/rural areas; 95% CI: 0.94–0.95), and substantial regional variation was observed. Participants from Jakarta (aOR = 1.65) and Sulawesi (aOR = 1.57) had substantially higher odds relative to those in the eastern provinces (Nusa Tenggara, Maluku, and Papua), which served as the reference category with the lowest surgical utilization.

These geographic disparities reflect a structural failure in equitable service distribution that formal insurance coverage cannot address on its own. Ophthalmological services and surgical capacity remain concentrated in urban and economically developed areas, particularly in Java (K. D. Salsabila et al., 2024). Eastern Indonesian provinces face chronic shortages of specialists

and facilities, creating de facto exclusion from specialized surgical care despite formal JKN enrollment.

Within the JKN framework, primary health centers often lack the capacity to handle complex cases, leading to over-reliance on higher-level referral facilities, a structural imbalance that particularly disadvantages populations in areas with limited tertiary care infrastructure (Damayanti et al., 2025). For cataract surgery specifically, this means that even patients who are correctly diagnosed at the primary care level may fail to complete the referral pathway if the receiving specialist facility is geographically inaccessible.

Evidence from BPJS Kesehatan's own referral networks confirms that the location of primary health facilities significantly affects referral rates and care accessibility, with facilities closer to villages reducing the need for long-distance referral and enhancing access for remote populations (Ridwan & Ramadhan, 2025). This finding directly supports the policy recommendation for geographic optimization of ophthalmological outreach and mobile surgical services in eastern Indonesia.

Despite JKN achieving near-universal enrollment, progress toward universal health coverage in the substantive sense (access to the services people need, when and where needed) remains incomplete, with significant challenges in health system capacity and facility distribution persisting. The regional disparities observed in this study are a direct empirical illustration of that gap. Addressing them requires not only financial protection for patients, but active investment in facility infrastructure, specialist workforce distribution, and referral system strengthening in underserved regions, all of which are governance responsibilities of the Ministry of Health and regional health authorities.

#### Machine Learning Model Performance (MLP Analysis)

**Table 4.**  
**Specifications of the Multilayer Perceptron Neural Network**

Metric	Training Phase	Testing Phase
Incorrect Prediction (%)	41.5	40.7
Accuracy (%)	58.5	59.3
AUC	-	0.62

Source: Processed by the authors

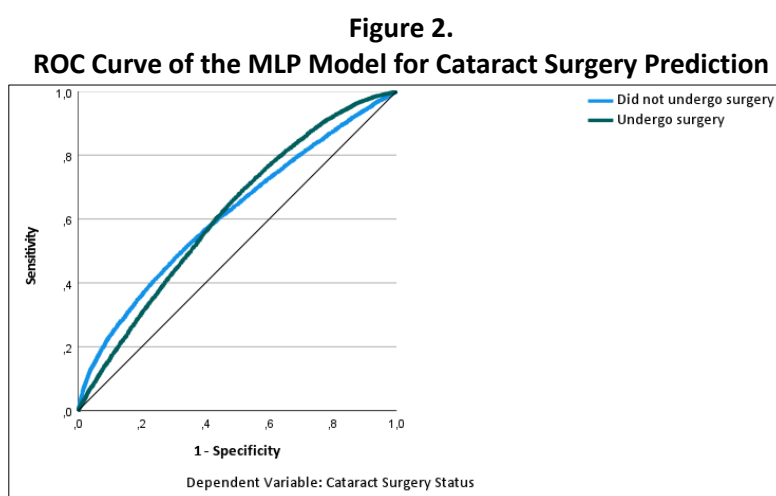
Reference: *BPJS Kesehatan*

The multilayer perceptron (MLP) model (Table 4) achieved 59.3% accuracy in the testing phase with a cross-validated AUC of 0.62. Training and testing error rates were similar (41.5% and 40.7%), indicating model stability without overfitting.

The AUC of 0.62 should be interpreted in its methodological context. Models trained exclusively on sociodemographic variables, without clinical severity indicators, typically demonstrate modest discriminative performance, with AUC values around 0.61 considered consistent with the multifactorial, socially mediated nature of the outcome being predicted, rather than indicative of a flawed model design (Kanade et al., 2026). This is a key distinction from clinical prediction models, which draw on biometric or diagnostic data and routinely achieve AUC values of 0.80 and above. The present model, by contrast, uses only population-level administrative and demographic predictors, and should be assessed against that benchmark rather than against clinical prediction studies.

The practical implication is constructive: an AUC of 0.62 demonstrates that sociodemographic and administrative data available within the existing BPJS Kesehatan claims system can predict cataract surgical utilization at a level meaningfully above chance. Machine learning models trained on administrative data can be used proactively to advance health equity by identifying population subgroups systematically underserved by existing service delivery arrangements (Rajkomar et al., 2018). In the context of this study, the MLP model confirms that age, geographic region, and social factors captured in insurance claims data carry a predictive signal for surgical access, a finding with actionable implications for equity monitoring within JKN.

Nevertheless, the model demonstrates that social and administrative data alone can predict cataract surgery utilization at a level above random chance (AUC = 0.62). Inequities in healthcare access can therefore be identified using existing BPJS Kesehatan datasets. Incorporating clinical severity indicators, comorbidities, or health-seeking behaviors could improve predictive capacity for policy monitoring.



Source: Processed by the authors

The receiver operating characteristic (ROC) curve (Figure 2) shows the model's discrimination between participants who underwent surgery and those who did not. The AUC of 0.617 indicates correct classification in 61.7% of pairwise comparisons. The curve shows consistent separation above the diagonal reference line. However, limited curvature indicates that sociodemographic and administrative predictors explain only part of the variability in surgery access. Non-clinical factors are informative but insufficient to fully predict surgical access patterns. Adding clinical and behavioral variables, including cataract severity, referral compliance, and comorbidity status, may improve model performance for policy monitoring and resource allocation.

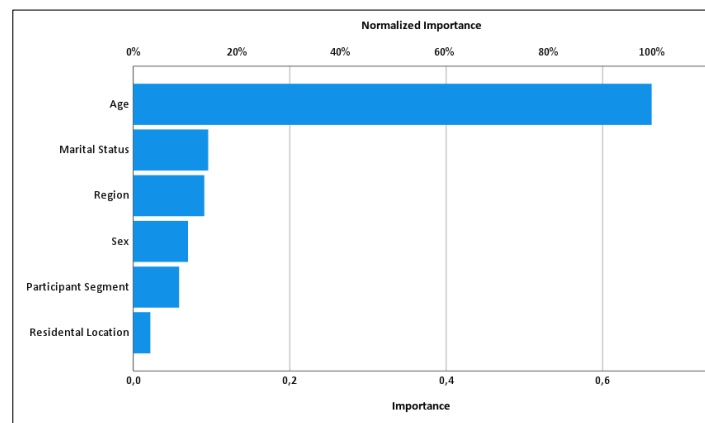
**Table 5.**  
**Predictor Importance in the MLP Model (unweighted)**

Variable	Importance	Normalized Importance (%)
Age	0.66	100.0
Regional	0.09	13.7
Marital Status	0.09	14.5
Sex	0.07	10.6
Participant Segment	0.06	8.8
Residential Location	0.02	3.3

Source: Processed by the authors

Variable importance analysis (Table 5, Figure 3) identified age as the dominant predictor (normalized importance = 100%), followed by marital status (14.5%), region (13.7%), sex (10.6%), participant segment (8.8%), and residential location (3.3%). The prominence of age is consistent with the epidemiology of cataract and aligns with the logistic regression findings. The secondary contributions of region and marital status reinforce the conclusion that geographic and social structural factors constitute meaningful, policy-relevant drivers of surgical access — not merely statistical associations.

**Figure 3.**  
**Normalized Importance of Predictors in the Multilayer Perceptron Neural Network Model for Cataract Surgery Prediction**



Source: Processed by the authors

The relatively modest contribution of insurance segment (8.8%) to the MLP model, compared to its significance in the logistic regression, does not invalidate the segment-level findings. The two methods are complementary: logistic regression identifies the direction and statistical significance of each predictor, while MLP importance scores reflect each variable's relative contribution in a non-linear, multivariate context. The combination of both approaches strengthens the overall analytical picture and is appropriate for a policy evaluation context where understanding both individual predictor effects and their relative weights is informative.

Future models that incorporate clinical variables — including cataract severity grading, referral compliance records, specialist waiting times, and comorbidity profiles — would likely improve predictive performance and provide a more granular basis for targeted policy intervention.

### Findings Summary

**Table 6.**  
**Results and Discussion Summary**

Theme	Key Findings	Interpretation
Equity in Access to Cataract Surgery Services	<ol style="list-style-type: none"> <li>Higher access in urban (53%) than rural areas (49.6%).</li> <li>Highest: Jakarta (60.2%); Lowest: eastern regions (43.1%).</li> <li>Males (53.2%) are higher than females (48.9%).</li> <li>Highest: PBU (58.6%); Lowest: PPU (38.9%).</li> </ol>	Access remains unequal by region, gender, and insurance segment; urban and self-employed groups are more advantaged.
Individual Characteristics (Sex,	<ol style="list-style-type: none"> <li>Older age increases surgery odds (aOR=1.03).</li> </ol>	Age and gender are key determinants; women and

Theme	Key Findings	Interpretation
Age, and Marital Status)	<ol style="list-style-type: none"> <li>2. Males are 1.21 times more likely than females.</li> <li>3. Single participants are more likely than married or widowed participants.</li> </ol>	socially constrained individuals have lower access.
Socioeconomic Characteristics (Participant Segments)	<ol style="list-style-type: none"> <li>1. Non-workers, PBI, and PBPU are more likely than PPU to undergo surgery.</li> <li>2. The pattern deviates from the global trend, where poorer groups have lower access.</li> </ol>	Possible data or administrative bias; structural inequality persists between <i>BPJS Kesehatan</i> participant classes.
Geography Characteristics (Residential and Regional)	<ol style="list-style-type: none"> <li>1. Regency residents are less likely than city dwellers (aOR=0.95).</li> <li>2. Highest: Jakarta and Sulawesi; Lowest: eastern regions.</li> <li>3. Ophthalmologists are concentrated in major cities.</li> </ol>	Geographic inequality is driven by uneven specialist and facility distribution; UHC alone cannot ensure service equity.
Machine Learning Model Performance (MLP)	<ol style="list-style-type: none"> <li>1. Accuracy 59.3%; AUC 0.62 (stable).</li> <li>2. Age is the strongest predictor (66% model weight).</li> <li>3. Other factors: region, marital status, sex, participant segment.</li> </ol>	The model predicted surgery access with limited accuracy (AUC < 0.7). Incorporating clinical data may improve predictive performance for policy monitoring.

Source: Processed by the authors

Table 6 summarizes the key findings and interpretations of the analyses on equity in access to cataract surgery among participants of Indonesia’s national health insurance system. The results highlight disparities in surgery utilization across demographic, socioeconomic, and geographic groups, with higher access among urban residents, males, and certain insurance segments. Taken together, these patterns confirm that formal insurance enrollment has not produced convergence in surgical utilization, a finding directly relevant to the governance accountability of the JKN program. Disparities of this nature are consistent with evidence that policy objectives in social protection programs do not automatically translate into equitable service delivery outcomes, particularly when the supply-side infrastructure necessary to enable utilization is unevenly distributed (Muharsono et al., 2023).

Taken together, the findings of this study reveal that equity in access to cataract surgery within the JKN system remains structurally incomplete. The disparities observed across gender, geographic region, and insurance segment indicate that financial protection alone is insufficient to produce equitable service utilization. This conclusion is consistent with a growing body of evidence on the limits of coverage expansion as a mechanism for equity in specialized care.

From a public administration standpoint, these findings carry direct implications for how BPJS Kesehatan and the Ministry of Health design, monitor, and govern essential surgical services. Three specific governance priorities are identified. First, the referral pathway for cataract surgery requires systematic strengthening, particularly for populations in rural and eastern regions where the geographic gap between primary diagnosis and specialist surgical services remains large. Barriers to effective referral within the JKN system include limited human resources, weak internal coordination, geographic constraints, and technical problems in online referral processes — all of which disproportionately affect patients in underserved areas. Addressing these operational barriers is a governance responsibility, not merely a clinical one (Bintang Dwi Maharani & Inge Dhamanti, 2026).

Second, gender-responsive service planning is warranted. The consistent male advantage in surgical access — despite women comprising the majority of the cataract-diagnosed population in this dataset — suggests that the design of JKN-supported eye care services has not adequately accounted for gendered barriers to care-seeking. Community-based screening and referral assistance programs targeted at women, particularly in rural and eastern regions, represent a cost-effective governance intervention.

Third, the anomalous pattern of higher surgical utilization among subsidized and self-enrolled participants relative to formal workers should be subject to administrative audit. Whether this pattern reflects genuine equity gains for historically underserved populations, or artifacts of differential claims recording practices across segments, has direct consequences for program accountability. Geographic variation in service unit costs and differential treatment intensity across JKN membership types has been documented to exacerbate underlying inequality in healthcare benefits — a concern that applies directly to the interpretation of surgical access differentials in this study (Sambodo et al., 2021).

Ultimately, achieving equity in cataract surgery under JKN requires a shift from a coverage-centric to a utilization-centric accountability framework — one that tracks not only who is enrolled, but who receives the services they are entitled to, where, and under what conditions. The analytical approach demonstrated in this study, combining population-level claims data with machine learning-based importance analysis, offers a replicable model for ongoing equity monitoring within Indonesia's universal health coverage system.

### **Limitation**

Several limitations of this study should be acknowledged when interpreting its findings. First, the analysis relied exclusively on BPJS Kesehatan administrative claims data, which lacks clinical information, including cataract severity grading, visual acuity measurements, comorbidity profiles, and referral pathway records. As a result, the study analyzes utilization patterns rather than clinically warranted demand — an important distinction when interpreting observed disparities.

Second, regional and socioeconomic classifications were necessarily aggregated, potentially masking finer-grained local disparities within provinces or between district types. The keyword-based classification of surgical status carries a risk of differential misclassification across facilities with varying coding practices.

Third, the MLP model achieved an AUC of 0.62, reflecting the inherent limitations of administrative data without clinical predictors. This performance level is expected when models are built on sociodemographic variables alone, and should not be interpreted as a model failure; it establishes a meaningful baseline for equity monitoring using routinely available data. Nonetheless, it confirms that administrative claims data alone are insufficient for precise individual-level prediction.

Fourth, the study design is cross-sectional, and all associations reported are correlational. No causal inferences can be drawn from these findings, and language implying causality has been deliberately avoided throughout the analysis.

Future research should integrate electronic medical records, hospital capacity data, ophthalmologist distribution records, and referral tracking systems to improve both analytical precision and the policy relevance of predictive models. Despite these limitations, the patterns identified here provide a substantively grounded basis for targeted policy intervention and data quality improvement within the JKN framework.

## CONCLUSION

This study examined equity in access to cataract surgery among BPJS Kesehatan participants, using logistic regression and multilayer perceptron (MLP) modeling applied to national administrative claims data covering 2017–2024. The analysis of more than 2.5 million individuals diagnosed with cataract at primary healthcare facilities reveals a consistent pattern: surgical utilization is not equitably distributed, and structural factors, geographic location, sex, insurance segment, and social characteristics, are independently associated with the likelihood of undergoing surgery.

The findings provide empirical confirmation, at national scale, of the Inverse Care Law (Health, 2021) operating within a formally universal coverage system. Participants in eastern Indonesia, the region with the highest disease burden and the most limited specialist infrastructure, had the lowest surgical utilization, while those in Jakarta and Sulawesi had the highest. This geographic pattern mirrors the well-documented maldistribution of medical specialists in Indonesia: the ratio of specialists to population in Maluku, East Nusa Tenggara, and Papua stands at 0.05 per 1,000 people, compared to 0.17 in Java–Bali, a structural deficit that directly limits the conversion of insurance entitlement into specialist surgical care (Kurniati et al., 2024).

Male participants were more likely to undergo surgery than females, despite women comprising the majority of the cataract-diagnosed population, consistent with the gender asymmetry in surgical access documented across LMICs (Mailu et al., 2020). The counterintuitive pattern in which subsidized (PBI) and self-enrolled (PBPU) participants had higher surgical odds than formal workers (PPU) does not straightforwardly indicate equity gains for poorer groups. Rather, it is more plausibly interpreted in light of evidence that formal sector and higher-income workers in Indonesia systematically underuse their JKN entitlements for outpatient care, with non-use increasing with income quartile, and may also reflect differences in claims recording completeness across segments that warrant administrative audit (Sujarwoto et al., 2026).

The MLP model's normalized importance analysis adds a complementary policy-diagnostic dimension. Age emerged as the dominant predictor (66% of model weight), as expected given the strong epidemiological link between advancing age and cataract incidence. However, geographic region (13.7%) and marital status (14.5%) contributed meaningfully — confirming that structural and social determinants of access are not merely residual confounders, but substantively important targets for equity-oriented governance intervention. The relatively modest contribution of insurance segment (8.8%) and residential location (3.3%) in the MLP model, despite their statistical significance in logistic regression, reflects a methodological complementarity: regression models identify whether an association is present and in which direction, while MLP importance scores reflect the variable's contribution within a non-linear, multi-predictor context. Both are needed to paint a complete picture of equity determinants.

This study contributes to the literature on equity in public service delivery in three respects. First, it provides the first national-level, insurance claims-based analysis of disparities in cataract surgery access under JKN, establishing a quantitative baseline against which future policy interventions can be evaluated. Second, it demonstrates the utility of combining logistic regression and machine learning approaches for equity monitoring using routinely collected administrative data. Machine learning methods applied to administrative data offer a principled approach to identifying population subgroups systematically underserved by existing service

delivery arrangements, and can contribute to public health policy evaluation when their limitations, including reliance on historical data and potential encoding of structural biases, are properly acknowledged. Third, it grounds the analysis of cataract surgery disparities within a public administration framework, positioning unequal utilization not as a clinical curiosity but as an accountability failure of the JKN governance system (Z. Li et al., 2025)

While BPJS Kesehatan's membership coverage is extensive, this has not yet been reflected in equitable access to healthcare services for all, as barriers, including uneven healthcare infrastructure and limited health literacy about proper use of JKN coverage, continue to constrain utilization among underserved populations. This study's findings confirm that cataract surgery, a cost-effective, fully covered, essential surgical intervention, exemplifies this gap.

Indonesia's JKN program represents a landmark institutional achievement in extending formal health coverage to nearly the entire population. Yet the findings of this study confirm that coverage expansion, while necessary, is not sufficient for equity. What remains to be built is a utilization-centered accountability architecture: one that tracks not merely who is enrolled, but who receives the services they are entitled to, where, and under what conditions. As Tudor Hart recognized in his original formulation of the Inverse Care Law, even universal coverage cannot achieve truly equitable care without evidence-based redistributive approaches targeting the structural conditions that determine whether formal entitlement translates into actual service use. For cataract surgery, a preventable cause of blindness, a covered benefit, and a measurable governance outcome, the path from coverage to equity runs through referral system strengthening, specialist workforce distribution, and data-driven service accountability. These are governance responsibilities, not merely clinical ones.

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