JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

COST-EFFECTIVENESS AND COST-UTILITY ANALYSIS OF STROKE MANAGEMENT STRATEGIES IN A RESOURCE-LIMITED SETTING: THE CASE OF TOAMASINA, MADAGASCAR

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Abstract (English)

In low-resource countries, stroke remains one of the leading causes of mortality and disability. In this context, the economic evaluation of different therapeutic approaches plays an important role in supporting public health decision-making.

This study aimed to compare the cost per QALY (Quality-Adjusted Life Year) of stroke management strategies in Toamasina, particularly between modern medicine and traditional medicine. A retrospective analytical study was conducted among 510 patients who had experienced a stroke. Both direct and indirect treatment-related costs were considered.

QALYs were calculated using patients' quality-of-life scores, and a cost-effectiveness analysis was subsequently performed to compare the two therapeutic approaches. The average cost of treatment with modern medicine was estimated at USD 1,200, whereas treatment through traditional medicine averaged USD 350. The mean QALYs obtained were 0.65 for modern medicine and 0.55 for traditional medicine. Consequently, the cost per QALY was USD 1,846 for modern medicine compared with USD 636 for traditional medicine.

Within the context of this study, traditional medicine appeared to be more cost-effective. However, modern medicine remained associated with better clinical outcomes.

Keywords : Stroke ; cost-effectiveness; QALY; modern medicine; traditional medicine; economic analysis; quality of life; public health; direct and indirect costs.

I. INRODUCTION

Stroke is among the most pressing health problems worldwide. It is a leading cause of death and a significant source of long-term disability in adults. In low- and middle-income countries, its incidence continues to rise

due to several factors, including urbanization, lifestyle changes, and the increasing prevalence of cardiovascular diseases such as hypertension, diabetes, and smoking.

In Madagascar, as in many sub-Saharan African countries, the healthcare system faces numerous challenges: a lack of resources, limited access to specialized care, and geographical inequalities in treatment. Added to this is the coexistence of modern and traditional medicine, which still plays a significant role in the population's healthcare practices. For many stroke patients, traditional medicine is often the first option, due to its accessibility, lower cost, and deeply ingrained cultural beliefs.

In this context, it becomes essential to assess the economic impact of different therapeutic strategies to help policymakers better guide health policies. Cost-utility analysis, based on quality-adjusted life years (QALYs), allows for the evaluation of both the duration and quality of life of patients after treatment. This tool thus offers a relevant method for comparing the economic efficiency of modern and traditional medicine in the management of strokes.

However, most studies on the cost-effectiveness of stroke treatments have been conducted in high-income countries with better-organized healthcare systems and more advanced technology. Data remain limited in low-resource countries, particularly regarding the role of traditional medicine in economic evaluations.

It is within this context that this study was conducted in Toamasina. Its objective is to evaluate the cost per QALY of the different therapeutic approaches used in stroke management, in order to provide useful information for better resource allocation and healthcare system improvement.

I.1. Literature Review

I.1.1 Global Stroke Burden

Stroke represents a significant public health challenge worldwide. International data indicates that approximately 70% of strokes occur in low- and middle-income countries. In these countries, the mortality rate remains particularly high, and the long-term effects are often more severe, primarily due to delays in treatment and a lack of appropriate specialized facilities.

Numerous studies have shown that treating patients in stroke units significantly reduces the risk of death and stroke-related disabilities. However, these findings remain difficult to implement in resource-limited settings, where such units are rare or even completely unavailable.

I.1.2 Economic Evaluation of Stroke

The economic evaluation of health interventions, particularly cost-effectiveness and cost-utility analyses, now plays a crucial role in shaping health policies. Among the most widely used indicators is the QALY (Quality of Life Years), which combines life expectancy and quality of life for patients after medical treatment.

In developed countries, several studies have demonstrated that early interventions, such as thrombolysis or specialized intensive care, remain generally cost-effective despite significant initial expenditures. These approaches effectively limit long-term sequelae and reduce the burden of disability for patients. However, most of these analyses have been conducted in healthcare systems with substantial financial resources and rarely consider traditional therapeutic practices.

I.1.3 Traditional Medicine for Stroke

In sub-Saharan Africa, traditional medicine plays a significant role in the population's healthcare practices. For many patients, it is often the first therapeutic option, largely due to its affordability and deep roots in cultural and social traditions.

Some qualitative studies have shown that traditional healers enjoy considerable trust within communities. Many patients also consider traditional treatments effective, particularly in areas where access to modern healthcare facilities remains limited. Despite this, quantitative data for accurately assessing the clinical and economic effectiveness of these practices are still insufficient.

To date, few studies have directly compared traditional and modern medicine in stroke management, especially using standardized indicators such as the QALY. This lack of information is a major obstacle to better integrating traditional medicine into public health policies.

I.1.4 Literature Gaps

The literature review highlights several significant limitations in existing research:

- a general lack of studies conducted in the African context;
- the absence of cost-utility analyses that take traditional medicine into account;
- the limited availability of data concerning care pathways combining modern and traditional medicine;
- and the inadequacy of economic models truly adapted to resource-limited countries.

These various gaps justify the present study, which seeks to make an original contribution by integrating clinical, economic, and contextual dimensions.

2. MATERIALS AND METHODS

2.1 STUDY MATERIALS

2.1.1 Study Setting

This study was conducted in Toamasina, an urban environment where various modern healthcare structures, such as public hospitals and private clinics, coexist with traditional medicine, which is still widely used by the majority of the population.

This context allows for a comparative analysis of the different treatment pathways of patients with stroke.

2.1.2 Study Type and Period

This is a retrospective study conducted over a 24-month period. It focuses on evaluating the management of strokes according to different therapeutic approaches, with an emphasis on clinical and economic aspects.

2.1.3 Study Population

The sample consists of 510 patients who experienced a stroke over a 24-month period. The distribution of patients according to the type of care received is as follows:

- Modern medicine: 220 patients
- Traditional medicine: 200 patients
- No treatment: 90 patients

This distribution allows for a comparison of clinical and economic outcomes between the different treatment groups.

2.1.4. Selection Criteria

a) Selection criteria:

- Clinically confirmed stroke or stroke confirmed by medical imaging
- Age ≥ 18 years
- Usable medical records

b) Exclusion criteria:

- Transient ischemic attacks (TIAs)
- Incomplete data
- Loss of follow-up

These criteria ensured the quality and reliability of the data analyzed in this research.

2.1.5. Variables studied

a) Clinical variables:

- Modified Rankin Scale (mRS) score
- Barthel Index
- Mortality

b) Economic variables:

- Direct medical costs
- Non-medical costs
- Indirect costs

c) Quality of life variables:

- Utilities derived from the mRS score

2.2 RESEARCH METHODS

2.2.1 Study Type

This is a retrospective analytical study with a comparative approach. It aims to utilize existing data from the medical records of patients who have experienced a stroke. The approach adopted is both comparative, contrasting therapeutic strategies from modern and traditional medicine, and economic, through the evaluation of costs and outcomes in terms of QALYs (Quality, Average, Life Years). This methodology allows for the simultaneous analysis of the clinical effectiveness and economic efficiency of different treatment approaches.

2.2.2 Data Collection

The data used in this study were collected from multiple sources to ensure greater reliability and triangulation of information. This approach allows for the cross-referencing of clinical, economic, and social data for a more comprehensive analysis of the treatment pathways of stroke patients.

2.2.2.1 Data Sources

Data were collected from three main sources:
Hospital records: the primary source of clinical data (diagnosis, management, progress, mRS and Barthel functional scores, length of hospital stay, examinations, treatments).

Surveys with patients and families: semi-structured interviews to gather information on indirect costs (loss of income, transportation, family support), perceptions of quality of life, care pathways, and reasons for treatment choices.

Registers of traditional healers: information on treatments administered, duration of care, and associated costs, providing better documentation of this often informal sector.

2.2.2.2 Data Collection Procedure

Data was collected retrospectively over a 24-month period. A standardized tool (data collection form) was used to harmonize the information gathered and limit measurement bias. The data were verified and cross-referenced across different sources to ensure consistency.

2.2.3 Cost Analysis

Costs were estimated using a societal approach, which takes into account all expenditures related to the illness, regardless of the actor bearing them (patient, family, healthcare system, or community). This approach is particularly well-suited to resource-limited settings, where a large portion of the costs is borne directly by households.

2.2.3.1 Cost Typology

The cost analysis was structured into three main categories:

a) Direct Medical Costs

Direct costs correspond to expenses immediately related to the patient's medical care. They represent all the costs incurred for care received in healthcare facilities.

These include, in particular:

- hospitalization costs (medical consultations, length of stay, nursing care),
- the costs of additional examinations (brain scan, laboratory tests),
- prescribed medications (such as thrombolytics, antihypertensives, anticoagulants, etc.),
- as well as medical and paramedical procedures performed during treatment.

This information was collected from hospital records and available invoices to ensure the most accurate possible estimate of the actual expenses incurred.

$$DC = FH + CEC + CM + CAM \qquad (2.1)$$

from where

- **CD** = Direct Costs
- **FH** = Hospitalization Costs
- **CEC** = Costs of Additional Tests

- **CM** = Costs of Medications
- **CAM** = Costs of Medical and Paramedical Procedures

This formula allows us to estimate all expenses directly associated with the care received by patients during their treatment.

a) Direct Non-Medical Costs

Non-medical costs encompass all expenses incurred by patients and their families outside of the actual medical care provided. Although not directly related to clinical treatment, they represent a significant financial burden, especially in the context of acute illnesses such as stroke.

They include, in particular:

- transportation costs (travel between home and hospital or home and traditional healer),
- accommodation expenses for accompanying persons,
- additional food costs related to the treatment period,
- and any informal payments made.

This information was gathered through surveys conducted with patients and their families to best estimate the true economic impact of the illness.

$$CNM = FT + FH + CA + PI \qquad (2.2)$$

from where

- **CNM** = Non-medical costs
- **FT** = Transportation costs
- **FH** = Accommodation costs
- **CA** = Additional food costs
- **PI** = Informal payments

This approach allows for the consideration of additional financial burdens borne by patients and their caregivers during treatment.

b) Indirect Costs

Indirect costs represent the economic losses caused by the illness, beyond healthcare expenses. In the case of stroke, these costs are particularly significant due to the functional impairments that can lead to temporary or permanent disability.

They include, in particular:

- the patient's loss of productivity (sick leave, partial or total disability),
- the loss of income for caregivers,
- the reduced participation in economic and social activities.

These costs were estimated using the human capital method, which involves valuing lost workdays based on the patient's average daily income.

$$CI = JPL \times R \qquad (2.3)$$

from where:

- **IC** = Indirect costs
- **JPL** = Number of lost workdays
- **R** = Average daily income

This method allows us to assess the economic impact of income losses caused by the illness, both for patients and their families.

c) Les coûts totaux

Les coûts ont été exprimés en dollars américains (USD) afin de faciliter la comparabilité internationale des résultats. Lorsque les données étaient disponibles en monnaie locale, une conversion a été effectuée à l'aide du taux de changement moyen observé pendant la période d'étude.

$$CT = CD + CNM + CI \qquad (2.4)$$

from where:

- **TC** = Total Cost

- **CD** = Direct Medical Costs
- **NMC** = Direct Non-Medical Costs
- **CI** = Indirect Costs

This formula allows us to obtain an overall estimate of the economic burden related to the disease and its management.

2.2.4 Comparative Analysis

A comparison of average costs between the two groups was conducted to identify significant differences. The results were presented as means, standard deviations, and distributions.

2.2.4.1 Bias Management and Limitations

To limit bias related to cost estimation:

- triangulation of sources was performed (records, surveys, registries)
- outliers were checked
- standardization of cost units was applied

Despite these precautions, some limitations remain, notably the possible underestimation of informal costs and the variability of practices in traditional medicine.

2.2.4.2 Calculation of QALYs

The QALY (Quality-Adjusted Life Year) is a widely used composite indicator in health economics to assess the effectiveness of medical interventions. It combines both lifespan and quality of life, thus allowing for the comparison of different therapeutic strategies on a common basis.

The QALY is defined as the product of life expectancy and a utility coefficient reflecting the quality of life associated with a given health status. This coefficient ranges from 0 (a state equivalent to death) to 1 (perfect health).

$$\text{QALY} = \sum(\text{Ui} \times \text{Ti}) \qquad (2.5)$$

from where:

- **Ui** represents the utility associated with a health state
- **Ti** corresponds to the duration spent in that state

This measure allows for the simultaneous assessment of the quantity and quality of life of patients during their care or clinical evolution.

2.2.4.3 Principle of Cost-Effectiveness Analysis

Cost-effectiveness analysis compares two health interventions (e.g., modern medicine vs. traditional medicine) by relating:

- Costs (in local currency: Ar, $…)
- Clinical effects (QALY, survival, mRS, Barthel Index, etc.)

Objective: to determine which strategy provides the best result at the lowest cost.

II.2.4.3.1 Cost-Effectiveness Ratio (CER)

The cost-effectiveness ratio (CER) is an indicator used in health economics to assess the cost required to achieve a given health outcome. It measures the efficiency of a therapeutic strategy
by comparing the costs incurred to the benefits obtained.

$$\text{CER} = \frac{\text{cost}}{\text{QALY}} \qquad (2.6)$$

from where:

- **CER:** Cost-Effectiveness Ratio
- **Cost:** Average total cost per patient (including direct and indirect costs)
- **QALY:** Quality-Adjusted Life Years

This indicator assesses the ratio between expenditures incurred and benefits obtained in terms of patient quality of life and life expectancy.

The ICER ratio is calculated as follows:

$$\text{ICER} = \frac{\text{Moderne cost} - \text{Traditional cost}}{\text{Modern QALY} - \text{Traditional QALY}} \qquad (2.7)$$

from where:

- **ICER:** Incremental Cost-Effectiveness Ratio
- **Modern Cost:** Average cost of care provided by modern medicine
- **Traditional Cost:** Average cost of care provided by traditional medicine
- **Modern QALY:** Average number of QALYs obtained with modern medicine
- **Traditional QALY:** Average number of QALYs obtained with traditional medicine

This indicator measures the additional cost required to achieve a further improvement in quality of life when a modern therapeutic strategy is compared to a traditional approach.

2.2.5 Statistical Analysis

Statistical analysis was performed to describe the characteristics of the study population and to compare the outcomes between the groups of patients treated with modern and traditional medicine. It includes both descriptive and comparative analyses.

II.2.5.1 Descriptive Analysis

Quantitative variables were expressed as means ± standard deviations, allowing for a summary of central tendency and data dispersion.

$$\text{Bar x} = \text{fracsum xi n} \qquad (2.8)$$
$$\text{SD} = \text{sqrt fracsum (xi – bar x)}^2\ \text{n}-1$$

from where:

- **Bar x:** sample mean
- **xi:** individual value
- **n:** sample size
- **SD:** standard deviation

These indicators allow us to describe the central tendency and dispersion of the data within the

sample, and qualitative variables were presented as counts and percentages.

2.2.5.2 Comparative Analysis

II.2.5.2.1 Student's t-test

Student's t-test was used to compare the means between two independent groups (modern medicine vs. traditional medicine), particularly for variables such as costs and QALYs.

$$\text{t} = \text{frac bar x}_1 - \text{bar x}_2\ \text{SE} \qquad (2.9)$$
$$\text{SE} = \text{sqrt frac SD}\frac{1}{2}\ \text{n}_1 + \text{frac SD}\frac{2}{2}\ \text{n}_2$$

from where:

- **t:** test statistic
- **bar x1, bar x2:** means of the two groups
- **SD1, SD2:** standard deviations
- **n1, n2:** sample sizes
- **SE:** standard error

This test helps determine if the observed difference between the two groups is statistically significant.

2.2.5.2.2 Chi-square (χ^2) Test

The chi-square test has been used to compare qualitative variables (e.g., mortality, level of autonomy).

$$\text{Chi}^2 = \text{sum frac}\ (\text{O}_\text{i} - \text{E}_\text{i})^2\ \text{E}_\text{i} \qquad (2.10)$$

from where:

- **Chi-square:** Chi-square statistic
- **Oi:** Observed frequency
- **Ei:** Expected frequency

This test assesses the existence of an association between two qualitative variables.

2.2.5.2.3 The Significance Threshold

The significance threshold (α) corresponds to the maximum probability of incorrectly accepting a difference as real when it is not (Type I error).

- If **$p < 0.05$** → statistically significant result
- If **$p \geq 0.05$** → non-significant result

This means that the observed differences are considered statistically significant if the probability of error is less than 5%.

2.2.6 Software Used

Statistical analyses were performed using specialized software such as SPSS, R, or Stata, ensuring the reliability and reproducibility of the results.

2.2.7 Ethical Considerations

Respect for confidentiality and anonymization of data.

2.2.7.1 Informed consent statement:

All human participants included in this retrospective study gave their free, informed, and written consent to participate, in accordance with the principles of the Declaration of Helsinki (2013) and Malagasy regulations on biomedical research and data protection.

Participants or their legal representatives (in cases of death or proven incapacity following stroke) were fully informed, both in writing and verbally, about the study objectives, data collection methods from medical records and interviews, the absence of additional risks, and their right to refuse or withdraw at any time without affecting their subsequent care.

Signed consent forms were obtained by the research team prior to any clinical, economic, or sociodemographic data collection. For deceased patients or those who lost cognitive abilities due to stroke, consent was obtained from the next of kin or legal guardian, following ethical guidelines for retrospective studies.

Complete anonymization of data (unique code assignment, removal of direct identifiers) was guaranteed. No information that could identify any participant will be published. Consent forms are kept by the principal investigator in secured archives, accessible only to research team members.

2.2.7.2 Ethical Approval Statement:

This study was conducted in accordance with the principles of the Declaration of Helsinki (2013). Although no institutional ethics committee was officially registered in Madagascar at the time of the study, all measures were taken to ensure compliance with international ethical standards. The Atsinanana Regional Directorate of Public Health and the Analakininina University Hospital Center in Toamasina granted administrative authorization for data collection. The study was also approved by the thesis supervisor and the research laboratory director of the EDGVM (Doctoral School of Engineering, Life Sciences and Modeling) at the University of Mahajanga.

3. RESULTS

3.1 Sampling

Sampling is a research method that involves selecting a representative subset of a population. This allows researchers to study its characteristics and draw conclusions that can then be generalized to the entire population.

3.1.1 Distribution of Patients According to Treatment Strategy

Table 1: Distribution of Patients

Therapeutic group	Number (n)	Percentage (%)
Modern medecine	220	43,1 %
Traditional medecine	200	39,2 %
No treatement	90	17,7 %
Total	510	100 %

***Source**: our* research, 2025

Modern medicine remained the most frequent recourse for patients (43.1%), closely followed by traditional medicine (39.2%). Furthermore, a significant proportion of patients (17.7%) received no treatment, reflecting the difficulties in accessing care in this context of limited resources.

3.1.2 Distribution by Age

Table 2: Distribution of Patients by Age

Age group (years)	Moderne medicine (n=220)	Traditional medicine (n=200)	No treatment (n=90)	Total (%)
N < 40	30	40	25	18,6 %
40 – 59	90	80	30	39,2 %
N ≥ 60	100	80	35	42,2 %
Total	220	200	90	100 %

***Source** : our* research, 2025

The study population consisted primarily of patients aged 60 and over (42.2%), confirming that stroke is a predominant condition in older adults.

Younger patients (< 40 years) were proportionally more numerous in the group receiving no treatment, suggesting a possible delay in seeking care.

3.1.3 Distribution by Sex

Table 3: Distribution of Patients by Sex

Sexe	Modern Medicine	Traditional Medicine	No Treatment	Total (%)
Male	130	110	50	56,9 %
Female	90	90	40	43,1 %
Total	220	200	90	100 %

***Source** : our research, 2025*

A male predominance was observed (56.9%), which is consistent with stroke epidemiological data. This trend could be explained by men's greater exposure to cardiovascular risk factors.

3.1.3 Distribution by Socioeconomic Level

Table 4: Socioeconomic Level of Patients

Socioeconomic Level	Modern Medicine	Traditional Medicine	No Treatment	Total (%)
Low	80	120	60	50,9 %
Medium	90	60	20	33,3 %
High	50	20	10	15,8 %
Total	220	200	90	100 %

***Source** : our research, 2025*

The majority of patients belong to the low socioeconomic class (50.9%). It is observed that low-income patients favor traditional medicine or receive no treatment, while middle- and high-income patients are more likely to use modern medicine.

This highlights an inequality in access to modern healthcare, strongly linked to financial constraints in a context like Toamasina.

3.2 Clinical Analysis

Clinical outcomes refer to all the effects observed in patients after a medical intervention or treatment, allowing for the evaluation of its efficacy, safety, and impact on health status. They concretely reflect the evolution of the disease through measurable indicators such as symptom improvement, functional recovery, the occurrence of complications, and mortality.

3.2.1 Functional Scores (mRS and Barthel)

Table 5: Functional Scores (mRS and Barthel)

Therapeutic Group	mRS Score (mean ± SD)	Barthel Score (mean ± SD)
Modern Medicine	2,5 ± 1,0	75 ± 12
Traditional Medicine	3,0 ± 1,2	65 ± 15
No Treatment	4,5 ± 1,3	40 ± 18

***Source** : our research, 2025*

Modern medicine does not save more lives than traditional medicine, but it significantly reduces disability in survivors (mRS: 2.5 vs. 3.0; Barthel: 75 vs. 65). No treatment is the worst option, both for survival and residual independence.

Statistical analysis (Student's t-test) shows highly significant differences ($p < 0.001$) for the mRS and Barthel scores. Patients treated with modern medicine have the best functional outcomes (less disability, greater independence). Traditional medicine yields intermediate results, while no treatment is associated with high dependency.

3.2.2 Level of independence and dependence

Table 6: Distribution according to functional level

Functional Level	Modern Medicine	Traditional Medicine	No Treatment
Complete Autonomy	40 %	30 %	10 %
Partial Autonomy	45 %	40 %	20 %
Severe Dependency	15 %	30 %	70 %

Source *: our research, 2025*

Modern medicine is the most expensive but offers the greatest autonomy to survivors. Traditional medicine costs three times less, with the same survival rate, but twice as much severe dependency. No treatment is the least expensive option, but unacceptable because it doubles mortality and leaves 70% of survivors severely dependent.

Statistical analysis (Chi-square test) shows a highly significant difference between the groups ($p < 0.001$).

3.2.3 Mortality rates

Table 7: Mortality by group

Treatment Group	Death (n)	Rate (%)
Modern Medicine	33	15 %
Traditional Medicine	30	15 %
No Treatment	27	30 %

Source *: our research, 2025*

Traditional medicine offers the same survival rate as modern medicine (85% survival) but at a total cost three times lower (400 000 versus 1 200 000). The absence of treatment, although the cheapest option, is unacceptable because it doubles the mortality rate (30% versus 15%).

3.3 Economic Analysis

Economic analysis is an evaluation method that compares the costs and consequences (effects or outcomes) of different interventions. Its goal is to identify the most efficient strategy for using available resources. It aids in healthcare decision-making by linking expenditures to the benefits obtained, whether clinical, functional, or related to quality of life.

3.3.1 Average Cost Per Treatment

Table 8: Average Costs Per Therapeutic Strategy

Cost Type	Modern Medicine(MGA)	Traditional Medicine(MGA)	No Treatment(MGA)
Direct Costs	1 000 000	300 000	80 000
Indirect Costs	200 000	100 000	20 000
Average Total Cost	1 200 000	400 000	100 000

Source *: our research, 2025*

No treatment is the least expensive strategy (100 000 MGA), but its clinical effectiveness has not been evaluated. Traditional medicine costs four times less than modern medicine (400 000 MGA versus 1 200 000 MGA) and represents an attractive financial compromise. From the perspective of direct and indirect costs alone, modern medicine is the most expensive, even though it potentially offers better health outcomes.

3.3.1 Cost-Effectiveness Analysis

3.3.1.1 Cost-Effectiveness Ratio (CER)

Table 9: CER by Strategy

Group	Average Cost (MGA)	Average QALY	CER (MGA/QALY)
Modern Medicine	1 200 000	0,75	1 600 000
Traditional Medicine	400 000	0,65	615 385
No Treatment	100 000	0,30	333 333

Source *: our research, 2025*

Modern medicine has the highest cost (1 200 000 MGA) but also the best effectiveness (0.75 QALY), with a high CER (1 600 000 MGA/QALY).

Traditional medicine offers a good compromise with an intermediate cost (400 000 MGA) and relatively high efficacy (0.65 QALYs), while also having the most favorable CER (615 385 MGA/QALY), making it the most cost-effective option.

No treatment is the least expensive (100 000 MGA) but also the least effective (0.30 QALYs), despite a low CER (333,333 MGA/QALY) which reflects poor clinical performance.

3.3.2 Incremental Cost-Effectiveness Ratio (ICER)

Table 10: ICER (Incremental Cost-Effectiveness Ratio)

Comparaison	Δ Cost (MGA)	Δ QALY	ICER (MGA/QALY)
Modern medicine vs. traditional medicine	800 000	0,10	8 000 000
Traditional medicine vs. no treatment	300 000	0,35	857 143
Modern medicine vs. no treatment	1 100 000	0,45	2 444 444

Source *: our research, 2025*

Comparison of treatment strategies shows that:
Modern medicine versus traditional medicine has the highest cost per health gain (8 000 000 MGA/QALY), indicating low marginal efficacy.

Traditional medicine versus no treatment offers the best cost-effectiveness ratio (857 143 MGA/QALY), reflecting good health profitability.

Modern medicine versus no treatment offers a greater health improvement, but at a high intermediate cost (2 444 444 MGA/QALY).

3.3.3 Overall Economic Interpretation

Table 11: Overall Economic Interpretation

Situation	Interpretation
Modern Medicine	More effective but very expensive
Traditional Medicine	Good cost-effectiveness compromise
No treatment	Low cost but ineffective

Source *: our research, 2025*

Modern medicine offers the best clinical efficacy (greater independence, less disability) but at a very high cost, which limits its accessibility. Traditional medicine represents an attractive compromise: cost three times lower, same survival rate, but with more functional after-effects. The absence of treatment, although the least expensive option, is unacceptable because it doubles mortality and severely worsens the functional prognosis of survivors.

3.3.4 Sensitivity Analysis

A sensitivity analysis was performed to assess the robustness of the cost-effectiveness analysis results by varying the main parameters: costs and QALYs.

3.3.4.1 Variation in Hospital Costs

Table 12: Impact of a 20% Increase in Hospital Costs

Therapeutic Strategy	Initial Cost (MGA)	Cost +20% (MGA)	QALY	initial CER	CER after variation
Modern Medicine	1 200 000	1 440 000	0,75	1 600 000	1 920 000
Traditional Medicine	400 000	480 000	0,65	615 385	738 462
No treatment	100 000	120 000	0,30	333 333	400 000

Source *: our research, 2025*

A 20% increase in costs (at constant quality of life) worsens the cost-effectiveness ratio (CER) of all strategies, but does not change their ranking. Modern medicine remains the most expensive (CER increases from 1.6 to 1.92 million), traditional medicine retains its intermediate economic advantage (CER from 615 385 to 738 462), while no treatment, although the least expensive, still exhibits the lowest clinical effectiveness (QALY of 0.30). Thus, regardless of the increase in costs, traditional medicine remains the best financial compromise, and no treatment remains the least advisable in terms of health benefits.

3.3.4.2 Variation des QALY (amélioration de l'efficacité clinique)

Tableau 13 : Impact d'une amélioration des QALY de la médecine moderne (+15%)

Therapeutic Strategy	Cost (MGA	Initial QALY	Improved QALY	Initial CER	Improved CER
Modern Medicine	1 200 000	0,75	0,86	1 600 000	1 395 349
Traditional Medicine	400 000	0,65	—	615 385	—
No treatment	100 000	0,30	—	333 333	—

***Source** : our research, 2025*

Modern medicine is the most expensive (1 200 000 MGA) but offers the greatest improvement in quality of life (QALY of 0.75 to 0.86), thus improving its cost-effectiveness ratio and making it more "profitable" from a health perspective. Traditional medicine, although accessible (400 000 MGA) with a lower initial CER, sees its clinical benefits stagnate, limiting its long-term effectiveness. No treatment, although the least expensive (100 000 MGA), results in a very low QALY (0.30) and reflects poor patient care, confirming that clinical effectiveness is the true driver of economic profitability.

3.4 Variables secondaires et analyses statistiques

3.4.1 Répartition selon le type d'AVC

Tableau 14 : Type d'AVC selon les groupes

Treatment Group	Ischemic Stroke (%)	Hemorrhagic Stroke (%)	Total
Modern Medicine	140 (63,6 %)	80 (36,4 %)	220
Traditional Medicine	120 (60 %)	80 (40 %)	200
No treatment	50 (55,6 %)	40 (44,4 %)	90

***Source** : our research, 2025*

In all three groups, ischemic stroke remained the most frequent, but its proportion decreased progressively from modern medicine (63.6%) to traditional medicine (60%), and then to no treatment (55.6%). Conversely, the proportion of hemorrhagic stroke increased (36.4% in modern medicine, 40% in traditional medicine, 44.4% without treatment). This trend suggests that the absence of treatment could be associated with a more unfavorable distribution of stroke types, with more potentially more severe hemorrhagic strokes.

However, the statistical test (Chi-square = 2.41; $p = 0.30$) indicates that this difference is not significant ($p > 0.05$). The groups are therefore comparable with respect to this parameter.

3.4.2 La Durée d'hospitalisation

Tableau 15 : Durée moyenne d'hospitalisation

Therapeutic Strategy	Average duration (days) ± AND
Modern Medicine	12 ± 4
Traditional Medicine	9 ± 3
No treatment	6 ± 2

***Source** : our research, 2025*

The duration of care is longer in modern medicine (12 days), which offers the greatest autonomy. Traditional medicine lasts 9 days, with similar survival rates but more long-term consequences. No treatment is the shortest duration (6 days) but clinically unacceptable.

Statistical tests (Student's t-test) show highly significant differences: $p < 0.001$ for the comparison between modern and traditional medicine, and $p < 0.001$ for modern medicine versus no treatment. The longer hospital stay in modern medicine is explained by more comprehensive and hospital-based care.

3.4.3. Clinical Complications

Table 16: Observed Complications

Complications	Modern Medicine (%)	Modern Medicine (%)	Modern Medicine (%)
Infection	10 %	12 %	8 %
Pressure ulcers	8 %	15 %	20 %
Recurrent stroke	5 %	10 %	15 %

***Source** : our research, 2025*

Modern medicine is the most effective at preventing pressure ulcers (8% vs. 15-20%) and stroke recurrence (5% vs. 10-15%). The absence of treatment exposes patients to the highest rates of pressure ulcers and recurrence, but paradoxically, to the lowest rates of infection, as these patients are not receiving hospital care.

The statistical test (overall Chi-square = 6.78; p = 0.03) indicates that complications are significantly more frequent in the absence of treatment, particularly pressure ulcers and recurrence. Overall, modern medicine has the lowest complication rate.

3.4.4 Analyse descriptive des scores fonctionnels

Tableau 17 : Scores fonctionnels comparatifs

Groupe thérapeutique	Barthel (moyenne ± ET)	mRS (moyenne ± ET)
Médecine moderne	75 ± 12	2,5 ± 1,0
Médecine traditionnelle	65 ± 15	3,0 ± 1,2
Aucun traitement	40 ± 18	4,5 ± 1,3

Source *: our research, 2025*

Modern medicine offers the highest level of independence (Barthel score: 75) and the least disability (mRS: 2.5). Traditional medicine provides intermediate but acceptable results (Barthel score: 65, mRS: 3.0). The absence of treatment leads to severe dependence (Barthel score: 40, mRS: 4.5) and double the mortality rate.

Statistical tests (Student's t-test) show highly significant differences for both the Barthel score ($p < 0.001$) and the mRS ($p < 0.001$). Modern medicine therefore offers the best functional recovery.

4. DISCUSSION

4.1 Overall Interpretive Summary of Results

This study highlights significant heterogeneity in the treatment trajectories of stroke patients in Toamasina, with a relatively balanced distribution between modern medicine (43.1%) and traditional medicine (39.2%), and a concerning proportion of patients without treatment (17.7%) (see table 1).

Clinically, modern medicine is associated with the best functional outcomes (lower mRS, higher Barthel score), followed by traditional medicine, while the absence of treatment is strongly correlated with poor functional prognosis and high mortality.

Economically, modern medicine is the most expensive but also the most effective, while traditional medicine has a better cost-effectiveness ratio (CER), and the absence of treatment is the dominant factor (low cost but very low effectiveness).

4.2 Analysis of the Structure of Therapeutic Use

4.2.1 Dual Healthcare System

The near-equal distribution between modern and traditional medicine reflects a dual healthcare system, characteristic of low- and middle-income countries. This situation reflects a coexistence between biomedical and traditional systems, already described in sub-Saharan Africa and several Asian countries.

Studies conducted in Ghana, Nigeria, and Tanzania also show that 30 to 60% of patients initially resort to traditional medicine before any hospital consultation, particularly for acute neurological illnesses.

4.2.2 International Comparison

- Nigeria: initial recourse to traditional medicine in ~45% of strokes.
- Ghana: delayed hospital admission in 50% of cases.
- Rural India: high use of non-biomedical care before hospitalization. Our results are therefore consistent with international literature, confirming that traditional medicine is a major first-line treatment option in resource-limited settings.

4.3. Sociodemographic Factors and Determinants of Patient Trajectories

4.3.1 Age and Vulnerability

The predominance of patients aged ≥60 years (42.2%) (see table 2) is consistent with global epidemiological data. Stroke remains a disease of the elderly, linked to the accumulation of cardiovascular risk factors.

International comparison:

- Europe (ESO, 2021): mean age at stroke ≈ 70 years
- Sub-Saharan Africa: slightly younger age (55–65 years)

The higher proportion of young patients without treatment suggests a delay in seeking care or an underestimation of initial severity, a phenomenon also reported in West Africa.

4.3.2 Sex and Risk Factors

The male majority found in our study (56.9%) (see table 3) aligns with the results described in several international scientific publications. Numerous studies indicate that strokes affect men more frequently, primarily due to greater exposure to certain risk factors.

Smoking, excessive alcohol consumption, and poorly managed hypertension are among the main factors contributing to the development of cardiovascular disease and stroke in this population.

Data published by the World Health Organization in 2023 also show that middle-aged men have a stroke risk approximately 1.25 times higher than that of women, which supports this epidemiological observation.

4.3.3 Socioeconomic Status and Inequalities in Access

The strong association between low socioeconomic status and the use of traditional medicine or lack of treatment is a key finding.

International comparison:

- Brazil (de Oliveira et al.): low income associated with delayed stroke care
- South Africa: limited access to specialized units in rural areas
- India: direct costs as the main barrier to hospitalization

This confirms that economic determinants are critical factors in health inequalities, particularly in acute conditions such as stroke.

4.4 Discussion of Clinical Results

4.4.1 Superiority of Modern Medicine

The results demonstrate a significant superiority of modern medicine (see table 17):

- Lower mRS (2.5 vs. 3.0 vs. 4.5)
- Higher Barthel score (75 vs. 65 vs. 40)
- More frequent return to independence (40% vs. 30% vs. 10%)

International Comparison:

- Stroke Unit Trials (Europe): 20–30% reduction in disability
- Stroke Registry USA: better functional recovery with specialized care
- South Africa (Ntshele et al.): significant improvement with neurovascular units

Our results confirm the effectiveness of specialized stroke care, even in resource-limited settings.

4.4.2 The Role of Traditional Medicine

Traditional medicine shows intermediate results, with:

- partial improvement in autonomy
- mortality equivalent to modern medicine (15%) (see table 7)

This can be explained by:

- selection of less severe cases
- symptomatic effects (rest, local treatments)
- delayed hospital transfer

International comparison: Few quantitative studies exist, but:

- Ghana and Nigeria: variable clinical results, often influenced by delayed treatment
- China (integrated traditional medicine): improved results only as a complement to modern medicine

In conclusion, traditional medicine cannot be considered a substitute but potentially complementary.

4.4.3 Lack of Treatment and Excess Mortality

The lack of treatment is associated with:

- High mortality (30%) (see table 7)
- Severe dependency (70%) (see table 6)
- Increased complications

International comparison:

- Sub-Saharan Africa: untreated stroke mortality 25–40%
- High-income countries: <15% thanks to early intervention

This confirms that the complete absence of treatment is a major factor in loss of opportunity.

4.5. Analysis of Complications and Length of Hospital Stay

4.5.1 Complications

Complications are more frequent without treatment (pressure ulcers, recurrences) (see table 16).

International comparison:

- Europe: effective prevention reduces pressure ulcers to <5%
- Africa: higher rates (10–25%) due to a lack of supportive care

4.5.2 Length of Hospital Stay

The longer length of stay in modern medicine (12 days) reflects:

- comprehensive care
- early rehabilitation
- specialized monitoring

This is consistent with international data from stroke units where the initial length of stay may be longer but with better functional outcomes.

4.6. Economic Discussion

4.6.1 Costs and Accessibility

Modern medicine is the most expensive (1 200 000 MGA), while traditional medicine is intermediate.

International Comparison:

- Sub-Saharan Africa: catastrophic stroke costs (often >40% of annual income)
- South Asia: high financial burden of hospital care

4.6.2 Cost-Effectiveness Analysis

Key Results (see table 9):

- Modern medicine: high CER (1 600 000 MGA/QALY)
- Traditional medicine: more favorable CER (615 385 MGA/QALY)
- No treatment: ineffective despite low cost

International Comparison:

- Ghana (Stroke Cost Study): expensive but more effective hospital care
- WHO-CHOICE: cost-effective hospital-based stroke interventions, but dependent on the funding threshold

ICER (8 000 000 MGA/QALY): This result suggests that modern medicine requires a high willingness-to-pay threshold to be economically justified.

4.6.3 Overall Economic Interpretation

Modern medicine appears to be the most clinically effective, but it remains associated with high costs. Traditional medicine, on the other hand, offers relative economic efficiency, with lower costs but slightly inferior clinical outcomes. Finally, no treatment proves to be the least favorable, with overall insufficient results and very limited effectiveness. This profile is typical of resource-limited healthcare systems.

4.7. Robustness and Methodological Comparison

Sensitivity analysis indicates that the results obtained remain generally stable, even when the parameters used vary. The hierarchy among the different therapeutic strategies does not change, which confirms the robustness of the study's conclusions. In this context, traditional medicine appears to be the most economically stable option.

International Comparison: Cost-effectiveness studies in Africa often show similar robustness, particularly when cost variations do not reverse the main trends.

4.8. Implications for Public Health

4.8.1 Integration of Healthcare Systems

The study results highlight the value of developing an integrated care model. This could include training traditional healers to recognize the warning signs of stroke, in order to promote early detection of severe cases. It would also be important to strengthen mechanisms for the rapid referral of patients to hospitals. Finally, improved collaboration with community stakeholders could contribute to enhancing the continuity and speed of care.

4.8.2 Reducing Inequalities

The results also highlight several areas for improvement in the healthcare system. In particular, it is necessary to strengthen financial access to care in order to reduce economic barriers. The development of specialized stroke units is also a priority for improving the quality of care. Finally, the implementation or strengthening of community health insurance mechanisms could contribute to better population coverage.

4.8.3 Awareness

Recognizing the warning signs of stroke, particularly through the FAST approach, is essential for improving early patient care. Greater public awareness would also help reduce delays in seeking medical attention, which remain a significant contributing factor to stroke-related morbidity and mortality.

4.9. Study Limitations

The study has some methodological limitations. It is an observational design, which may introduce selection bias into the results. Furthermore, the lack of randomization limits the possibility of establishing strict causal relationships. QALY estimation also relies on indirect methods, which can influence the accuracy of the results. Finally, since some socioeconomic data are self-reported, they may be subject to errors or reporting biases.

This study highlights a strong therapeutic duality in stroke management in Toamasina. Modern medicine remains the most clinically effective strategy, while traditional medicine offers relative economic efficiency in a context of financial constraints. Lack of treatment is a major factor in excess mortality and severe disability.

These results are generally consistent with the international literature and underscore the importance of an integrated health model combining biomedical efficacy and community accessibility to improve stroke prognosis in resource-limited countries.

5. CONCLUSION

This study highlights a complex and heterogeneous therapeutic organization in the management of strokes in Toamasina. It is characterized by the coexistence of modern medicine, traditional medicine, and a significant proportion of patients receiving no treatment at all.

The results show that modern medicine generally offers the best clinical outcomes, with a notable improvement in functional autonomy, a reduction in disability (lower mRS), and better overall recovery (higher Barthel score). Traditional medicine shows intermediate results, suggesting some clinical efficacy, but insufficient to achieve the performance observed in specialized hospital settings. Conversely, the absence of treatment is associated with an unfavorable outcome, characterized by significant dependence and higher mortality.

From an economic standpoint, modern medicine appears to be the most effective but also the most expensive strategy. Traditional medicine, on the other hand, offers a better compromise between cost and efficacy. Cost-effectiveness analysis (CER and ICER) confirms that, in a context of limited resources, it can represent an economically attractive alternative, despite less effective clinical outcomes. The absence of treatment, while inexpensive, is clearly ineffective due to its limited health benefits.

Overall, these results highlight that the main challenge in stroke care in Madagascar is not limited to treatment selection, but primarily concerns rapid access to appropriate care. Delays in care and socioeconomic inequalities significantly impact patient outcomes.

Therefore, an integrated approach to the health system appears necessary, combining the strengthening of specialized facilities, improved financial and geographical accessibility, and better-structured collaboration with traditional medicine practitioners to facilitate early referral of patients to hospitals.

In conclusion, optimizing stroke care in a resource-limited setting relies on a balance between clinical effectiveness, equitable access to care, and economic viability. An integrated and coordinated health strategy could significantly reduce the burden of stroke in Madagascar, while improving patient survival and quality of life.

BIBLIOGRAPHICAL REFERENCES

[1] World Health Organization. Stroke, 2023. Cerebrovascular accident. Geneva:
[2] World Stroke Organization. 2022.Global stroke fact sheet 2022. Geneva: WSO.
[3] Feigin VL, Brainin M, Norrving B. 2021. Global burden of stroke and risk factors. Lancet Neurol.;20(10)
[4] Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. 2015. Methods for the economic evaluation of health care programs. 4th ed. Oxford: Oxford University Press.
[5] National Institute for Health and Care Excellence. 2022. Guide to the methods of technology appraisal. London: NICE.
[6] World Health Organization. 2003. WHO guide to cost-effectiveness analysis. Geneva: WHO.
[7] Kind P. 1996. The EuroQol instrument: an index of health-related quality of life. Health Policy.
[8] Whitehead SJ, Ali S. Health outcomes in economic evaluation: the QALY and utilities. Health Econ. 2010
[9] Johnson W, Onuma O, Owolabi M, Sachdev S. 2020. Stroke: a global response is needed. Lancet Global Health.
[10] African Stroke Organization. 2021. Stroke epidemiology in Africa.
[11] James PB, Wardle J, Steel A, Adams J. 2019.Traditional medicine use among African populations. BMC Public Health.
[12] World Health Organization. 2013. WHO traditional medicine strategy 2014–2023. Geneva: WHO.
[13] World Bank. 2022. Health financing and access to care in low-income countries. Washington DC: World Bank;
[14] Hosseinpoor AR, Bergen N, Schlotheuber A. 2021. Socioeconomic inequalities in health care access. Int J Equity Health.
[15] Murray CJL, Lopez AD. 1996. The global burden of disease: a comprehensive assessment. Cambridge: Harvard University Press.
[16] Gold MR, Siegel JE, Russell LB, Weinstein MC. 1996. Cost-effectiveness in health and medicine. New York: Oxford University Press.
[17] GBD 2019 Stroke Collaborators. Global, regional, and national burden of stroke. Lancet Neurol. 2021
[18] Owolabi MO, Thrift AG, Mahal A, et al. 2022. Primary stroke prevention worldwide. Lancet Public Health.
[19] Adeloye D. 2014. An estimate of the incidence and prevalence of stroke in Africa. BMC Neurol.
[20] Ezejimofor MC, Uthman OA, Maduka O, et al. 2017. Stroke survivors in Africa: systematic review. PLoS One.
[21] Watkins DA, Jamison DT, Mills A, et al. 2018. Universal health coverage and economic evaluation. Lancet.
[22] Bertram MY, Lauer JA, De Joncheere K, et al. 2016. Cost–effectiveness thresholds. Bull World Health Organ.
[23] Neumann PJ, Sanders GD, Russell LB, Siegel JE, Ganiats TG. 2016. Cost-effectiveness in health and medicine (2nd ed.). Oxford: Oxford University Press.
[24] Briggs AH, Claxton K, Sculpher MJ. 2006. Decision modeling for health economic evaluation. Oxford: Oxford University Press.
[25] Diener HC, Hankey GJ. 2020. Primary and secondary prevention of stroke. Lancet.
[26] Pandian JD, Kalkonde Y, Sebastian IA, et al. 2020. Stroke systems of care in low-income countries. Lancet.
[27] O'Donnell MJ, Chin SL, Rangarajan S, et al. 2016. Risk factors for stroke globally. Lancet.

[18] Bloom DE, Cafiero ET, Jané-Llopis E, et al. 2011. The global economic burden of noncommunicable diseases. Geneva: World Economic Forum.
[29] Gyasi RM, Mensah CM. The role of traditional medicine in Ghana. J Ethnobiol Ethnomed. 2015
[30] Donkor, E. S. 2018. Stroke in the 21st Century : A Focus on the Burden and the Need for Contextualization. *Journal of Stroke and Cerebrovascular Diseases*, 27(11), 2966-2971.
[31] Pandian, J. D., & et al. 2016. Family-led rehabilitation after stroke in India: the ATTEND trial, study protocol for a randomized controlled trial. *Trials*, 17(13).
[32] Akinyemi RO, Jenkins C, Nichols M, et al. 2020 Jan-Dec;Unraveling the Ethical, Legal, and Social Implications of Neurobiobanking and Stroke Genomic Research in Africa: A Study Protocol of the African Neurobiobank for Precision Stroke Medicine ELSI Project. *International Journal of Qualitative Methods*. 19. DOI: 10.1177/1609406920923194

Conflicts of interest: None.
Funding: None.
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