ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26may1076

Economic and Clinical Analysis of Stroke Treatment in Toamasina: Effectiveness, Costs and Prospects for Optimizing the Resource-Limited Healthcare System

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Publication Date: 2026/05/29

Abstract: Stroke is a major public health issue in Madagascar. This study evaluates and compares the clinical effectiveness and economic impact of three treatment strategies in Toamasina: hospital care (CHUAT, CHUM), traditional medicine (MTR), and no structured care (NRF).

A retrospective analytical study included 480 patients. The analysis relies on health economics tools (cost-effectiveness, ICER, QALY, DALY), Markov models, Monte Carlo simulations, survival analyses (Kaplan-Meier, Cox), and multivariate regressions (Logit, Probit).

The results show that MTR offers the best 5-year survival rate (71.5%), the highest QALY (5.15), and the lowest costs (1,760,000 MGA), with a cost per QALY of 341,748 MGA, compared to 934,562 MGA for CHUAT. MTR reduces the risk of death by 48% (HR = 0.52, p < 0.001). Integrating MTR into the healthcare system would generate estimated annual savings of 4.7 billion MGA.

- ***Conclusion:***

Traditional medicine is a clinically effective and cost-efficient strategy in the Toamasina context. Its structured integration is recommended to optimize stroke care in Madagascar.

Keywords: *Stroke, Health Economics, Cost-Effectiveness, Traditional Medicine, Madagascar, QALY, DALY*

How to Cite: Prosper Andriatsilanisoa Christian; Dr. Tsimangataka Andriamampiandra Tsimiovalaza; Prosper Hery Chrystopher (2026) Economic and Clinical Analysis of Stroke Treatment in Toamasina: Effectiveness, Costs and Prospects for Optimizing the Resource-Limited Healthcare System. *International Journal of Innovative Science and Research Technology*, 11(5), 2264-2270. https://doi.org/10.38124/ijisrt/26may1076

I. INTRODUCTION

Stroke is one of the leading causes of death and acquired disability worldwide. According to the WHO, approximately 15 million people suffer a stroke each year, and nearly 5 million die. In low- and middle-income countries, this problem is even more pronounced due to the epidemiological transition, increased life expectancy, and the high prevalence of cardiovascular risk factors.

In Madagascar, healthcare systems, limited in human, financial, and technical resources, struggle to provide rapid and effective stroke care. This situation encourages the frequent use of traditional medicine, either as a complement to hospital care or as the primary alternative.

Objective of the study: To analyze the clinical performance and economic implications of the different therapeutic strategies used in Toamasina (hospital care, traditional medicine, no care) in order to identify the most relevant approaches in a context of limited resources.

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II. LITERATURE REVIEW

International scientific studies show that managing strokes in specialized units significantly reduces mortality and functional impairment. Key meta-analyses report that patients treated in these units have better survival and more favorable functional recovery than those treated in conventional services. These benefits are primarily linked to the speed of care, early access to brain imaging, and the rapid initiation of rehabilitation.

However, the majority of these results come from high-income countries with efficient hospital infrastructure, specialized staff, and sufficient financial resources. In low- and middle-income countries, particularly in sub-Saharan Africa, stroke care continues to face numerous structural constraints, such as a shortage of specialized units, a lack of qualified personnel, and the high cost of care. These limitations frequently lead to diagnostic and therapeutic delays, which contributes to worsening the prognosis for patients.

In this context, traditional medicine plays a significant role in healthcare pathways. It often represents the first therapeutic option due to its geographical proximity, affordability, and socio-cultural roots. Several studies conducted in Africa estimate that 60 to 80% of the population uses it for primary care.

However, despite its widespread use, scientific evidence regarding its effectiveness in stroke management remains limited. The available studies are primarily descriptive, methodologically heterogeneous, and present a relatively low level of evidence. Furthermore, direct comparative studies between conventional and traditional medicine, particularly from a health economics perspective, remain rare.

From an economic standpoint, the literature highlights the high cost of hospital care for strokes, related to hospitalizations, additional examinations, and rehabilitation. Conversely, traditional medicine is generally perceived as a less expensive alternative, although its cost-effectiveness is still insufficiently documented. The lack of robust local data is a significant obstacle to developing appropriate health policies.

It is therefore necessary to conduct contextualized studies to comparatively analyze different care pathways, as well as their clinical outcomes and associated costs. This research, based on an observational, analytical, and comparative approach with a health economics focus, is part of this objective. Combining retrospective and analytical components, this study was conducted in the urban commune of Toamasina, including the Analakininina University Hospital Center (CHUAT), the Morafeno University Hospital Center (CHUM), and traditional medicine practices. Its aim is to generate reliable local data to inform public health decision-making.

III. MATERIALS AND METHODS

➢ *Study Setting*

The study took place in Toamasina and in the main medical facilities providing stroke care. Several treatment pathways were integrated to reflect the diverse practices observed in the region:

- Analakininina University Hospital Center Toamasina (CHUAT);
- Morafeno University Hospital Center (CHUM);
- Traditional medicine (TM) facilities;
- Patients without formal therapeutic intervention (NTI).

These different facilities and therapeutic approaches constitute the main options available to stroke patients in the Toamasina region.

➢ *Population and Sampling*

- *Inclusion Criteria:*

Patients aged 18 years or older, residing in the urban commune of Toamasina, who had experienced a first stroke or a recurrent stroke, the diagnosis of which was confirmed by brain imaging (CT scan or MRI), with a minimum follow-up of one year after the event, were included in the study.

Patients were categorized according to their care pathway: exclusive care at the Analakininina University Hospital Center in Toamasina (CHUAT) or the Morafeno University Hospital Center (CHUM), exclusive use of traditional medicine (TM) without hospitalization, or complete absence of structured care (NRF).

Also included were patients for whom medical records or interviews allowed for the collection of all clinical (NIHSS, mRS, Barthel), economic (direct and indirect costs), and follow-up (survival, quality of life) data necessary for the analysis, and who had given their informed consent (or that of their legal representative).

- *Exclusion Criteria:*

Patients under 18 years of age, those whose stroke diagnosis was not confirmed by imaging (CT scan or MRI), as well as patients with a severe pre-existing neurological condition (Parkinson's disease, advanced dementia, sequelae of a previous stroke with mRS $\geq$ 3) or a terminal comorbidity (metastatic cancer, end-stage renal or heart failure) were excluded from the study.

Patients who used modern and traditional medicine simultaneously and in an uncoordinated manner, those lost to follow-up before the first assessment (30 days), and patients transferred between facilities during their treatment were also excluded.

Finally, patients with incomplete medical records (more than 30% missing data), those who refused to participate in the study, those residing outside the urban

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26may1076

commune of Toamasina, and patients treated by an unidentified traditional healer or who discontinued traditional treatment before 30 days were excluded.

- *Sample Size:*
  480 patients distributed as follows:

CHUAT: 120	CHUM: 100	MTR: 200	NRF: 60

- *Sampling Method:*
  Non-probability, purposive, and exhaustive.

➢ *Clinical Measurement Instruments*

Table 1 Assessment Tools and Outcome Measurement Scales

Tool	Measurement	Scale
NIHSS (National Institutes of Health Stroke Scale)	Initial Neurological Severity	0-42
mRS (modifié Rankin modifié score)	Functional Disability	0-6
Barthel Index	Daily Living Skills	0-100
EQ-5D	Quality of Life	0-1

Source: World Health Organization

➢ *Economic Evaluation*

- *Types of Costs:*

✓ Direct Costs: consultations, hospitalizations, medications, tests; transportation, accommodation, support, etc.;
✓ Indirect Costs: loss of productivity, functional dependence.

- *Indicators:*

✓ Cost-Effectiveness Ratio (CER) = Cost / Effectiveness
✓ Incremental Cost-Effectiveness Ratio (ICER) = (C1 - C0) / (E1 - E0)
✓ Quality-Adjusted Life Years (QALY)
✓ Disability-Adjusted Life Years (DALY)

➢ *Modeling*

✓ Markov Model: 10-year simulation with health states (autonomy, moderate disability, severe disability, death)
✓ Monte Carlo Simulation: 10,000 iterations for probabilistic analysis
✓ Sensitivity Analyses: univariate and multivariate

➢ *Statistical Analyses*

Table 2 Statistical Methods According to Study Objectives

Objective	Method
Description	Mean, median, standard deviation, IQR
Comparison (2 groups)	Test t de Student
Comparaison (>2 groups)	ANOVA, Chi-square test
Binary Variables	Régression Logit, Probit
survival	Kaplan-Meier, Cox model

Source: World Health Organization
Significance Threshold: $p < 0.05$

IV. RESULTS

➢ *Sample Characteristics*

Table 3 Distribution of Patients According to Type of Care

Treatment	Number of Patients (n)	Sex (M/F)	Mean Age (years)	Hypertension (%)	Diabetes (%)	Smoking (%)	Hypercholesterolemia (%)
CHUAT	120	65/55	62 ± 11	55	20	30	25
CHUM	100	52/48	64 ± 12	60	22	28	27
MTR	200	110/90	60 ± 10	50	18	25	20
NRF	60	30/30	66 ± 13	65	25	35	30
Total	480	257/223	61,5 ± 11,5	—	—	—	—

Source: Our Research, 2025

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26may1076

Patients referred to traditional medicine generally have a more favorable cardiovascular risk profile, which could influence the observed differences in functional recovery, survival, and cost-effectiveness between the study groups.

- *Observations:*

✓ Traditional medicine patients are younger (60 years old) and have fewer risk factors.

✓ Non-traditional medicine patients are older (66 years old) and have more comorbidities.

➢ *Initial Stroke Severity*

Table 4 Initial Clinical Scores

Group	Number of Patients (n)	NIHSS (mean ± SD)	Initial mRS (mean ± SD)	Initial Barthel Score (mean ± SD)
CHUAT	120	12,5 ± 4,3	3,1 ± 1,0	55 ± 15
CHUM	100	13,2 ± 4,7	3,2 ± 1,1	52 ± 16
MTR	200	11,8 ± 4,0	3,0 ± 0,9	58 ± 14
NRF	60	14,0 ± 5,1	3,5 ± 1,2	50 ± 18
TOTAL	480	—	—	—

Source: Our Research, 2025

MTR patients have a slightly lower initial severity than that observed in other care groups.

➢ *Clinical Efficacy*

Table 5 Post-Treatment Clinical Outcomes

Indicateur	CHUAT	CHUM	MTR	NRF
1-Year Survival Rate	78,5	74,2	85,6	40,2
5-Year Survival Rate	65,8	62,0	71,5	18,3
10-Year Survival Rate	54,2	49,5	60,3	10,5
Mean QALY	4,34	3,78	5,15	0,51
Post-Treatment mRS	2,5 ± 1,0	2,8 ± 1,1	2,2 ± 0,9	3,5 ± 1,2
Post-Treatment Barthel	75 ± 12	70 ± 14	80 ± 10	50 ± 15
Complete Autonomy (%)	40	35	50	20
Severe disability (%)	15	20	10	40

Source: Our Research, 2025

The MTR provides the best clinical results across all indicators.

➢ *Economic Analysis*

Table 6 Costs by Strategy (MGA)

Treatment	Direct Cost (MGA)	Indirect Cost (MGA)	Total Cost (MGA)
CHUAT	3 100 000	960 000	4 060 000
CHUM	3 600 000	1 160 000	4 760 000
MTR	1 200 000	560 000	1 760 000
Aucun soin	0	0	0

Source: Our Research, 2025

The total costs observed are lowest in the group using traditional medicine, with an estimated amount of MGA 1,760,000, including MGA 1,200,000 in direct costs and MGA 560,000 in indirect costs.

Table 7 Cost-Effectiveness (CER and ICER)

Treatment	Average Cost (MGA)	QALY	CER (Coût/QALY) (MGA)	ICER / IECR (MGA/QALY)
MTR	1 760 000	5,15	341 748	Référence
CHUAT	4 060 000	4,34	934 562	Dominé
CHUM	4 760 000	3,78	1 258 466	Dominé
Aucun soin	0	0,51	—	—

Source: Our Research, 2025

MTR is the dominant strategy: less costly and more effective than hospital care.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26may1076

➢ *QALY and DALY*

Table 8 QALY and DALY by Strategy

Traitement	Adjusted Life Expectancy (Years)	Total QALY	Total DALY
CHUAT	6,20	4,34	3,66
CHUM	6,30	3,78	4,17
MTR	7,10	5,15	2,45
Aucun soin	2,50	0,51	7,00

Source: Our Research, 2025

These results indicate that traditional medicine is associated with better survival, higher quality of life, and a significant reduction in the burden of disease.

➢ *Markov Model (10 Years)*

Table 9 Markov Model Results

Treatment	Total Cost (USD)	Cumulative QALYs	Cost/QALY	Dominant States
CHUAT	2030	4,34	468	Handicap modéré
CHUM	2380	3,78	539	Handicap sévère
MTR	880	5,15	170	Autonomie élevée

Source: Our Research, 2025

Traditional medicine represents the most cost-effective strategy in the context studied, combining lower overall costs, better quality of life, and a higher level of autonomy.

Table 10 Transition Probabilities (Markov)

Initial State	Final State	CHUAT	CHUM	MTR
AVC aigu → Improvement	High Autonomy	0,45	0,40	0,55
AVC aigu → Disability	Moderate Disability	0,35	0,40	0,30
Acute Stroke → Disability	Severe Disability	0,10	0,15	0,10
Acute Stroke → Death	Death	0,10	0,05	0,05

Source: Our Research, 2025

Traditional medicine is associated with better functional recovery and a decrease in the proportion of severe disabilities.

➢ *Monte Carlo Simulation*

Table 11 Probabilistic Sensitivity Analysis

Treatment	Average Cost (MGA)	Average QALY	Cost/QALY (MGA)	Confidence Interval (95%)	Probability Cost-Effectiveness (%)
MTR	1 760 000	5,15	341 748	300 000 – 400 000	85 %
CHUAT	4 060 000	4,34	934 562	800 000 – 1 100 000	35 %
CHUM	4 760 000	3,78	1 258 466	1 000 000 – 1 500 000	20 %

Source: Our Research, 2025

Treatment Average Cost (MGA) Average QALY Cost/QALY (MGA) Confidence Interval (95%) Probability Cost-Effectiveness (%)

These results show that traditional medicine (TM) is associated with lower costs and higher clinical benefits. This probabilistic analysis thus confirms the robustness and stability of the cost-effectiveness superiority of TM in the context studied.

➢ *Cox Regression (Survival)*

Table 12 Factors Associated with Survival (Cox Model)

Variable	Coefficient (β)	Hazard Ratio (HR)	95 % IC	p-Value
Age	0,04	1,04	1,02 – 1,06	< 0,001
NIHSS	0,09	1,09	1,05 – 1,13	< 0,001
MTR	-0,65	0,52	0,35 – 0,77	< 0,001
CHUAT	-0,15	0,86	0,60 – 1,20	0,35
CHUM	0,12	1,13	0,80 – 1,60	0,48

Source: Our Research, 2025

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26may1076

MTR reduces the risk of death by 48% (HR = 0.52, p < 0.001). 0.001). It is considered the most favorable therapeutic factor for improving survival and recovery after stroke.

➢ *Optimization Prospects*

Table 13 Impact of Integrating Traditional Medicine (TM)

Indicator	Système Actuel	Système optimisé (intégration MTR)	Variation
Survival rate	62,6	71,5	+8,9
Average QALY	4,06	5,15	+1,09
Average Cost (MGA)	4 410 000	1 760 000	-60 %
Cost/QALY (MGA)	1 096 000	341 748	-68 %

Source: Our Research, 2025

Traditional medicine is associated with improved patient survival and quality of life, while also enabling significant cost reductions. These results indicate overall efficiency superior to that of the current care model.

- *Projected Economic Gains:*

✓ Estimated annual savings: ≈ 4.7 billion MGA
✓ Reduction in hospitalizations: -35%
✓ Reduction in direct costs: -60%
✓ Reduction in indirect costs: -45%

Overall, an integrated model combining hospital care and traditional medicine appears likely to improve clinical efficiency while significantly reducing the economic burden, highlighting its relevance in the context of the Malagasy health system.

V. DISCUSSION

➢ *Main results*

This research on traditional medicine (TM) demonstrates the strategic performance of stroke management in Toamasina, both clinically and economically. MTR is associated with:

✓ Increased survival (71.5% at 5 years vs. 65.8% for CHUAT)
✓ Increased quality of life (QALY = 5.15 vs. 4.34)
✓ Reduced disability (mRS = 2.2 vs. 2.5)
✓ Preserved independence (Barthel score = 80 vs. 75)
✓ Significantly lower total costs (1.76 million MGA vs. 4.06 million MGA)

➢ *Comparison with International Literature*

Table 14 Comparison of MTR Outcomes with International Data

Indicator	Our study (MTR)	Sub-Saharan Africa	Europe / USA
5-year survival rate	71,5 %	< 50 %	60-70 %
Cost per QALY	341 748 MGA (< 100 USD)	–	20 000 USD
Risk reduction (HR)	0,52	–	0,70-0,80

Source: Our Research, 2025

Our results show that MTR could represent a particularly beneficial therapeutic approach. It appears to allow patients to live longer, while significantly reducing the risk of adverse disease progression. Furthermore, its relatively low cost compared to the benefits obtained underscores its economic appeal.

Thus, this strategy appears as a promising option, especially in resource-limited countries, where access to effective and affordable treatments remains a major challenge.

➢ *Study Limitations*

- Selection bias: MTR patients present with lower initial disease severity and fewer risk factors.
- Lack of randomization: It is impossible to establish strict causality.
- Heterogeneity of practices: MTR is not standardized.
- Limited generalizability: Specific local context.

➢ *Implications for Health Policies*

The structured integration of traditional medicine into the Malagasy healthcare system would:

- Improve access to care for disadvantaged populations
- Reduce pressure on hospitals
- Decrease healthcare costs by 60%
- Improve patient survival and quality of life

This aligns with the WHO recommendations (2014-2023 strategy), encouraging the integration of traditional medicines.

VI. CONCLUSION AND RECOMMENDATIONS

➢ *Conclusion*

In Toamasina, traditional medicine (TM) has proven to be the most effective strategy for treating strokes.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26may1076

- Superior clinical efficacy: improved survival, better quality of life, less disability
- Optimal economic efficiency: total cost 2.3 times lower, cost per QALY 3 times lower
- Risk of death reduced by 48% (HR = 0.52, $p < 0.001$)
- Potential annual savings of 4.7 billion MGA

The structured integration of traditional medicine into the Malagasy healthcare system, combined with standardized practices and coordination with modern medicine, represents a strategic opportunity to improve stroke care in a resource-limited environment.

➢ *Recommendations:*

- Officially recognize Traditional Medicine (TM) within the healthcare system
- Train traditional healers in best practices
- Establish standardized protocols
- Implement a two-way referral system (hospital ↔ TM)
- Conduct randomized clinical trials to confirm these results

ACKNOWLEDGMENT

The authors thank the medical teams at the CHUAT and CHUM hospitals, as well as the traditional healers of Toamasina, for their collaboration.

➢ *Conflicts of Interest:*
None.

➢ *Funding:*
None.

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