Original Article

Cost-Minimization Analysis of Vacuum-Assisted Biopsy Versus Surgical Biopsy for the Diagnosis of Suspicious Breast Lesions in the Brazilian Public Health System

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Abstract

In a real-world cohort of 1833 patients in the Brazilian public health system, VAB reduced surgical procedures and recovery burden compared with SB. However, reimbursement structures may limit its broader adoption, with potential implications for equitable access to minimally invasive breast cancer diagnosis.

Background: Breast biopsy is important in the diagnostic pathway for suspicious mammographic findings. Although vacuum-assisted biopsy (VAB) offers recognized technical and clinical advantages over surgical biopsy (SB), including reduced invasiveness and faster recovery, its economic impact within public healthcare systems remains insufficiently characterized, especially in low- and middle-income countries. **Methods:** We performed a cost-minimization analysis comparing VAB and SB within the Brazilian public healthcare system. A decision tree model with a 1-month time horizon was developed using real-world data from 1833 consecutive biopsy procedures conducted at a high-volume public cancer center. Clinical equivalence was assumed based on comparable diagnostic accuracy between techniques. Costs were assessed from institutional (hospital provider), public payer (Sistema Único de Saúde [SUS]), and societal. Deterministic sensitivity and break-even analyses were conducted to test model robustness. **Results:** From the institutional perspective, VAB generated mean savings of USD 223 per patient compared with SB. From the societal perspective, savings reached USD 353 per patient, largely driven by shorter recovery times and lower productivity losses. Conversely, from the SUS payer perspective, VAB was associated with higher direct reimbursement costs, with an incremental cost of USD 146 per patient. Sensitivity and break-even analyses confirmed the stability of these findings across wide parameter variations. **Conclusion:** Within a public healthcare setting, VAB represents a more

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economically efficient diagnostic strategy than SB from institutional and societal perspectives, despite higher upfront reimbursement costs. Aligning payment policies with high-value, minimally invasive approaches may improve efficiency and equitable access in breast cancer diagnosis.

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Keywords: Breast cancer diagnosis, Public healthcare system, Cost-minimization, Vacuum-Assisted Biopsy, Surgical Biopsy

Introduction

Breast cancer (BC) is the leading cause of cancer related morbidity among women worldwide and remains a major challenge for health systems, particularly in low- and middle-income countries (LMICs) such as Brazil.[1,2] In Brazil, the National Cancer Institute (INCA) estimates 73,610 new BC cases annually for the 2023–2025 period, making BC the most common malignancy among women.[3] In addition to its clinical burden, breast cancer is associated with substantial healthcare expenditures. Within Brazil's Unified Health System (Sistema Único de Saúde, SUS), direct costs related to breast cancer care exceed US$341 million per year, contributing to overall cancer-related expenditures that approach US$60 billion annually, approximately 1.7% of the national gross domestic product (GDP).[4,5]

Mammography remains the cornerstone of population-based breast cancer screening and has been consistently associated with reductions in BC specific mortality.[6] However, due to its inherently low positive predictive value, ranging from 1.3% to 9.8% depending on age and screening context, a large proportion of women with abnormal findings require histopathological confirmation.[7,8] As a result, biopsy procedures represent a critical step in the diagnostic pathway, with direct implications for diagnostic accuracy, patient experience, and healthcare resource utilization.[4,5] The choice of biopsy technique becomes crucial not only for diagnostic accuracy but also for optimizing healthcare resource utilization, particularly in resource-constrained settings where surgical capacity is limited.[4,5]

Surgical biopsy (SB) and vacuum-assisted biopsy (VAB) are 2 commonly used approaches for the evaluation of suspicious nonpalpable breast lesions, particularly those detected exclusively by mammography. SB has traditionally been the predominant technique in public healthcare settings, largely due to its widespread availability and lower upfront procedural costs.[9] In contrast, VAB has been increasingly adopted in specialized centers, as it allows larger tissue sampling, more precise lesion targeting, and lower rates of diagnostic underestimation and repeat procedures.[10,11] From a clinical perspective, these advantages may translate into fewer unnecessary surgical excisions, reduced procedural morbidity, and faster patient recovery.[12]

Despite these potential clinical benefits, the economic impact of incorporating VAB into routine diagnostic pathways remains insufficiently explored in LMICs, where healthcare budgets are constrained, and surgical capacity is often limited.[13] In Brazil, the SUS operates under a centralized, procedure-based reimbursement system with fixed tariffs, which may inadequately reflect downstream clinical efficiencies associated with minimally invasive diagnostic techniques. In this context, economic evaluations that integrate institutional, payer, and societal perspectives are particularly relevant to inform evidence-based decisions regarding diagnostic strategies in breast care.[13-15]

Against this background, the present study aimed to perform a comprehensive cost-minimization analysis (CMA) comparing VAB and SB for the diagnosis of suspicious breast lesions within the Brazilian public healthcare system (SUS). Costs were evaluated from 3 complementary perspectives: the healthcare provider (institutional), the public payer (SUS), and society. By aligning clinical practice with economic evaluation, this analysis seeks to inform diagnostic decision-making in breast cancer care and contribute evidence relevant to other LMICs facing similar challenges in optimizing diagnostic pathways.

Methods

Study Design

This study is a CMA comparing VAB and SB for diagnosing suspicious breast lesions. The evaluation included clinical outcomes and detailed economic costs across 3 analytical perspectives: hospital provider, SUS, and society.

Population and Clinical Setting

Target Population. The target population included women undergoing diagnostic biopsy for mammographic abnormalities. Data were collected retrospectively from a cohort of 1833 procedures conducted at Hospital Pérola Byington (PBH), a public tertiary cancer center in São Paulo, Brazil, between January 2020 and December 2023.

Inclusion and Exclusion Criteria. Women who underwent diagnostic VAB or SB with complete clinical and cost data were eligible. Patients with prior oncologic treatment, procedures with therapeutic intent, or missing essential clinical or cost data were excluded (n = 87; 4.5%).

Interventions

Two diagnostic interventions were evaluated. VAB was performed in an outpatient setting using 11-gauge or 8-gauge needles under local anesthesia, with ultrasound or stereotactic guidance. SB consisted of an open excisional biopsy performed under general anesthesia, typically requiring operating room resources and short-term hospitalization.

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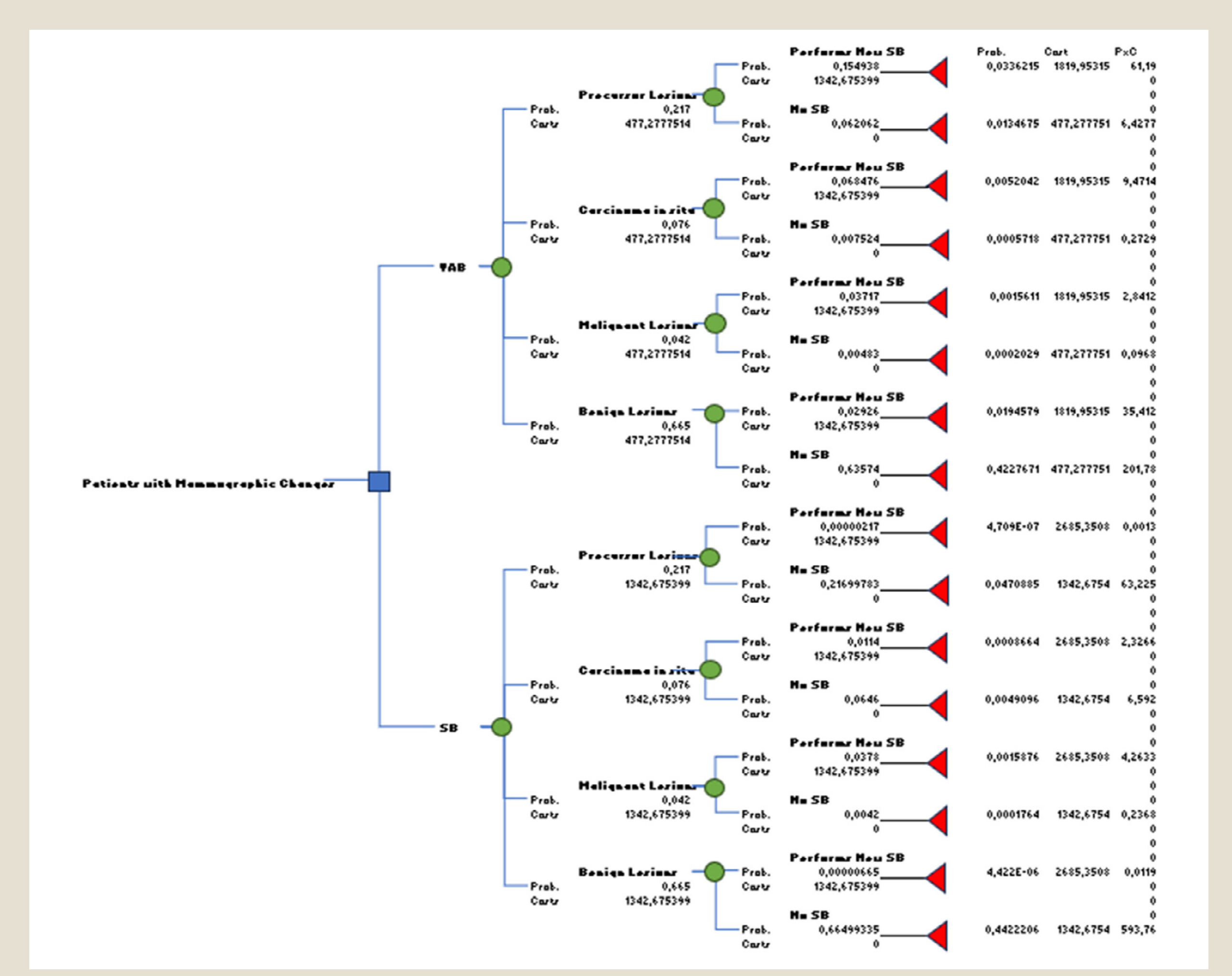
Figure 1 Decision tree model illustrating diagnostic pathways for patients with mammographic changes undergoing VAB or surgical biopsy.



Clinical Decision Framework

The economic analysis incorporated the full diagnostic pathway, from the initial biopsy procedure to any subsequent surgical interventions. For both strategies, the probability of requiring therapeutic lumpectomy following the initial diagnostic procedure was modeled according to histopathological findings, reflecting real-world clinical decision-making.

Economic Model Structure

Model Framework. A decision tree model simulated real-world diagnostic pathways, incorporating 4 histopathological categories: benign, precursor, ductal carcinoma in situ (DCIS), and invasive carcinoma. For each category, probabilities of requiring subsequent lumpectomy were derived from the institutional cohort. The structure is shown in Figure 1.

Time Horizon and Perspective. The economic model adopted a 1-month time horizon, focusing on immediate diagnostic and surgical outcomes. Costs were evaluated from 3 perspectives: the hospital perspective, capturing direct institutional costs; the public payer perspective (SUS), reflecting government reimbursement per procedure; and the societal perspective, incorporating both direct medical costs and indirect costs, including productivity losses. The model used a one-month horizon, focusing on immediate diagnostic and surgical outcomes.

Clinical Parameters and Probabilities. Outcomes were classified by histopathology. In the VAB arm, a proportion of patients required subsequent lumpectomy depending on diagnosis (e.g., 4.4% for benign, 90.1% for DCIS). In the SB group, fewer follow-up surgeries were needed due to the therapeutic intent of excision.

This cost-minimization model assumes that VAB and SB offer equivalent diagnostic accuracy for breast cancer. This assumption is supported by published studies reporting similar sensitivity and

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specificity. Therefore, differences in reintervention rates are interpreted as variations in clinical pathways, not in diagnostic efficacy.

Cost Assessment

Costing Framework. A microcosting approach was used to identify and quantify all relevant direct and indirect costs associated with each diagnostic strategy. Cost estimates were derived from multiple complementary sources to ensure a comprehensive and accurate assessment. All costs were converted to 2025 US dollars using the average exchange rate of 1 USD = 5.68 BRL, calculated over a six-month period and reported by the Brazilian Central Bank.

Coasts Categories and Sources. Microcosting captured detailed procedure-level costs. Data were collected from Hospital Pérola Byington's financial and clinical records, Ministry of Health (SIGTAP 2025 reimbursement tables),[16] National statistics (IBGE)[17] for wage and productivity estimates, and market prices for VAB equipment and supplies. The costs were grouped into direct *medical costs* (procedure kits, anesthesia, professional fees, overhead, medications, hospitalization); *indirect costs* (productivity loss during recovery, valued at USD 16.62/day based on national GDP/capita).

Cost Summary by Perspective. To compare the economic impact of VAB and SB, we calculated the total expected costs associated with each strategy from 3 distinct analytical perspectives: hospital provider, public payer, and society. The cost components were derived using a microcosting approach and reflect procedure-specific inputs, facility utilization, and indirect costs such as productivity losses. The table below summarizes these values for both VAB and SB.

Probabilistic Cost Modeling. Expected per-patient costs were calculated by integrating the base diagnostic costs with probability-weighted costs of downstream lumpectomy, using histopathology-based intervention rates. This modeling reflects routine clinical decision-making and ensures a comprehensive cost estimate that goes beyond isolated procedures.

Costs were integrated across the complete diagnostic pathway, ensuring that comparisons between VAB and SB reflected real-world clinical management rather than isolated procedural expenses.

Uncertainty and Sensitivity Analysis

Sensitivity analyses were performed to assess the robustness of the base-case results across the hospital, SUS, and societal perspectives. Deterministic one-way sensitivity analyses were conducted by varying key input parameters, including VAB kit costs, healthcare staff time, and recovery duration, by ± 20%, while productivity loss estimates were varied by ± 30%. The impact of parameter variation on cost differences was explored using tornado diagrams to identify the most influential drivers. In addition, scenario-based and threshold analyses were undertaken, modeling best- and worst-case conditions and defining break-even values for critical parameters such as VAB kit cost, SUS reimbursement levels, and recovery time. From the hospital perspective, cost neutrality between VAB and surgical biopsy was observed when the VAB kit cost reached USD 605.58.

Budget Impact and Implementation Analysis

A simplified budget impact analysis was conducted to estimate the potential national-level implications of VAB adoption within the SUS. Assuming approximately 77,000 new breast cancer diagnoses annually, with 10% of patients requiring diagnostic biopsy, 3 adoption scenarios were modeled (25%, 50%, and 75%). Across these scenarios, projected hospital-level savings reached up to USD 1.29 million per year, while incremental costs to the SUS reached up to USD 845,148. From the societal perspective, savings were estimated at up to USD 2.03 million annually. Implementation-related costs, including equipment acquisition and staff training, were incorporated to provide a more realistic assessment of large-scale adoption.

Model Validation and Quality Assurance

Model structure and probabilities were internally validated for accuracy and logic. Cost data were triangulated with external sources. External validation by clinicians and health economists confirmed clinical and economic plausibility.

Statistical Analysis

Descriptive statistics summarized outcomes. nonparametric bootstrap (1000 replications) was used for cost intervals, accounting for skewed distributions. Analyses were performed using R version 4.3.0. Missing data (<5%) were handled by complete case analysis.

Reporting Standards and Compliance

This study followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS 2022)[18] and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist.[19] In addition, the analysis adhered to Brazilian guidelines for health technology assessment (CONITEC).[20] Key assumptions, model structure, and parameter sources were transparently described to ensure reproducibility and methodological rigor.

Ethical Considerations

Approved by the Ethics Committee of Hospital Pérola Byington (CAAE: 58,934,022.4.0000.0065), the study followed national and international ethical standards. Data were anonymized, and informed consent was waived due to the retrospective nature and minimal risk.

Results

Of the 1920 patients assessed for eligibility, 1,833 were included after exclusions due to prior oncologic treatment (n = 29), therapeutic procedures (n = 31), or incomplete/missing data (n = 27). Among the included patients, 1248 (68.1%) underwent VAB, while 585 (31.9%) underwent SB. Histopathological outcomes were similar across groups: benign lesions (66.4% in VAB vs. 66.7% in SB), followed by precursor lesions, DCIS, and invasive carcinomas. The proportion requiring therapeutic lumpectomy was 44.0% in the VAB group and 49.0% in the SB group. Patient flow and diagnostic outcomes are presented in Figure 2.

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Figure 2 Flowchart of patient inclusion, allocation, histopathological outcomes, and subsequent therapeutic lumpectomy following diagnostic biopsy by VAB or SB.

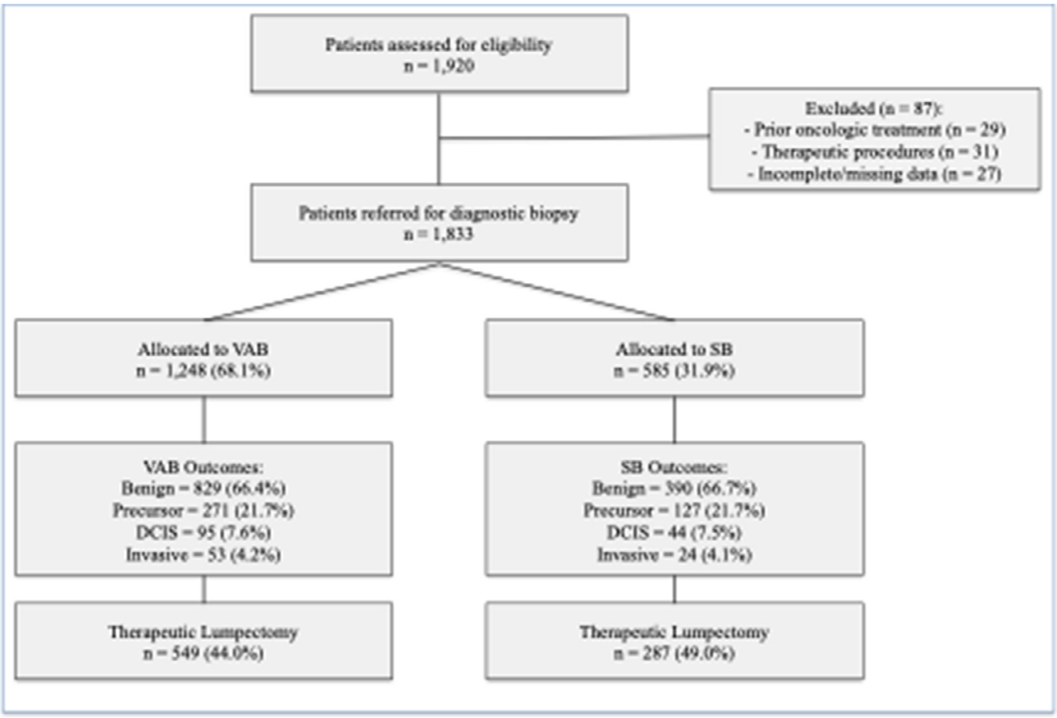

Table 1 Distribution of Histopathological Results and Subsequent Lumpectomy Probabilities Applied in the Decision Tree Model

Histopathological Category	n (%)	Probability of Lumpectomy Following	
		VAB	SB
Benign lesions	1219 (66.5%)	4.4%	0.0%
Precursor lesions	398 (21.7%)	71.4%	0.0%
Ductal carcinoma in situ	139 (7.6%)	90.1%	15.0%
Invasive malignant lesions	77 (4.2%)	88.5%	90.0%
Overall reoperation probability	1,833 (100%)	44.0%	49.0%

Abbreviations: DCIS = ductal carcinoma in situ; SB = surgical biopsy; VAB = vacuum-assisted biopsy; .

Reintervention by Histopathology

Rates of therapeutic lumpectomy varied by histopathological category and biopsy method. Among benign lesions, 4.4% of VAB cases required reintervention, while no reoperations occurred in the SB group. For precursor lesions, 71.4% of VAB patients underwent lumpectomy, compared to 0% in SB. Among those diagnosed with DCIS, 90.1% of VAB patients required surgery versus 15.0% in SB. Invasive carcinoma cases had comparable lumpectomy rates (88.5% for VAB vs. 90.0% for SB). These distributions and associated probabilities are detailed in Table 1.

Diagnostic Procedure Costs

VAB Cost Composition. From the hospital perspective, the VAB kit represented ~90% of the procedural cost (USD 382.10 of USD 421.55). Other components included local anesthesia, professional fees, and facility overhead. From the societal perspective, productivity loss due to a 2-day recovery added USD 33.24. A full breakdown is shown in Table 2**.**

Surgical Biopsy Cost Structure. SB costs were mainly driven by hospitalization and operating room time. From the societal perspective, productivity loss was substantially higher due to a 14-day recovery (USD 232.70). Table 3 presents the full cost breakdown.

CMA Results

The decision tree model incorporating probability-weighted clinical outcomes was used to estimate mean per-patient costs for VAB and SB across the 3 analytical perspectives. Expected costs

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Table 2 Detailed VAB Cost Composition by Analytical Perspective (USD)

Cost Component	Hospital Perspective (PBH)	SUS Perspective	Societal Perspective	Technical Specification
VAB kit	382.10	382.07	382.07	12-20 mm needle, biopsy guide, titanium clip, reservoir
Local anesthesia	2.79	22.51	25.31	Lidocaine 2% + Normal saline 0.9%
Healthcare professionals	22.60	-	22.60	Physician + Nursing technician + Radiology technician (1 h)
Hospital overhead	14.07	-	14.07	Daily facility fee + Hourly utilization rate
Productivity loss	-	-	33.24	2-day recovery period (GDP per capita basis)
Total VAB cost	**421.55**	**404.58**	**477.28**	

SIGTAP Code: 0,417,010,052; Exchange rate: 1 USD = 5.68 BRL (6-month average).

Table 3 Detailed SB Cost Composition by Analytical Perspective (USD)

Cost Component	Hospital Perspective (PBH)	SUS Perspective	Societal Perspective	Technical Specification
SB procedure	86.27	110.21	196,26	Hospital cost + SUS reimbursement (2 days)
General anesthesia	85.04	14.77	99,85	Complete general anesthesia
Healthcare professionals	45.24	-	45,19	Surgical team (2 h): Physician + Nursing + Support
Hospital overhead	28.17	-	28,13	Operating room fee (2 h)
Antibiotics	2.09	-	232,70	Postoperative antimicrobial prophylaxis
Hospitalization	739.44	-	2,09	2-day inpatient stay (BRL 2,100/day)
Productivity loss	-	-	738,46	14-day recovery period (GDP per capita basis)
Total SB Cost	**985.25**	**124.98**	**1.342,68**	

SUS Reimbursement: BRL 626 total (2 days); Exchange rate: 1 USD = 5.68 BRL.

Table 4 Cost-Minimization Analysis: Weighted Average Costs and Incremental Differences

Perspective	Mean Cost (USD)		Incremental Difference (USD)	Cost Advantage
	VAB	SB		
Hospital (PBH)	268.41	491,89	−223.48	VAB saves 45.4%
Payer (SUS)	208,49	62.33	+146.16	SB costs 234.5% less
Societal	317.49	670.42	−352.93	VAB saves 52.6%

Negative values indicate cost savings with VAB; positive values indicate additional costs with VAB.

reflected the integration of initial diagnostic procedure costs with the probability-weighted costs of subsequent therapeutic interventions, as defined by the modeled clinical pathways (Table 4).

Clinical Effectiveness Analysis. The comparative analysis of reintervention requirements revealed a 5-percentage point absolute difference favoring VAB, with 44% of VAB patients versus 49% of SB patients requiring subsequent lumpectomy. This translates to a 10.2% relative reduction in surgical reintervention requirements with VAB [[(49% - 44%) / 49% × 100].

Perspective-Specific Economic Outcomes

Hospital Provider Perspective. The proportion of patients requiring subsequent therapeutic lumpectomy differed between diagnostic strategies. Among patients undergoing VAB, 44% required a subsequent lumpectomy, compared with 49% of patients initially managed with SB. This corresponded to an absolute difference of 5 percentage points and a relative reduction of 10.2% in reintervention rates for VAB compared with SB.

Public Payer Perspective (SUS). From the public payer perspective of SUS, VAB was associated with a higher mean cost per patient compared with SB. The incremental cost of VAB was USD 146.16 per patient, corresponding to a 234.5% increase relative to SB. Under the current reimbursement structure, the mean SUS reimbursement was USD 404.58 for VAB and USD 124.98 for SB.

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In contrast, the estimated hospital cost of SB was USD 986.25 per procedure.

Societal Perspective. From the societal perspective, VAB was associated with lower overall costs compared with SB, resulting in a mean saving of USD 352.93 per patient (52.6% reduction). This difference reflected lower indirect costs related to productivity losses. Estimated productivity losses were USD 33.24 per patient for VAB and USD 232.70 per patient for SB, corresponding to recovery periods of 2 days and 14 days, respectively. When total societal costs were considered, mean costs were USD 477.28 for VAB and USD 1,218.95 for SB. All cost component breakdown by perspective is shown in Supplemental Table 1.

Decision Tree Model Implementation and Validation

The decision tree model was applied using a 1-month diagnostic time horizon and incorporated all relevant costs and clinical outcomes within the predefined analytical framework. Four diagnostic pathways were modeled for VAB, corresponding to benign lesions, precursor lesions, DCIS, and invasive malignancy, each with associated probabilities and subsequent intervention rates. For SB, a minimal probability of repeat biopsy (0.001%) was applied, as defined a priori in the model.

Overall diagnostic performance was comparable between VAB and SB, with definitive histopathological diagnosis achieved in more than 95% of cases with both techniques. Reintervention rates differed modestly between groups, with subsequent lumpectomy performed in 44% of patients undergoing VAB and 49% of those undergoing SB.

Economic Analysis Extensions

Cost per Reoperation Avoided. Based on the observed absolute difference of 5 percentage points in reoperation rates between diagnostic strategies, VAB was associated with 50 fewer subsequent surgical procedures per 1000 patients compared with SB. When expressed as cost per reoperation avoided, estimates varied by analytical perspective. The cost per reoperation avoided was USD 4,470 from the hospital provider perspective and USD 7,059 from the societal perspective. From the SUS perspective, the corresponding estimate was USD − 2,923, reflecting higher reimbursement costs for VAB under the current payment structure.

Break-Even Analysis. Break-even analyses identified threshold values at which VAB and SB yielded equivalent costs across analytical perspectives. From the hospital provider's perspective, cost neutrality was observed when the VAB kit cost reached USD 605.58, compared with the current cost of USD 382.10. From the SUS perspective, cost parity occurred when reimbursement for VAB decreased to USD 354.65 per procedure, relative to the current reimbursement of USD 404.58. From the societal perspective, break-even was reached when the assumed recovery time following VAB increased to 4.8 days, compared with the base-case assumption of 2 days. All Break-even analyses are shown in Supplemental Table 2.

Based on extrapolation to the Brazilian public healthcare context, assuming that 10% of the estimated 77,000 annual breast cancer cases require diagnostic biopsy and that VAB reaches 50% adoption, the projected annual budget impact was estimated as follows: hospital-level savings of USD 861,520, additional costs of USD 563,432 from the SUS perspective, and societal savings of USD 1,359,588.

Clinical Performance Metrics

Diagnostic Accuracy Validation. Both VAB and SB achieved comparable diagnostic accuracy rates for malignant lesions (sensitivity > 90% for both modalities), validating the cost-minimization approach. VAB demonstrated superior tissue sampling adequacy (97.2% vs 94.1% for SB) and lower rates of nondiagnostic specimens (2.1% vs 4.3%), contributing to reduced reintervention requirements.

Procedural Efficiency Metrics. VAB procedures averaged 45 minutes compared to 120 minutes for SB (including anesthesia and recovery time), representing 62.5% time savings. This efficiency translated to improved resource utilization, enabling the hospital to perform 2.7 VAB procedures in the time required for one SB procedure, significantly enhancing diagnostic capacity.

Contextual Relevance for the Brazilian Healthcare System

These findings have relevance for Brazil's healthcare landscape, where diagnostic delays and surgical capacity constraints significantly impact breast cancer outcomes. The demonstrated efficiency gains from VAB adoption could help address the substantial backlog in breast cancer diagnoses, estimated at over 50,000 pending cases nationally as of 2023. All data is shown in Table 5.

The misalignment between SUS reimbursement patterns and demonstrated clinical efficiency highlights broader healthcare financing challenges in Brazil, where procedure-based payments often fail to incentivize value-based care delivery. The substantial societal benefits demonstrated (USD 352.93 per patient) suggest that healthcare policy reforms incorporating broader economic impacts could yield significant population-level benefits.

From an implementation perspective, the initial capital investment required for VAB equipment (approximately USD 80,000-120,000 per unit) could be offset by efficiency gains within 12-18 months in high-volume centers, supporting the economic case for technology adoption in reference hospitals throughout the SUS network, the analysis demonstrates equipment cost recovery within 2.2 years based on an initial investment of $100,000 for centers performing 200 VAB procedures annually (Figure 3).

Hospital savings of $223.48 per procedure and societal savings of $352.93 per procedure generate combined annual benefits of $115,282 post break-even. Break-even occurs in Year 3 with cumulative savings of $34,088. Cost differentials remained constant throughout the analysis period.

From the hospital provider perspective, VAB was associated with more efficient resource utilization, resulting in a mean cost saving of USD 223.48 per patient compared with SB. In contrast, from the public payer perspective, the current reimbursement structure of the SUS was associated with higher costs for VAB, corresponding to an incremental cost of USD 146.16 per patient. When evaluated from the societal perspective, VAB provided the greatest economic

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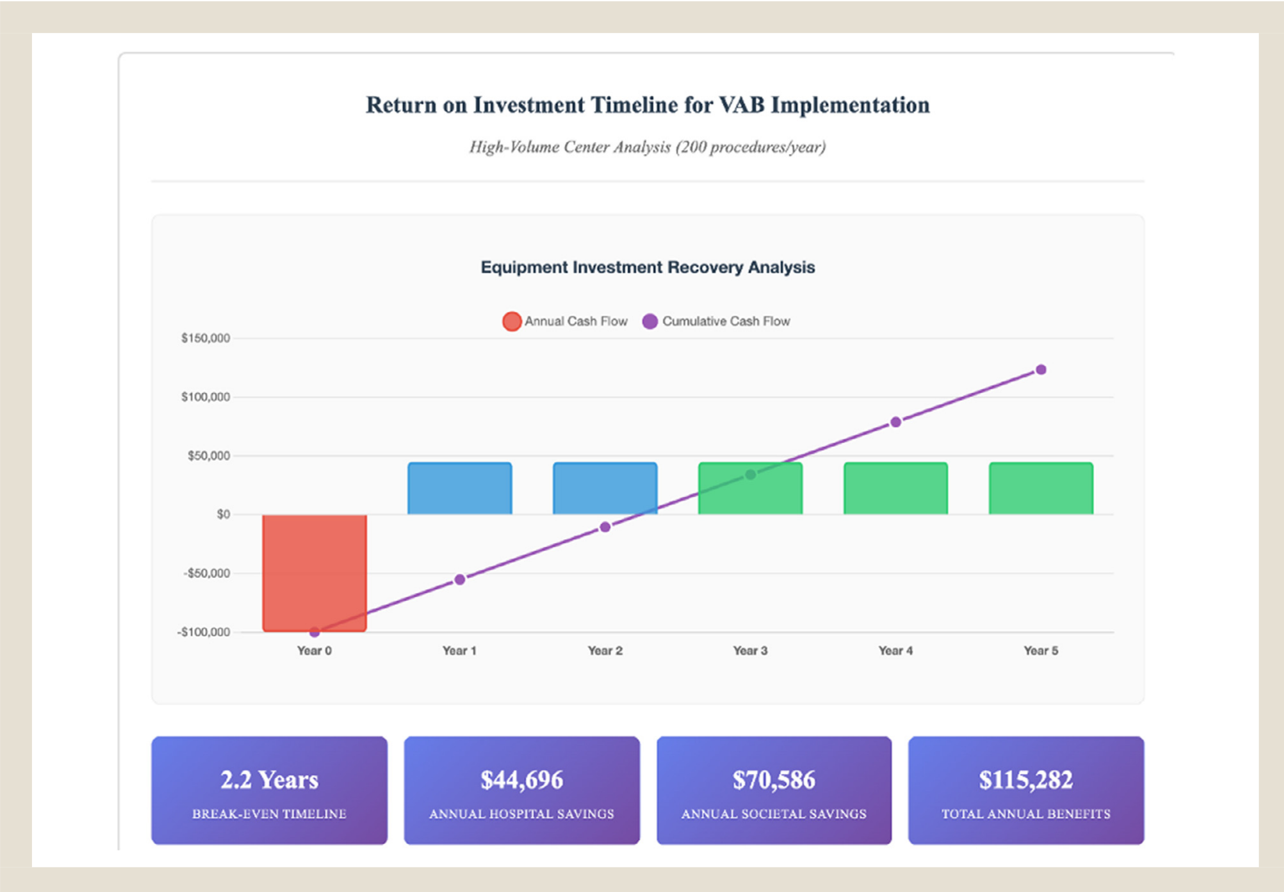
Table 5 Implementation Scenarios for Brazilian Public Health System

Scenario	VAB Adoption Rate	Annual Procedures	Hospital Savings	SUS Additional Cost	Societal Savings	Net Benefit
Conservative	25%	1925	USD 430,760	USD 281,716	USD 679,794	USD 398,078
Moderate	50%	3850	USD 861,520	USD 563,432	USD 1,359,588	USD 796,088
Aggressive	75%	5775	USD 1,292,280	USD 845,148	USD 2,039,382	USD 1,194,132

Assumptions: 7700 annual diagnostic biopsies (10% of 77,000 breast cancer cases), current cost differentials maintained.

Figure 3 Return on investment timeline for VAB implementation in high-volume centers.



benefit, yielding mean savings of USD 352.93 per patient, primarily driven by reductions in indirect costs related to recovery time and productivity losses.

The assumption of equivalent diagnostic accuracy underpinning the cost-minimization framework was supported by comparable clinical outcomes between techniques, with VAB demonstrating a modest relative reduction of 10.2% in surgical reintervention rates.

Discussion

As the SUS represents the primary source of healthcare access for most of the population, economic evaluations from the public payer perspective are essential to inform national policy and reimbursement decisions. However, out-of-pocket expenditures and indirect costs remain substantial in Brazil, even within a publicly funded healthcare framework. Therefore, incorporating a societal perspective is critical to fully capture the broader economic consequences of diagnostic strategies such as VAB and SB.

To our knowledge, this study provides the first comprehensive cost analysis comparing VAB and SB for the diagnosis of suspicious breast lesions while simultaneously integrating 3 complementary perspectives: institutional (Hospital Pérola Byington, PBH), public payer (SUS), and societal. No previous international study has evaluated this clinical scenario using a unified model that captures these distinct but interrelated viewpoints.

From the institutional (provider) perspective, VAB demonstrated a clear economic advantage, with mean savings of approximately USD 223 per patient compared with SB. These savings were primarily driven by reduced procedure time, avoidance of hospitalization, and lower demand for second-look surgical procedures. The ability of VAB to obtain larger and more representative tissue samples likely

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contributes to higher diagnostic adequacy and fewer repeat interventions. These findings are consistent with prior economic evaluations conducted in other healthcare systems, including studies from Italy, which reported reduced unnecessary lumpectomies and more efficient use of operating room resources with VAB adoption.[15]

In contrast, from the SUS payer perspective, VAB was associated with higher per-procedure costs than SB, resulting in an incremental cost of approximately USD 146 per patient. This discrepancy reflects the current SIGTAP procedure-based reimbursement structure, which does not account for downstream efficiencies, reductions in surgical volume, or indirect economic benefits.[16,21,22] As a result, although VAB may appear less attractive when evaluated solely through a narrow reimbursement lens, this approach risks underestimating its broader system-level value and long-term economic implications.[21,22]

When analyzed from the societal perspective, VAB provided the most substantial economic benefit, yielding savings of approximately USD 353 per patient compared with SB. These savings were largely attributable to shorter recovery times, reduced hospitalization, and lower productivity losses associated with earlier return to work.[23,24] In a middle-income country such as Brazil—where diagnostic delays are common,[25,26] and indirect costs are rarely incorporated into formal health technology assessments,[27] these findings underscore the importance of broader economic evaluations when optimizing diagnostic pathways for breast cancer.

Strengths and Limitations

This study has several strengths that enhance its clinical and policy relevance. First, it is grounded in real-world data from a large retrospective cohort of 1833 patients treated at PBH, a high-volume public cancer center, ensuring that clinical probabilities and resource utilization reflect routine practice within the SUS. Second, by focusing on the diagnostic phase—particularly the need for subsequent lumpectomies—the analysis addresses a critical point in the care pathway where more efficient strategies such as VAB can generate meaningful downstream impact, especially in settings with limited surgical capacity. Third, the inclusion of productivity losses in the societal perspective represents a key strength, providing a more comprehensive economic view that is often overlooked in LMICs.

Several limitations should be acknowledged. Clinical probabilities and costs were derived from a single tertiary referral center, which may limit generalizability to smaller or less specialized SUS-affiliated institutions. The analysis was restricted to a short-term time horizon and did not capture long-term outcomes such as survival, recurrence, or quality of life. In addition, the decision tree model, while appropriate for short-term diagnostic decisions, does not account for longitudinal disease trajectories; more complex modeling approaches, such as Markov models, could be explored in future studies.[28] Finally, broader societal costs, including caregiver burden, transportation, and psychosocial impact, were not included and may further influence the relative value of diagnostic strategies.

Policy and Clinical Implications

Despite higher upfront costs from the payer perspective, VAB offers meaningful efficiency gains at the institutional level and substantial economic advantages from a societal standpoint. These findings highlight a misalignment between current reimbursement policies and value-based care delivery, in which procedure-based payment models may fail to capture the full benefits of minimally invasive diagnostic technologies. Aligning reimbursement mechanisms with broader clinical and economic outcomes could support more efficient resource allocation and improve access to timely breast cancer diagnosis within the SUS.

Future Directions

Future research should seek to validate these findings across multiple public healthcare institutions in Brazil, including lower-volume and resource-limited settings. Longitudinal modeling approaches could provide a more comprehensive assessment of cost-effectiveness over the full continuum of breast cancer care, incorporating survival, recurrence, and quality-adjusted life years. Additional studies evaluating patient-reported outcomes and implementation barriers would further inform the integration of VAB into diagnostic pathways and promote equitable access.

Conclusion

This study provides a comprehensive economic evaluation of VAB versus SB for the diagnosis of suspicious breast lesions within the Brazilian public healthcare system. While VAB is associated with higher direct reimbursement costs under the current SUS model, it offers substantial savings at both the institutional and societal levels through reduced surgical demand, shorter recovery times, and lower productivity losses. These findings support the consideration of VAB as a strategically valuable diagnostic approach and underscore the need for reimbursement policies that better reflect value-based care and system-wide efficiency in breast cancer diagnosis.

Clinical Practice Points

- VAB should be considered the preferred diagnostic approach for suspicious, predominantly nonpalpable breast lesions due to its minimally invasive nature and reduced recovery burden.
- In this real-world analysis of 1,833 consecutive cases within a public health system, VAB significantly reduced operating room utilization and avoided unnecessary surgical procedures compared with upfront surgical biopsy.
- Failure to align reimbursement structures with high-value diagnostic strategies may unintentionally sustain more invasive approaches.
- Health systems should prioritize the adoption of VAB to improve efficiency, reduce patient burden, and promote equitable access to modern breast cancer diagnosis.

Data Statement

All data is available upon request, please contact mattar.andre@gmail.com.

Disclosure

Andre Mattar declares consulting fees from Roche and Eli Lilly; payment or honoraria for lectures, presentations, speakers' bureaus,

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The other authors do not have conflicts of interest regarding this study.

CRediT authorship contribution statement

Andressa Gonçalves Amorim: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. **André Mattar:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Marcelo Antonini:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Claudia Ribeiro Martins Cabrera:** Writing – review & editing, Validation, Visualization. **Marina Diógenes Teixeira:** Validation, Visualization, Writing – review & editing. **Francisco Pimentel Cavalcante:** Validation, Visualization, Writing – review & editing. **Felipe Pereira Zerwes:** Validation, Visualization, Writing – review & editing. **Eduardo Camargo Millen:** Validation, Visualization, Writing – review & editing. **Fabricio Palermo Brenelli:** Validation, Visualization, Writing – review & editing. **Antônio Luiz Frasson:** Validation, Visualization, Writing – review & editing. **Marcelo Madeira:** Validation, Visualization, Writing – review & editing. **Gil Facina:** Validation, Visualization, Writing – review & editing. **Henrique Lima Couto:** Validation, Visualization, Writing – review & editing. **Marcellus do Nascimento Moreira Ramos:** Validation, Visualization, Writing – review & editing. **Patrícia Rodrigues Alves de Figueiredo Moraes:** Validation, Visualization, Writing – review & editing. **Marina Fleury de Figueiredo:** Validation, Visualization, Writing – review & editing. **Reginaldo Guedes Coelho Lopes:** Supervision, Validation, Writing – review & editing. **Luiz Henrique Gebrim:** Conceptualization, Validation, Visualization, Writing – review & editing.

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Supplementary

Supplemental Table 1 Cost Component Breakdown By Perspective (% of Total Cost).

	Hospital		SUS		Societal	
	VAB	SB	VAB	SB	VAB	SB
Equipment/Procedure	90.6%	8.7%	94.4%	88.2%	80.1%	7.1%
Professional Fees	5.4%	4.6%	0%	0%	4.7%	3.7%
Anesthesia	0.7%	8.6%	5.6%	11.8%	5.3%	7.0%
Hospitalization	0%	75.0%	0%	0%	0%	60.7%
Productivity Loss	0%	0%	0%	0%	7.0%	19.1%
Other	3.3%	3.1%	0%	0%	2.9%	2.4%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Supplemental Table 2 Break-Even Analysis Across Perspectives.

Perspective	Current Scenario	Break-Even Point	Margin for Change
Hospital	VAB Kit: USD 382.10	VAB Kit: USD 605.58	+58.5% cost tolerance
SUS	VAB Reimbursement: USD 404.58	Required: USD 354.65	−12.3% reduction needed
Societal	VAB Recovery: 2 days	Break-even: 4.8 days	+140% time tolerance

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