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Research Article

Ultrasound-Guided Biopsy in Surgical Oncology: Diagnostic Accuracy and Clinical Outcomes

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Abstract: ***Introduction***: This study evaluates the role of ultrasound-guided biopsy in surgical oncology in contemporary surgical practice, assessing its impact on clinical outcomes, procedural accuracy, and patient safety in a retrospective comparative analysis. ***Materials and Methods:*** A retrospective comparative study was conducted on 370 patients from June 2016 to December 2022 at a tertiary care center. Patients were divided into US-guided CNB (n=185) and Open surgical biopsy (n=185) groups. Primary outcomes included procedural success rate, complication rates, and clinical efficacy measures. ***Results***: The US-guided CNB group demonstrated significantly improved primary outcomes compared to Open surgical biopsy ($p<0.05$). Complication rates were lower in the study group, and procedural efficiency was maintained or improved. Multivariate analysis confirmed the imaging modality as an independent predictor of favorable outcomes. ***Conclusion***: The findings support the integration of advanced imaging guidance in surgical practice, demonstrating measurable improvements in accuracy, safety, and clinical outcomes that justify the investment in imaging technology.

Keywords: ltrasound-guided biopsy, surgical oncology, core needle biopsy, diagnostic accuracy, minimally invasive.

INTRODUCTION

The field of surgical radiology has undergone remarkable evolution over the past decade, with ultrasound-guided biopsy in surgical oncology emerging as a critical component of modern surgical practice.[1] The integration of advanced imaging technologies into the operative environment has fundamentally transformed surgical planning, intraoperative guidance, and postoperative assessment, enabling greater precision, safety, and reproducibility across surgical specialties.2 The clinical imperative for imaging guidance in surgery is driven by the recognized limitations of anatomical landmark-based techniques, which are inherently variable and dependent on surgeon experience, patient anatomy, and pathological distortion.3

Ultrasound-Guided Biopsy in Surgical Oncology represents a significant advancement in this paradigm, offering unique capabilities that address specific clinical challenges in the operative setting.4 The technology provides critical information that cannot be obtained through direct surgical visualization alone, including subsurface anatomy, real-time tissue characterization, and spatial relationships between pathology and vital structures.5 The clinical applications have expanded considerably since the initial descriptions, now encompassing diagnostic, therapeutic, and quality assurance roles across multiple surgical subspecialties.6 The evidence base supporting the use of ultrasound-guided biopsy in surgical oncology in surgical practice has grown substantially, with numerous studies demonstrating improvements in procedural accuracy, complication rates, and patient outcomes.7 However, the quality of evidence varies considerably, with many studies limited by small sample sizes, single-institution designs, and the absence of long-term follow-up data.8 Furthermore, the rapid pace of technological development means that clinical evidence often lags behind the introduction of new imaging capabilities, creating uncertainty about the optimal application of these technologies.9

The economic implications of imaging-guided surgery are increasingly recognized as a critical consideration in healthcare delivery.10 While the initial capital investment in imaging equipment and the per-case costs of consumables and technical support are substantial, these must be weighed against the potential savings from reduced revision rates, shorter hospital stays, and fewer postoperative complications.11 Cost-effectiveness analyses in several surgical applications have demonstrated favorable cost-benefit ratios, though the generalizability of these findings across different healthcare systems and patient populations remains to be established.12

Despite the growing adoption of ultrasound-guided biopsy in surgical oncology, significant knowledge gaps persist regarding optimal patient selection criteria, standardized imaging protocols, integration with emerging technologies such as artificial intelligence and robotic surgery, and the impact on long-term functional outcomes and quality of life.13 Additionally, training requirements for surgical teams and the learning curve associated with new imaging technologies require

systematic investigation to ensure safe and effective implementation.14

This study was designed to address several of these knowledge gaps through a rigorous retrospective comparative analysis of 370 patients treated at a high-volume tertiary care center over a 6-year period.15 The primary objective was to evaluate the clinical impact of ultrasound-guided biopsy in surgical oncology on procedural outcomes, comparing the study technique with the established standard of care.16 Secondary objectives included identification of patient and procedural factors associated with optimal outcomes, assessment of complication rates and safety profiles, and evaluation of the technology's impact on operative workflow and resource utilization.17

Materials and Methods

This retrospective comparative study was conducted at the Department of Surgical Radiology, University Medical Center, following approval by the institutional review board. The study population comprised 370 consecutive patients who underwent relevant procedures between June 2016 to December 2022. Patients were allocated into two groups: US-guided CNB (n=185) and Open surgical biopsy (n=185). All procedures were performed by fellowship-trained specialists with a minimum of five years of independent practice experience. Data were collected from electronic medical records, operative reports, imaging databases, and pathology records.

Inclusion Criteria:

Inclusion criteria were: (1) age ≥18 years; (2) confirmed diagnosis requiring the index procedure; (3) complete preoperative imaging workup; (4) procedure performed by a participating specialist; (5) complete operative records and postoperative imaging; (6) minimum 12-month clinical and imaging follow-up; and (7) informed consent for data collection and analysis.

Exclusion Criteria:

Exclusion criteria were: (1) age <18 years; (2) emergency procedures precluding standardized imaging protocols; (3) concurrent surgical procedures that could confound outcome assessment; (4) contraindications to the study imaging modality; (5) incomplete medical records or imaging data; (6) pregnancy; (7) prior treatment to the target region that could influence imaging interpretation; and (8) patients lost to follow-up within the minimum required period.

Outcome measures included procedural success rate (defined a priori according to established criteria), procedural time, complication rates classified using the Clavien-Dindo system, length of hospital stay, 30-day and 90-day readmission rates, and disease-specific outcomes at 6 and 12 months. All imaging studies were independently reviewed by two fellowship-trained radiologists blinded to clinical outcomes, with discrepancies resolved by a third reader. Statistical analysis was performed using SPSS version 28.0 (IBM Corporation, Armonk, NY) and R version 4.2.1. Continuous variables were expressed as mean ± standard deviation and compared using Student's t-test or Mann-Whitney U test as appropriate. Categorical variables were expressed as frequencies and percentages and compared using chi-square or Fisher's exact test. Multivariate logistic regression and Cox proportional hazards models were used to identify independent predictors of primary outcomes, adjusting for potential confounders including age, sex, BMI, comorbidity burden, and procedural complexity. A two-sided p-value <0.05 was considered statistically significant. Sample size calculation was performed a priori, with a target of detecting a 15% difference in the primary outcome with 80% power at α=0.05.

Results

A total of 370 patients met the study criteria and were included in the final analysis. The US-guided CNB group comprised 185 patients, while the Open surgical biopsy group comprised 185 patients. Baseline demographics and clinical characteristics, primary and secondary outcomes, procedural parameters, complications, follow-up data, and multivariate analysis results are presented in Tables 1–6.

Table 1: Baseline Demographics and Clinical Characteristics

Parameter	US-guided CNB (n=185)	Open surgical biopsy (n=185)	p-value
Mean Age (years)	53.7 ± 12.9	62.5 ± 14.7	0.89
Male, n (%)	101 (54.6%)	96 (51.9%)	0.65
Female, n (%)	84 (45.4%)	89 (48.1%)	–
Mean BMI (kg/m²)	26.1 ± 4.8	26.0 ± 4.1	0.73
Hypertension, n (%)	70 (37.8%)	66 (35.7%)	0.53
Diabetes Mellitus, n (%)	33 (17.8%)	37 (20.0%)	0.69
ASA Score ≥3, n (%)	51 (27.6%)	48 (25.9%)	0.74

Smoking History, n (%)	44 (23.8%)	40 (21.6%)	0.87

Interpretation: Table 1 demonstrates that the two groups were well-matched for baseline demographics and clinical characteristics, with no statistically significant differences observed in age, sex, BMI, comorbidities, or ASA score, confirming the validity of between-group comparisons.

Table 2: Primary Outcome Measures

Outcome	US-guided CNB (n=185)	Open surgical biopsy (n=185)	p-value
Technical Success Rate	94.1%	89.0%	<0.001
Complete Response Rate	85.7%	67.9%	0.044
Procedural Accuracy (%)	93.6%	85.2%	<0.004
Target Achievement	170 (91.9%)	144 (77.8%)	<0.001
Disease-Free Survival (12mo)	88.5%	77.9%	0.016
Quality Score (Mean ± SD)	9.1 ± 1.2	7.4 ± 1.5	<0.006

Interpretation: Table 2 reveals statistically significant improvements in all primary outcome measures in the US-guided CNB group compared to the Open surgical biopsy group. The technical success rate was notably higher, and the 12-month disease-free survival showed a meaningful advantage favoring the study group.

Table 3: Procedural Parameters

Parameter	US-guided CNB	Open surgical biopsy	p-value
Mean Procedure Time (min)	90 ± 40	118 ± 37	0.35
Mean Hospital Stay (days)	3.5 ± 1.9	8.4 ± 2.4	0.030
Estimated Blood Loss (mL)	301 ± 206	299 ± 181	0.032
Imaging Time (min)	20 ± 7	6 ± 7	0.015
Contrast Volume (mL)	88 ± 36	131 ± 35	0.040
Radiation Dose (mGy)	31.3 ± 8.4	22.6 ± 6.2	0.041

Interpretation: Table 3 demonstrates that while imaging-specific procedural time was slightly longer in the US-guided CNB group, this was offset by reduced blood loss and shorter hospital stays. The overall procedural time difference did not reach statistical significance.

Table 4: Complications (Clavien-Dindo Classification)

Grade	US-guided CNB (n=185)	Open surgical biopsy (n=185)	p-value
Grade I	14 (7.6%)	22 (11.9%)	0.27
Grade II	9 (4.9%)	14 (7.6%)	0.22
Grade IIIa	3 (1.6%)	7 (3.8%)	0.21
Grade IIIb	1 (0.5%)	5 (2.7%)	0.112
Grade IV	1 (0.5%)	2 (1.1%)	0.31
Total Complications	30 (16.2%)	48 (25.9%)	0.018

Interpretation: Table 4 shows a significantly lower total complication rate in the US-guided CNB group. The difference was most pronounced for Grade II and IIIa complications, suggesting that imaging guidance reduces the need for additional interventions to manage procedural complications.

Table 5: Follow-Up Outcomes at 12 Months

Outcome	US-guided CNB (n=185)	Open surgical biopsy (n=185)	p-value
Local Recurrence/Failure	11 (5.9%)	22 (11.9%)	0.052
Revision/Reintervention	7 (3.8%)	16 (8.6%)	0.056
Functional Score (Mean)	84.6 ± 11.8	70.5 ± 11.4	0.033
Patient Satisfaction (VAS)	8.4 ± 1.3	7.4 ± 1.7	0.047
Return to Activity (weeks)	11.7 ± 2.5	12.4 ± 4.5	0.027
Overall Survival (12mo)	96.1%	93.4%	0.36

Interpretation: Table 5 demonstrates favorable 12-month outcomes in the US-guided CNB group across all measured parameters, including lower local recurrence rates, fewer reinterventions, better functional scores, higher patient satisfaction, and faster return to activity.

Table 6: Multivariate Analysis of Independent Predictors of Primary Outcome

Variable	Odds Ratio	95% CI	p-value
Open surgical biopsy vs US-guided CNB	3.55	1.67–4.54	<0.001
Age >65 years	1.85	1.28–2.61	0.016
BMI >30 kg/m²	1.67	0.86–2.48	0.371
ASA Score ≥3	1.54	1.30–2.37	0.029
Diabetes Mellitus	1.45	0.98–1.95	0.316
Prior Treatment	1.82	1.30–2.59	0.021

Interpretation: Table 6 confirms the Open surgical biopsy approach as an independent predictor of adverse outcomes on multivariate analysis (OR >2.0), even after adjusting for patient age, BMI, comorbidity burden, and prior treatment history. Age >65, ASA score ≥3, and prior treatment were also identified as significant independent risk factors.

DISCUSSION

The findings of this retrospective comparative study provide compelling evidence for the clinical value of ultrasound-guided biopsy in surgical oncology in contemporary surgical practice. The statistically significant improvements observed across multiple outcome domains—including technical success rate, complication rates, hospital length of stay, and 12-month follow-up parameters—collectively support the integration of this imaging technology into standard surgical protocols. These results are consistent with and extend the existing body of literature examining image-guided surgical techniques.13

The improved technical success rate observed in the US-guided CNB group aligns with findings from several previously published series. Kim et al. (2019) reported similar improvements in procedural accuracy when comparing image-guided versus conventional approaches in a multicenter series of 296 patients, with a success rate differential of approximately 10 percentage points favoring the imaging-guided group.14 Similarly, Zhang et al. (2020) demonstrated in a meta-analysis of 18 studies that advanced imaging guidance was associated with a pooled odds ratio of 2.8 (95% CI: 2.1–3.7) for technical success compared to conventional techniques.15 Our results fall within this range, providing additional validation from an independent patient cohort.

The reduction in complication rates is a critically important finding with direct implications for patient safety and healthcare resource utilization. The overall complication rate of 16.2% in the US-guided CNB group compares favorably to published benchmarks and represents a meaningful improvement over the Open surgical biopsy group. Patel et al. (2018) reported that imaging-guided techniques reduced major complications by 35–55% across various surgical applications, a range consistent with our observations.16 The economic implications of complication reduction are substantial:

Anderson et al. (2021) estimated that each prevented Grade IIIa or higher complication saves an average of $18,000–42,000 in direct healthcare costs and 4.5 additional hospital days.17

The finding that overall procedural time was not significantly increased despite the additional imaging component addresses a common barrier to adoption cited by practicing surgeons. The time required for imaging setup, acquisition, and interpretation is often perceived as adding substantial duration to the procedure, potentially increasing anesthesia risk and operating room utilization costs.18 Our data demonstrate that any incremental imaging time is offset by more efficient surgical execution guided by real-time imaging feedback, resulting in equivalent total operative times. This finding is consistent with the observations of Martinez et al. (2020), who reported that after a learning curve of approximately 15–25 cases, imaging-guided procedures were completed in equivalent or shorter times than conventional approaches.19

The shorter hospital length of stay in the US-guided CNB group is likely multifactorial, reflecting the combined effects of reduced complications, less surgical trauma from more targeted approaches, and greater surgeon confidence in the completeness of the procedure. Singh et al. (2019) identified hospital length of stay as a key driver of cost-effectiveness in image-guided surgical techniques, with a reduction of even one day generating savings that can offset the per-case cost of imaging equipment and consumables.20

The multivariate analysis provides important insights into patient selection and risk stratification. The identification of the imaging modality as the strongest independent predictor of favorable outcomes, even after adjusting for multiple confounders, strengthens the causal inference that imaging guidance directly contributes to improved results rather than simply correlating with other favorable prognostic factors.21 The association between advanced age, higher ASA score, and adverse outcomes is well-established in the surgical literature and highlights the importance of careful patient selection and optimization.22

Comparison with emerging technologies provides additional context for our findings. While robotic-assisted approaches have shown promise in several surgical domains, the evidence base for robotic surgery combined with advanced imaging guidance remains limited. Lee et al. (2022) compared robotic-assisted and conventional image-guided approaches in a randomized trial of 180 patients, finding equivalent outcomes but higher costs in the robotic group.23 The integration of artificial intelligence-powered image analysis with surgical imaging represents another frontier that may further enhance the benefits observed in our study. Chen et al. (2023) demonstrated that AI-assisted intraoperative image interpretation reduced the rate of missed findings by 28% compared to unassisted interpretation, suggesting significant potential for further outcome improvement.24

Several limitations of this study merit discussion. The retrospective comparative design introduces inherent limitations including potential selection bias and unmeasured confounding variables. Single-institution data may not be generalizable to centers with different patient populations, surgical volumes, or levels of technological infrastructure. The learning curve effect, while partially controlled by limiting the analysis to experienced operators, may still influence results in the early adoption period. The 12-month follow-up, while adequate for assessing procedural outcomes, may be insufficient for evaluating long-term oncologic outcomes or detecting late complications. Patient-reported outcome measures were limited to satisfaction scores and functional assessment; more comprehensive quality-of-life instruments would provide a fuller picture of the patient experience. Future research should include prospective, multicenter, randomized controlled trials with longer follow-up, detailed cost-effectiveness analysis, and integration of patient-reported outcomes to establish the highest level of evidence for clinical practice guidelines.25

CONCLUSION

This retrospective comparative analysis of 370 patients demonstrates that ultrasound-guided biopsy in surgical oncology significantly improves procedural success rates, reduces complication rates, shortens hospital length of stay, and improves 12-month clinical outcomes compared to conventional approaches. The technology does not substantially increase operative time and is confirmed as an independent predictor of favorable outcomes on multivariate analysis. These findings support the routine integration of advanced imaging guidance into surgical practice for the studied indications. The benefits are most pronounced in complex cases and in patients with additional risk factors, suggesting that imaging guidance should be strongly prioritized in these populations. Future prospective multicenter trials with cost-effectiveness analysis and long-term follow-up are warranted to further refine clinical practice guidelines and identify optimal patient selection criteria.

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