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Research Article

Integrated Radiologic and Intraoperative Assessment of Gallbladder Carcinoma: Evaluating the Role of Multidetector CT in T and N Staging

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ABSTRACT

Background: Gallbladder carcinoma (GBC) is an aggressive malignancy often diagnosed at an advanced stage, particularly in South Asian populations. Accurate preoperative staging is essential for surgical planning and prognosis. While multidetector computed tomography (MDCT) is commonly employed for this purpose, its diagnostic performance relative to intraoperative findings remains underexplored in resource-limited settings.

Objective: To evaluate the accuracy of MDCT in predicting T (tumor) and N (nodal) staging in gallbladder carcinoma, using intraoperative findings as the reference standard.

Methods: This prospective cross-sectional study included 50 patients with suspected or radiologically confirmed GBC at Kuwait Teaching Hospital, Peshawar, between December 2024 and June 2025. All patients underwent triphasic contrast-enhanced MDCT using a Toshiba Activion 16-slice scanner, followed by exploratory surgery. T and N staging based on MDCT was compared with intraoperative findings. Sensitivity, specificity, predictive values, accuracy, and Cohen's kappa coefficient were calculated.

Results: The study population had a mean age of 58.4 years; 68% were female. MDCT demonstrated an overall accuracy of 84% for T staging and 82% for N staging. Sensitivity and specificity for T staging were 87.5% and 80.0%, respectively; for N staging, they were 83.7% and 78.6%. Kappa coefficients indicated substantial agreement between radiologic and intraoperative staging ($\kappa = 0.72$ for T; $\kappa = 0.68$ for N). Discrepancies were most common in early-stage tumors and in cases of reactive lymphadenopathy.

Conclusion: MDCT shows high diagnostic accuracy in the preoperative staging of gallbladder carcinoma, particularly in identifying advanced-stage disease. While early-stage tumors and nodal involvement may be underestimated, MDCT remains a reliable tool for surgical decision-making in settings lacking immediate histopathology. Integration with intraoperative assessment enhances the effectiveness of staging and improves patient management.

Keywords: Gallbladder Carcinoma, MDCT, T Staging, N Staging, Intraoperative Assessment, Radiologic Accuracy.

INTRODUCTION

Gallbladder carcinoma (GBC) is a highly aggressive malignancy of the biliary tract with a poor prognosis, primarily due to its insidious onset and late clinical presentation. Although it remains relatively uncommon globally, it poses a significant health burden in regions such as South Asia and Latin America[1]. In Pakistan, GBC is frequently encountered in tertiary care settings, particularly among females over the age of 50, often presenting at an advanced stage[2]. The delayed detection of GBC drastically reduces the likelihood of curative surgical resection, highlighting the critical importance of early and accurate staging for effective clinical management[3].

Staging of gallbladder carcinoma is primarily performed using the Tumor–Node–Metastasis (TNM) system, which determines the depth of tumor invasion (T stage) and the extent of regional lymph node involvement (N stage). Early-stage tumors (T1–T2) are potentially resectable with favorable outcomes, while advanced tumors (T3–T4, N1–N2) typically

require extended hepatic resections and lymphadenectomy, often with limited survival benefit[4]. Thus, accurate preoperative assessment of T and N stage is vital to determine surgical eligibility, avoid futile procedures, and guide appropriate neoadjuvant or palliative interventions.

Imaging plays a pivotal role in the initial evaluation and staging of GBC. While ultrasonography is frequently employed due to its accessibility, it has limitations in sensitivity and staging precision. Advanced modalities such as magnetic resonance imaging (MRI) and positron emission tomography-computed tomography (PET-CT) provide excellent soft-tissue characterization and metabolic insights but are often inaccessible in resource-constrained settings. Multidetector computed tomography (MDCT), in contrast, offers a widely available, fast, and high-resolution imaging solution for preoperative evaluation of gallbladder tumors[5].

Triphasic MDCT enables detailed visualization of the gallbladder wall, liver infiltration, vascular encasement, and regional lymph nodes. It provides key staging indicators such as serosal breach, pericholecystic fat stranding, hepatic extension, and nodal enlargement[6]. These features are crucial in differentiating resectable from unresectable disease and in formulating appropriate surgical strategies. However, MDCT interpretation remains challenging, particularly in early-stage disease or in the presence of inflammatory conditions such as xanthogranulomatous cholecystitis, which can mimic malignancy. Similarly, reliance on lymph node size and morphology for N staging may result in over- or underestimation, especially when reactive or micrometastatic nodes are present.

Intraoperative findings serve as a reliable reference for tumor spread and lymph node involvement, allowing direct visualization and palpation of affected tissues. In many low- and middle-income countries, surgical decisions are frequently made without immediate histopathologic confirmation, underscoring the need to validate imaging findings against operative assessments[7].

This prospective study aims to assess the diagnostic accuracy of preoperative MDCT in predicting T and N staging of gallbladder carcinoma by comparing it with intraoperative findings at Kuwait Teaching Hospital, Peshawar. The study also seeks to identify imaging features that influence staging accuracy and highlight common causes of staging discrepancies. The findings are expected to guide standardized radiologic reporting, enhance radiology-surgery coordination, and improve patient outcomes in settings where histopathology is limited or delayed.

METHODS

This research followed a forward-looking cross-sectional design and took place in the Radiology and Surgery units at Kuwait Teaching Hospital Peshawar during the period from June 2024 to June 2025. The main aim was to check how well multidetector computed tomography can determine tumor and lymph node stages in gallbladder cancer compared to what was found during surgery. Kuwait Teaching Hospital serves as a high-level medical center connected to Khyber Medical University and provides care to people from both city and village areas of Khyber Pakhtunkhwa.

Individuals aged eighteen and above were selected if gallbladder cancer was either indicated on imaging or proven through biopsy. Participation required completion of contrast enhanced multidetector CT followed by surgical treatment at Kuwait Teaching Hospital Peshawar. Only those with full surgical staging records were taken for final evaluation

Patients were not included if initial scans showed spread to distant organs or if surgery was not performed due to advanced illness. Others were also excluded if they had undergone gallbladder removal earlier or if CT scans were unclear or records were incomplete. Those who did not agree to take part in the study were also left out.

A total of 50 patients were included in the study using non-probability consecutive sampling. All eligible patients who presented during the 7-month study period and fulfilled the inclusion criteria were enrolled.

All patients underwent contrast-enhanced triphasic multidetector computed tomography (MDCT) using a Toshiba Activion 16-slice CT scanner installed at the Radiology Department of Kuwait Teaching Hospital, Peshawar. The imaging protocol included a non-contrast phase to identify calcification or hemorrhage, followed by an arterial phase acquired 25–30 seconds after contrast injection, a portal venous phase at 60–70 seconds, and an optional delayed phase obtained approximately 180 seconds post-injection when required.

The technical parameters for MDCT imaging included a scan range extending from the diaphragm to the iliac crest, with images

acquired at a slice thickness of 0.625 mm to ensure high spatial resolution. A non-ionic iodinated contrast agent, Iohexol 300 mgI/mL, was administered intravenously at a dose of 1.5 mL per kilogram of body weight, using an injection rate of 3–4 mL per second, followed by a 30 mL saline flush to enhance contrast delivery. Image reconstruction was performed using multiplanar reformation (MPR) and maximum intensity projection (MIP) techniques to facilitate detailed evaluation of tumor morphology, vascular involvement, and lymph node assessment.

Two consultant radiologists, each with over five years of experience in abdominal imaging, independently reviewed the MDCT scans. Both radiologists were blinded to intraoperative findings to ensure unbiased assessment. Tumor (T) and nodal (N) staging were determined according to the American Joint Committee on Cancer (AJCC) 8th edition criteria. T staging was classified as follows: T1—tumor invasion of the lamina propria or muscle layer; T2—tumor invasion of the perimuscular connective tissue; T3—tumor perforation of the serosa and/or direct invasion of the liver or one adjacent organ; and T4—tumor invasion of the main portal vein, hepatic artery, or multiple extrahepatic organs. N staging was defined as N0 for no regional lymph node metastasis, N1 for involvement of one to three regional lymph nodes, and N2 for metastasis in four or more regional lymph nodes. Lymph node involvement on MDCT was considered positive if the nodes measured more than 10 mm in short-axis diameter, appeared round in shape, exhibited central necrosis or absence of a fatty hilum, and were located at anatomical sites such as the porta hepatis, celiac axis, or peripancreatic region.

All patients underwent either laparotomy or laparoscopy performed by experienced hepatobiliary surgeons at Kuwait Teaching Hospital. During the surgical procedure, the extent of tumor invasion and regional lymph node involvement was carefully evaluated through direct visualization and palpation. The intraoperative assessment included documentation of the depth of tumor invasion corresponding to T staging, involvement of adjacent organs such as the liver, stomach, duodenum, omentum, and bile ducts, as well as the presence, size, and number of regional lymph nodes consistent with N staging. Additionally, any evidence of vascular encasement or unresectability was noted. These intraoperative findings were considered the reference standard against which the diagnostic accuracy of MDCT-based staging was evaluated.

This study is to examine how well multidetector CT can match surgical findings for classifying tumor size and lymph node involvement in gallbladder cancer and to find typical CT scan signs seen in later stages of the disease and uncover main factors leading to mismatch in stage determination.

Ethical Consideration

Permission to carry out this research was officially provided by the ethics committee at Kuwait Teaching Hospital. All individuals taking part in the study signed a consent form before enrollment. Participant information was handled with full privacy and the work was conducted in line with international ethical standards for human research

Statistical Analysis.

All observations were recorded using a predesigned information sheet. The collected material was later transferred into Microsoft Excel for organization and processed using IBM SPSS version 25. To assess the ability of MDCT to correctly classify both tumor extent and lymph node status, measures such as true positive rate, true negative rate, probability of correct positive prediction, probability of correct negative prediction, and total accuracy were computed. The consistency between staging based on imaging and surgical assessment was measured through Cohen kappa statistics and a probability value below 0.05 was taken as the threshold for meaningful difference

RESULTS

A total of 50 patients with clinically or radiologically suspected gallbladder carcinoma were enrolled in the study at Kuwait Teaching Hospital, Peshawar, between December 2024 and June 2025. The mean age of the study population was 58.4 years (range: 42–76 years). Among these, 34 patients (68%) were female and 16 (32%) were male, with a male-to-female ratio of approximately 1:2.1.

The majority of patients (n = 45; 90%) presented with right upper quadrant abdominal pain. Jaundice was reported in 21 patients (42%), followed by weight loss and anorexia in 11 patients (22%), and fever in 9 patients (18%). Four patients (8%) had incidental radiologic findings of gallbladder carcinoma during imaging for unrelated abdominal complaints.

Multidetector CT findings were compared with intraoperative staging for evaluation of local tumor invasion (T stage). The results are shown in Table 1.

Table 1: Comparison of MDCT and Intraoperative T-Staging (N = 50)

T Stage	Intraoperative Cases (n)	MDCT Correct (n)	Accuracy (%)
T1	5	3	60.0%
T2	12	9	75.0%
T3	22	20	90.9%
T4	11	10	90.9%
Total	**50**	**42**	**84.0%**

MDCT was more accurate in identifying advanced T-stage lesions (T3 and T4). Early stages (T1 and T2) were sometimes over- or under-estimated due to pericholecystic inflammation or subtle serosal involvement not easily visualized on imaging.

MDCT-based evaluation of regional lymph node involvement was compared with intraoperative nodal staging, summarized in Table 2

Table 2: Comparison of MDCT and Intraoperative N-Staging (N = 50)

N Stage	Intraoperative Cases (n)	MDCT Correct (n)	Accuracy (%)
N0	28	24	85.7%
N1	15	12	80.0%
N2	7	5	71.4%
Total	**50**	**41**	**82.0%**

MDCT demonstrated reasonable accuracy in differentiating node-negative from node-positive disease. However, micrometastases in normal-sized nodes and reactive lymphadenopathy contributed to staging discrepancies. The overall diagnostic performance of MDCT in assessing T and N staging is summarized in Table 3

Table 3: Overall Diagnostic Performance of MDCT

Parameter	T-Staging (%)	N-Staging (%)
Sensitivity	87.5	83.7
Specificity	80.0	78.6
Positive Predictive Value (PPV)	88.4	79.4
Negative Predictive Value (NPV)	78.2	82.1
Accuracy	84.0	82.0
Kappa Coefficient (κ)	0.72 (substantial agreement)	0.68 (substantial agreement)

These results indicate that MDCT is a reliable modality for preoperative T and N staging, especially for advanced disease. The Kappa statistics suggest substantial agreement between radiologic and intraoperative staging.

Among the study population, the most frequently observed radiologic feature on MDCT was gallbladder wall thickening, present in all patients (100%, n = 50), with both focal and diffuse patterns noted. Breach of the gallbladder serosa was identified in 34 patients (68%), while direct liver infiltration was seen in 20 cases (40%). Disruption of fat planes with the liver or adjacent organs was noted in 19 patients (38%), indicating possible local tumor extension. Regional lymphadenopathy, characterized by lymph nodes larger than 10 mm with round morphology or central necrosis, was observed in 22 patients (44%). Intrahepatic biliary duct dilatation was seen in 11 patients (22%), often associated with advanced-stage disease and biliary obstructionThese features aided in staging and surgical planning, particularly in detecting locally advanced disease.

Discrepancies between MDCT-based staging and intraoperative findings were identified in 8 patients (16%). Among these, three early-stage tumors (T1–T2) were overstaged as T3 on MDCT due to dense pericholecystic fat stranding that mimicked hepatic invasion. Conversely, two T2 tumors were understaged as T1 owing to the non-visualization of serosal breach on imaging. In terms of nodal staging, two patients initially categorized as N0 on surgical evaluation were overstaged as N1 on MDCT due to the presence of enlarged but reactive lymph nodes. Additionally, one case of

N1 disease was missed on MDCT, as the involved lymph nodes were sub-centimeter in size and lacked overt radiologic features suggestive of malignancy.

MDCT demonstrated an overall accuracy of 84% for T staging and 82% for N staging when compared to intraoperative findings. The modality was especially effective in identifying advanced tumors requiring extended resection. Staging errors were mostly confined to early disease or reactive lymphadenopathy. Despite these limitations, MDCT remains a valuable tool in the preoperative evaluation of gallbladder carcinoma, particularly in settings where histopathology is delayed or unavailable.

DISCUSSION

Advanced cross-sectional scanning using multiple detector rows has become a key method for assessing gallbladder cancer before surgery with a focus on evaluating how far the tumor has spread and whether nearby lymph nodes are affected. Several research efforts have shown that this technique performs strongly in identifying later stages of the illness. Kumaran et al. reported an overall staging accuracy of 93.3% using dual-phase helical CT in a prospective study, emphasizing the importance of arterial and portal venous phases in visualizing critical staging features such as serosal breach, liver invasion, and vascular encasement[8]. Their findings confirmed the utility of MDCT in reliably differentiating resectable from unresectable tumors. Similarly, Kalra et al. found that MDCT had a sensitivity of 72.7% and specificity of 100% in predicting resectability. Notably, hepatic and vascular invasion were correctly identified in all surgical cases, supporting MDCT's value in preoperative surgical planning for advanced-stage disease[9].

While MDCT performs well in advanced stages, early-stage tumors (T1–T2) remain difficult to evaluate accurately due to radiologic overlap with inflammatory conditions. Chun et al. found that features such as pericholecystic fat infiltration, intramural hypoattenuated nodules, and diffuse wall thickening were significantly more prevalent in xanthogranulomatous cholecystitis (XGC) than in early gallbladder carcinoma[10]. Recent advances in artificial intelligence have shown promise in addressing the diagnostic overlap between inflammatory conditions and early gallbladder carcinoma. Zhang et al. developed a deep learning–based CT nomogram that accurately distinguished xanthogranulomatous cholecystitis (XGC) from gallbladder carcinoma, achieving internal and external validation accuracies of 98% and 89%, respectively. This AI-driven model may serve as a valuable decision-support tool for improving preoperative staging and avoiding unnecessary surgical interventions in ambiguous cases.[11]

Preoperative MDCT often relies on lymph node size (e.g., >10 mm in short-axis) as a criterion for metastatic involvement; however, this approach alone frequently results in false-positive findings. Recent evidence suggests that incorporating additional morphologic features—such as round shape, loss of fatty hilum, central necrosis, and proximity to the primary tumor—significantly enhances diagnostic specificity. A multicenter validation study confirmed that these CT morphologic parameters are more reliable than size alone in predicting lymph node metastases in biliary tract malignancies, including gallbladder carcinoma.[12]

Clinically, MDCT significantly influences surgical planning. The OMEGA international cohort (2023) found that patients with T3–T4 stage and lymph node involvement identified on preoperative MDCT were more likely to experience early recurrence or 90-day mortality after surgery, underscoring the importance of identifying high-risk individuals to avoid futile upfront procedures.[13]

Beyond its staging utility**,** MDCT also plays a key role in identifying surgical risk factors, such as intrahepatic ductal dilatation, pericholecystic fluid, vascular encasement, and direct liver infiltration. In Kalra et al.'s study of 27 patients, MDCT with 3D reconstruction achieved 100% accuracy in detecting hepatic and vascular invasion, and even revealed vascular anatomical variations in six cases, which are critical for surgical planning[14]. These findings support our observations that gallbladder wall thickening and adjacent fat-plane disruption correlate with the need for extended resections, suggesting that detailed MDCT interpretation can inform surgical strategy beyond standard TNM staging.

Moreover**,** combining CT imaging data with intraoperative findings may enable the development of quantitative scoring systems to predict resectability and recurrence risk in gallbladder carcinoma[15]. Similar structured indices have been successful in pancreatic and colorectal cancers Evaluating parameters such as serosal breach, liver interface involvement, and lymph node enhancement during operative correlation could improve patient selection for neoadjuvant therapy versus immediate

resection, reducing the risk of futile surgeries in aggressive tumors.

In addition**,** implementing a structured radiology reporting template for GBC like GB-RADS in gallbladder US may enhance staging accuracy and consistency. Although structured CT reporting has improved interobserver agreement in liver and pancreatic malignancies, no formal MDCT template for gallbladder carcinoma currently exists. A synoptic CT template with defined fields for wall enhancement, serosal integrity, liver interface, nodal morphology, and vascular involvement could standardize reporting and benefit centers lacking hepatobiliary radiology expertise.

CONCLUSION

In summary, MDCT remains a highly valuable modality for preoperative staging in gallbladder carcinoma. Its strengths lie in detecting advanced disease and informing surgical strategy, while its limitations persist in early-stage tumor evaluation and nodal characterization. Future improvements, including AI-based interpretation and radiomics, may help bridge these diagnostic gaps and optimize patient outcomes, particularly in resource-constrained environments where histopathologic confirmation is often delayed.

LIMITATIONS

Finally**,** despite its strengths, MDCT has limited sensitivity in detecting micrometastases and subtler serosal invasion—underscoring the need for complementary modalities. Alternatives such as MRI with hepatobiliary contrast, contrast-enhanced ultrasound (CEUS), and PET-CT show promise in equivocal cases, though their availability is often limited in resource-constrained settings[16]. Furthermore, integrating deep learning and radiomics into CT analysis may improve early-stage diagnostic accuracy and personalize surgical decisions in gallbladder carcinoma.

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