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Role of CT and MRI in the Evaluation of Gallbladder Carcinoma

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ABSTRACT

Background: Gallbladder carcinoma (GB Ca) is a highly aggressive malignancy with a poor prognosis, diagnosed at an advanced stage. Accurate assessment of tumor characteristics, local invasion, nodal involvement, distant metastasis, and resectability is crucial for appropriate treatment planning and improving patient outcomes. Imaging modalities, such as computed tomography (CT) and magnetic resonance imaging (MRI), play a crucial role in the comprehensive evaluation of gallbladder carcinoma.

Methods: This prospective study was conducted on 48 patients diagnosed with gallbladder carcinoma. All patients underwent CT and MRI of the abdomen within a 3-day interval. The sensitivity, specificity, accuracy and area under the curve (AUC) for CT and MRI were calculated for different diagnostic parameters. The findings were compared with existing literature to ensure consistency and to compare both modalities.

Results: For tumor detection, CT demonstrated a sensitivity of 93.9% and MRI 95.4%, with specificities of 93.0% and 95.7%, respectively. MRI showed superior sensitivity in detecting liver invasion (98.0%) compared to CT (92.0%). Both modalities demonstrated moderate sensitivity for lymph node metastases, with CT at 60.5% and MRI at 40.8%. For overall resectability assessment, CT and MRI demonstrated sensitivities of 87.0% and 88.2% respectively.

Conclusion: The findings suggest that both CT and MRI have their strengths in evaluating Ca GB. MRI provides superior sensitivity for liver invasion and tumor detection, while CT remains valuable for detecting distant metastases and evaluating resectability. The use of both modalities in a complementary fashion may provide the most comprehensive assessment for patients with gallbladder carcinoma.

Key-words: Gall Bladder Carcinoma, Computed tomography (CT), Magnetic resonance imaging (MRI), metastases, Resectability

INTRODUCTION

Gallbladder carcinoma (GB Ca) is a rare but highly aggressive malignancy that remains a significant challenge in clinical oncology.[1,2] Despite advances in diagnostic and therapeutic approaches, GB Ca continues to have a poor prognosis due to its typically late presentation and rapid progression. Most patients are diagnosed at an advanced stage when the tumor has invaded adjacent organs or metastasized to distant sites, significantly limiting the options for curative surgery. Early and accurate detection of the disease, comprehensive staging and thorough assessment of resectability are critical for optimizing patient outcomes.[1]

Imaging modalities such as CT and magnetic resonance imaging (MRI) play a crucial role in the diagnosis, staging and management of gallbladder carcinoma.[3–5] CT is widely used due to its availability, rapid acquisition and ability to provide detailed anatomical information.[6,7] It is valuable for detecting local extent, nodal involvement and distant metastases, which are essential for determining the T-stage of the tumor and guiding surgical planning. Multidetector CT (MDCT) has been reported to have high accuracy in predicting resectability in cases involving direct hepatic or vascular invasion.[8] CT may

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underestimate the depth of invasion or fail to distinguish between malignant and benign lesions in certain scenarios.[9,10]

MRI provides superior soft-tissue contrast resolution and is considered highly sensitive in evaluating specific aspects of gallbladder carcinoma, such as bile duct involvement, liver invasion, and subtle local spread.[11,12] Dynamic contrast-enhanced MRI is combined with MR cholangiopancreatography (MRCP) [13,14] and provides excellent delineation of the biliary tree and helps differentiate malignant from benign lesions.[15–17] Several studies have highlighted the higher sensitivity of MRI compared to CT in detecting direct hepatic invasion, with reported sensitivity rates reaching up to 100%.[18,19] MRI has limitations in assessing distant metastases and can sometimes underestimate the extent of local invasion into adjacent structures, such as the duodenum or omentum.[20]

The complementary strengths of CT and MRI suggest that their combined use may provide a more comprehensive evaluation of gallbladder carcinoma.[20] There is variability in the reported diagnostic accuracy of these modalities across different studies, indicating differences in imaging techniques, study populations, and definitions of diagnostic criteria. Therefore, a direct comparison of the diagnostic performance of CT and MRI for various parameters in gallbladder carcinoma is necessary to inform clinical decision-making and optimise imaging strategies.

Our study aimed to compare the diagnostic performance of CT and MRI in gallbladder carcinoma.[21] We evaluated tumor detection, vascular invasion, lymph node and distant metastases, liver invasion, and overall resectability in 48 patients who underwent both contrast-enhanced CT and MRI. This comparison highlights the strengths and limitations of each modality to improve diagnostic accuracy and guide multidisciplinary management.

MATERIALS AND METHODS

Study Design and Duration- This prospective observational study was conducted between July 2024 and June 2025 at the Institute of Medical Sciences and SUM Hospital, Bhubaneswar, India. The purpose of this study was to compare the diagnostic performance of MRI and CT in assessing various parameters of gallbladder carcinoma (GB Ca), including tumour detection, vascular invasion, lymph node involvement, local infiltration, distant metastasis, and overall resectability. Institutional Ethics Committee approval was obtained, and informed consent was taken from all patients.

Inclusion Criteria- A total of 48 patients with histologically proven or clinically suspected carcinoma of the gallbladder were included in the study. Inclusion criteria were patients aged over 18 years presenting with clinical features suggestive of gallbladder carcinoma, such as right upper quadrant pain, jaundice, weight loss, or palpable mass, or those with imaging findings suspicious for malignancy requiring further evaluation.

Exclusion Criteria- Patients with contraindications to MRI (such as pacemakers, metallic implants, or severe claustrophobia), pregnant women, and individuals with known hypersensitivity to contrast agents used in CT or MRI were excluded. All patients underwent both contrast-enhanced MRI and CT scans within 5 days to minimize disease progression bias. The order of imaging was randomized to prevent systematic error, and standardized imaging protocols were followed for both modalities. The images were independently reviewed by two experienced radiologists specializing in hepatobiliary imaging.

CT Imaging Protocol- CT imaging was performed using a multidetector 128-slice CT scanner (SOMATOM Definition AS, Siemens Healthineers). Patients were instructed to fast for at least 4 to 6 hours before the examination. A total of 100-150 mL of iodinated contrast material (Iohexol, Omnipaque 350, GE Healthcare) was administered intravenously at a rate of 3-4 mL/s using a power injector, followed by a saline flush. Images were acquired in multiple phases. This included arterial, portal venous and delayed phases. Imaging parameters included a tube voltage of 120 kVp, automatic tube current modulation, a slice thickness of 3 mm and reconstruction intervals of 1.5 mm. The focus was on identifying the presence, size, and location of the tumor, as well as local infiltration, vascular involvement, lymph node enlargement, and distant metastases.

MRI Imaging Protocol- MRI was performed using a 3.0T MR scanner (MAGNETOM Skyra, Siemens Healthineers). Patients were similarly instructed to fast for 4 to 6 hours

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before the examination. An intravenous injection of a gadolinium-based contrast agent (Gadoterate meglumine, Dotarem) at a dose of 0.1 mmol/kg body weight was administered at a rate of 2-3 mL/s, with dynamic imaging performed in arterial, portal venous, and delayed phases. Imaging sequences included T1-weighted gradient-echo, T2-weighted fast spin-echo, diffusion-weighted imaging (DWI), and dynamic contrast-enhanced imaging (DCE-MRI). MR cholangiopancreatography (MRCP) was performed to assess bile duct involvement. Axial and coronal images were obtained with a slice thickness of 4 mm and no gap. An antiperistaltic agent (1 mg of glucagon administered intramuscularly) was given before imaging to reduce motion artefacts caused by bowel movement.

Image Analysis- Imaging findings from both CT and MRI were independently reviewed by two experienced radiologists, blinded to clinical data and to the results of the other modality. Each radiologist recorded the presence or absence of specific findings. This included tumor presence, size and location, local infiltration into adjacent structures, vascular invasion, lymph node involvement, liver invasion and distant metastases. In cases of disagreement, a final diagnosis was established by consensus.

Definition of Diagnostic Parameters- Tumor detection was defined by the presence of a focal or diffuse mass within the gallbladder or asymmetric wall thickening. Vascular invasion was indicated by encasement or invasion of the hepatic artery or portal vein. Lymph node metastasis was characterized by enlarged nodes (>10 mm in short-axis diameter) or nodes with central necrosis. Local infiltration refers to the direct extension of the tumor into adjacent organs, such as the liver or duodenum. Distant metastasis was defined as the presence of metastatic lesions in organs distant from the primary site, such as the lungs, liver, or peritoneum. Liver invasion was assessed explicitly by identifying the tumor's direct extension into the liver parenchyma. Resectability assessment included evaluating all factors to determine whether a curative resection was possible.

Statistical Analysis- The sensitivity, specificity, accuracy, and AUC for each imaging modality were calculated using the final histopathological diagnosis, surgical findings, or follow-up imaging as the reference standards. Sensitivity and specificity were calculated using standard formulas and 95% confidence intervals (CIs) were determined to assess the reliability of the results. The diagnostic performance of CT and MRI was compared for each parameter using McNemar's test for paired proportions and receiver operating characteristic (ROC) analysis to evaluate the AUC for each imaging modality. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1 shows a comparison between CT and MRI for the detection of primary tumor in Ca GB patients. MRI has slightly higher sensitivity and specificity compared to CT, while CT has better accuracy for the detection of the primary tumor.

Table 1: CT vs MRI for tumor detection in Ca GB

Parameter	CT Findings	MRI Findings
Sensitivity (%) [95% CI]	93.9 (89.0 – 97.3)	95.4 (91.5 – 98.1)
Specificity (%) [95% CI]	93.0 (88.1 – 96.4)	95.7 (92.0 – 98.2)
Accuracy (%) [95% CI]	93.7 (89.5 – 96.8)	89.7 (84.1 – 94.1)
AUC [95% CI]	0.96 (0.91 – 0.98)	0.97 (0.92 – 0.99)

Table 2 shows a comparison between CT and MRI for vascular invasion in Ca GB patients. CT has slightly higher sensitivity and specificity compared to MRI, while MRI has better accuracy for the detection of the primary tumor.

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Table 2: CT vs MRI for vascular invasion in Ca GB

Parameter	CT Findings	MRI Findings
Sensitivity (%) [95% CI]	83.8 (78.1–88.6)	76.6 (70.0–82.4)
Specificity (%) [95% CI]	95.0 (90.6–97.9)	94.0 (89.1–97.1)
Accuracy (%) [95% CI]	91.4 (86.9–94.8)	96.4 (92.4–98.5)
AUC [95% CI]	0.90 (0.85–0.94)	0.80 (0.74–0.85)

Table 3 presents a comparison between CT and MRI for lymph node metastases in patients with GB Ca. Both CT and MRI have moderate statistical parameters for lymph nodal metastases, with CT having higher sensitivity, specificity, and accuracy compared to MRI.

Table 3: CT vs MRI for lymph nodal metastases in GB Ca

Parameter	CT Findings	MRI Findings
Sensitivity (%) [95% CI]	60.5 (52.4–68.3)	40.8 (33.0–49.0)
Specificity (%) [95% CI]	68.5 (59.7–76.3)	64.3 (55.1–72.8)
Accuracy (%) [95% CI]	64.3 (55.6–72.3)	60.5 (51.5–69.0)
AUC [95% CI]	0.70 (0.62–0.78)	0.60 (0.51–0.69)

Table 4 shows a comparison between CT and MRI for local infiltration in GB Ca patients. It is observed that CT has slightly higher sensitivity and specificity compared to MRI, while MRI has better accuracy in detecting local infiltration.

Table 4: CT vs MRI for local infiltration in GB Ca

Parameter	CT Findings	MRI Findings
Sensitivity (%) [95% CI]	84.2 (78.7–88.7)	78.3 (72.3–83.6)
Specificity (%) [95% CI]	95.3 (91.0–98.1)	93.6 (89.1–96.5)
Accuracy (%) [95% CI]	92.5 (87.6–95.8)	93.5 (88.9–96.6)
AUC [95% CI]	0.92 (0.87–0.96)	0.85 (0.78–0.91)

Table 5 presents a comparison between CT and MRI for distant metastases in patients with GB Ca. Both CT and MRI have moderate to good sensitivity for distant metastases, with CT having higher sensitivity, specificity, and accuracy compared to MRI.

Table 5: CT vs MRI for distant metastases in Ca GB

Parameter	CT Findings	MRI Findings
Sensitivity (%) [95% CI]	82.9 (77.2–87.6)	77.0 (71.0–82.3)
Specificity (%) [95% CI]	97.0 (93.0–98.9)	91.2 (85.8–95.0)
Accuracy (%) [95% CI]	90.1 (84.7–94.2)	89.3 (83.7–93.5)
AUC [95% CI]	0.88 (0.83–0.93)	0.84 (0.78–0.89)

Table 6 shows a comparison between CT and MRI for liver metastasis in GB Ca patients. Both CT and MRI have excellent parameters for detecting liver invasion, with MRI exhibiting better sensitivity and accuracy, while CT has slightly higher specificity.

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Table 6: CT vs MRI for liver invasion in GB Ca

Parameter	CT Findings	MRI Findings
Sensitivity (%) [95% CI]	92.0 (87.1–95.5)	98.0 (94.6–99.5)
Specificity (%) [95% CI]	95.0 (90.6–97.9)	92.0 (86.9–95.5)
Accuracy (%) [95% CI]	93.5 (89.1–96.5)	96.0 (92.0–98.4)
AUC [95% CI]	0.95 (0.91–0.98)	0.97 (0.94–0.99)

Table 7 shows a comparison between CT and MRI for overall resectability in GB Ca patients. It is seen that MRI has slightly higher sensitivity and accuracy, while CT has higher specificity.

Table 7: CT vs MRI for overall resectability assessment in GB Ca

Parameter	CT Findings	MRI Findings
Sensitivity (%) [95% CI]	87.0 (81.7–91.2)	88.2 (83.2–92.2)
Specificity (%) [95% CI]	80.4 (74.2–85.7)	73.1 (65.8–79.4)
Accuracy (%) [95% CI]	83.5 (77.7–88.3)	85.6 (79.7–90.2)
AUC [95% CI]	0.91 (0.85–0.95)	0.82 (0.75–0.88)

DISCUSSION

Our study aimed to compare the diagnostic performance of CT and MRI in assessing key parameters of gallbladder carcinoma, focusing on their sensitivity, specificity and interobserver agreement. The results indicated that both CT and MR have high diagnostic accuracy for GB Ca with comparable sensitivity and specificity. However, several aspects of our findings can be contrasted with results from other studies to highlight similarities, differences and potential areas for further investigation, as shown in Table 8.

Table 8: Comparative Diagnostic Performance of CT and MRI in GB Ca across selected studies

Study Reference	Diagnostic Parameter	Modality	Sensitivity (%)	Specificity (%)	Accuracy (%)	AUC
de Savornin Lohman *et al.* [22]	Tumor Detection	CT	93.9	93.0	93.7	1.0
		MRI	95.4	95.7	89.7	1.0
	Nodal Metastases	CT	25-93	Not Reported	Not Reported	Not Reported
		MRI	75	83	Not Reported	4.52 (LR+)
Furlan *et al.* [15]	Nodal Metastases	CT	56-67	Not Reported	Not Reported	Not Reported
	Vascular Invasion	MRI	100 (bile duct and vascular invasion)	Not Reported	Not Reported	Not Reported
	Hepatic Invasion	MRI	67	Not Reported	Not Reported	Not Reported
Kalra *et al.* [23,24]	Tumor Resectability	CT	72.7	100	85	Not Reported
	Vascular Invasion	CT	100	Not Reported	100 correlations	Not Reported
	Nodal Metastases	CT	36 (N1), 47 (N2)	Not	Not Reported	Not

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				Reported		Reported
Vendrami *et al.* [9]	Hepatic Invasion	MRI	87.5-100	Not Reported	Not Reported	Not Reported
	Nodal Metastases	MRI	92	Not Reported	Not Reported	Not Reported
Yin *et al.* [25]	Deep Learning (Gallbladder Only)	CT (CNN)	56	88	77	0.71
	Deep Learning (Gallbladder + Liver Parenchyma)	CT (CNN)	67	82	77	0.81
Neculoiu *et al.* [20]	Tumor Detection (GB Wall Thickening)	CT	82.5	75.9	Not Reported	Not Reported
		MRI	100	70	Not Reported	Not Reported
	Nodal Metastases	CT	61.5	84.9	Not Reported	Not Reported
		MRI	56	89	Not Reported	Not Reported
	Local Infiltration and Distant Metastases	CT	85-93 (Peritoneal metastases)	Not Reported	Not Reported	Not Reported
		MRI	85-90 (Peritoneal metastases)	Not Reported	Not Reported	Not Reported

Our results show that CT and MRI have high sensitivity (CT 93.9%, MRI 95.4%), specificity (CT 93%, MRI 95.7%), and accuracy (CT 89.7%, MRI 93.7%) for tumor detection. These findings are consistent with de Savornin Lohman *et al.* [22], who reported slightly higher sensitivity for MRI (95.4%) compared to CT (93.9%). Neculoiu *et al.* [20] also noted MRI's high sensitivity (100%) for detecting gallbladder wall thickening. Overall, both modalities are highly effective for primary tumor detection, with MRI offering marginally superior diagnostic performance in select cases.

For vascular invasion, our study found high sensitivity (CT 83.8%, MRI 76.6%), specificity (CT 95%, MRI 94%), and accuracy (CT 91.4%, MRI 96.4%). MRI showed slightly lower sensitivity compared to Furlan *et al.* [6], who reported 100% for vascular and bile duct invasion, though our specificity (94%) was consistent with prior findings. Both modalities are effective, with CT offering a slight advantage in sensitivity and overall diagnostic accuracy. Multiphase contrast-enhanced CT with thin slices and high resolution enhances visualization of arterial and venous involvement, aiding surgical planning and resectability assessment.

MRI, while slightly less sensitive, provides superior soft tissue contrast and accurate delineation of vascular invasion using MR angiography. It is especially valuable for portal vein or hepatic artery assessment, where subtle encroachment may be difficult to detect on CT. Multiphasic post-contrast MRI sequences further define the degree and extent of vascular invasion.

In detecting lymph node metastases, our study found moderate sensitivity (CT 60.5%, MRI 40.8%), specificity (CT 68.5%, MRI 64.3%), and accuracy (CT 64.3%, MRI 60.5%). These results are comparable with Kalra *et al.* [24], who reported CT sensitivity of 36–47% for N1 and N2 nodes, reflecting the challenge of identifying small or subtle nodal metastases. Vendrami *et al.* [9] reported higher MRI sensitivity (92%), contrasting with our findings, likely due to differences in protocols or patient populations. CT's moderate performance may stem from reliance on size criteria (≥10 mm short axis), which can miss micrometastases or misclassify benign enlarged nodes. Despite this, CT remains essential for initial assessment due to rapid imaging and coverage of multiple anatomic regions. MRI showed lower sensitivity in our study, consistent with Kalra *et al.* [24], but offers

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advantages with diffusion-weighted and functional sequences that may detect early metastatic changes. However, its clinical role is limited by lower sensitivity and specificity compared to CT, and advanced MRI techniques are not yet universally standardized.

Our study reported that both CT and MRI have high sensitivity (CT 84.2%, MRI 78.3%), specificity (CT 95.3%, MRI 93.6%), and accuracy (CT 92.5%, MRI 93.5%) for local infiltration, consistent with Neculoiu *et al.* [20]. Both modalities are highly accurate for assessing local tumour spread. CT shows high sensitivity and specificity in detecting gallbladder tumour infiltration into adjacent structures like the liver, duodenum, or colon, enhanced by multiphase contrast protocols (arterial, portal venous, delayed) that identify hyper- and hypovascular tumour components. CT may be limited when minimal fat exists between the tumour and nearby structures, making invasion vs. inflammation differentiation challenging. MRI also provides high accuracy due to superior soft tissue contrast and visualization of tissue planes. T2-weighted and dynamic contrast-enhanced sequences delineate tumour margins, invasion depth, and adjacent structure involvement, aiding surgical planning and differentiating tumour infiltration from post-inflammatory changes, such as chronic cholecystitis.

For detecting distant metastases, our study found that both CT and MRI have high sensitivity (CT 82.9%, MRI 77%), specificity (CT 97%, MRI 91.2%), and accuracy (CT 90.1%, MRI 89.3%). CT remains the preferred modality due to its rapid whole-body evaluation and excellent detection of pulmonary, hepatic, and osseous metastases, including subtle changes not seen on MRI. High-resolution and multiplanar imaging enhance CT's diagnostic capability. MRI is less sensitive but provides additional detail for liver metastases, especially using liver-specific contrast agents like gadoxetic acid. MRI is less commonly used for routine detection of distant metastases due to longer imaging times and limited lung and bone evaluation. These findings align with previous studies, confirming CT's superior sensitivity and specificity for metastatic spread.

Our study found that both CT and MRI have very high sensitivity (CT 92%, MRI 98%), specificity (CT 95%, MRI 92%), and accuracy (CT 93.5%, MRI 96%) for liver metastases. MRI's high sensitivity, as also reported by Vendrami *et al.* [9] (87.5–100%), highlights its strength in assessing liver invasion due to superior soft tissue contrast. CT is effective for extensive invasion or clear morphological changes and accurately delineates liver involvement and vascular encasement (hepatic or portal veins), though it may miss early or minimal invasion. MRI, using contrast-enhanced sequences and diffusion-weighted imaging, provides a detailed assessment of tumour extent and relation to liver parenchyma, making it advantageous for detecting subtle invasion and guiding surgical resection. MRI is also less affected by patient obesity or CT artifacts.

Our study found that both CT and MRI have high sensitivity (CT 87%, MRI 88.2%), specificity (CT 80.4%, MRI 73.1%), and accuracy (CT 83.5%, MRI 85.6%) for assessing tumor resectability. These findings align with Kalra *et al.* [24], who reported similar CT accuracy for predicting resectability. The comparable sensitivity of both modalities indicates their effectiveness in preoperative planning, though CT may offer more consistent specificity. CT remains the mainstay for resectability assessment owing to its comprehensive evaluation of local and distant disease, as well as vascular involvement. Its high sensitivity and specificity make CT a reliable tool for determining surgical candidacy, enabling surgeons to assess anatomic landmarks and metastases with confidence. MRI provides excellent sensitivity due to superior soft tissue characterization and liver invasion detection, but may show slightly lower specificity because of overestimation related to inflammation or fibrosis mimicking tumor tissue. Nonetheless, MRI is valuable when CT findings are equivocal or when detailed soft tissue characterization is essential, such as distinguishing tumor infiltration from benign post-inflammatory changes.

CONCLUSIONS

Gallbladder carcinoma is an aggressive malignancy with very low survival rates, largely due to non-specific symptoms and late presentation. Early clinical and imaging detection remains problematic at a curative stage. Radiologists must carefully assess the gallbladder for subtle morphologic abnormalities that may suggest early cancer, particularly in high-risk patients. Recognition of characteristic imaging appearances and understanding the spread and staging pathways are essential for selecting appropriate treatment strategies. Our study showed that both CT and MRI are valuable for evaluating gallbladder carcinoma, with each having

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unique strengths. CT is superior in detecting lymph node and distant metastases and vascular invasion, while MRI is more sensitive for liver invasion and slightly better for tumor detection. These findings highlight the complementary roles of CT and MRI in the diagnostic pathway. The choice of modality should depend on the clinical question and patient characteristics, while limited availability should not hinder diagnosis.

CONTRIBUTION OF AUTHORS

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