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RESEARCH

Correlation between Tomographic and Histopathological Staging in Upfront Resected Gastric Cancer: Enhancing Diagnostic Accuracy in the Era of Perioperative Therapy

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Abstract

Purpose This study aimed to assess the diagnostic accuracy of multidetector contrast-enhanced computerised tomography (MDCT) and to establish a correlation between radiological and histopathological staging in upfront resected localised gastric cancers (GC).

Methods All consecutive patients of resectable, localised GC who underwent upfront elective resection between 2010 and 2022 were included. The initial clinical staging determined during multidisciplinary meetings was compared with the pathological stage obtained after surgery. Subsequently, a retrospective, blinded review was conducted to assign a revised clinical staging, and accuracy was correlated.

Results The analysis of 138 patients revealed varying accuracy of MDCT in determining the T stage (66.9% for T1/T2, 64.6% for T3, and 87.2% for T4) and N stage (60.8% for N0, 63.7% for N1, and 83.2% for N2). The accuracy for stage group ranged from 71 to 78.65%. There was weak agreement observed between the T, N, and overall stage on clinicopathological correlation. However, a blinded radiology review by oncoradiologists resulted in improved accuracy, particularly in T1/T2 disease, and also improved pathological stage correlation.

Conclusions Although MDCT is a valuable initial staging tool for gastric cancer, we found weak agreement between the clinical and the pathological stages in upfront resected gastric cancers. By implementing an expert radiology review and standardising scanning and reporting protocols, we can significantly improve the accuracy and correlation of MDCT with pathology, even for T1/T2 disease. This may help in better selecting patients for upfront surgery versus perioperative chemotherapy, especially in resource-constrained settings.

Keywords Computerised tomography · Histopathology · Correlation · Gastric cancer · Upfront resection

Introduction

Gastric cancer is the fifth most common malignancy globally and the fourth leading cause of cancer-related deaths [1]. While the incidence of gastric cancer is higher in China, Japan, and the Republic of Korea, the mortality rates are conversely lower due to rigorous screening programs, resulting in early diagnosis in up to half of all gastric cancers [2–4]. Early gastric cancer (EGC) is an invasive cancer that invades no deeper than the submucosa, regardless of lymph node metastasis [5]. In the Indian subcontinent, although the incidence is relatively lower, the mortality-to-incidence ratio is reported to be as high as 0.9 [2]. Limited access to healthcare, socio-cultural barriers, and the absence of a national screening program make advanced gastric cancer the predominant presentation [6].

Multidetector contrast-enhanced computerised tomography (MDCT) is commonly used for initial assessment due to its availability and the ability to evaluate the locoregional extent of the tumour as well as to screen for distant metastasis. However, up to 40% of clinical early-stage disease may be inadequately staged [7]. Endoscopic ultrasound (EUS) remains largely unavailable and adds significantly to costs in resource-constrained settings [8].

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While surgery is the primary treatment for localised tumours, offering upfront resection to clinically early patients may provide definitive staging whilst being curative. However, frequently understaged patients are deprived of the potential benefits of neoadjuvant chemotherapy [9–12]. Accurate preoperative clinical staging is crucial and has direct implications for treatment sequencing. In previous studies evaluating the diagnostic accuracy of MDCT in gastric cancer, less than half of the patients were staged as T1 or T2 [13–16].

With this hypothesis, we analyse the diagnostic accuracy of MDCT and correlate the radiological clinical stage with the histopathological stage, for upfront resected localised gastric cancers. Furthermore, we assess if a simple targeted intervention in the form of a blinded radiology review by two independent senior gastrointestinal oncoradiologists can enhance the diagnostic accuracy of MDCT.

Materials and Methods

Study Population

Data was collected from a prospectively maintained database in the Gastrointestinal and Hepato-Biliary-Pancreatic Division of the Department of Surgical Oncology at a tertiary care cancer centre. Between January 2010 and December 2022, all consecutive resectable, localised gastric cancer patients who underwent upfront elective resection were analysed. Patients who had emergent surgery for complicated gastric cancer (bleeding, severe outlet obstruction, gastric perforation), non-curative resections, or non-adenocarcinoma histologies were excluded from the analysis.

Preoperative Assessment

The preferred initial imaging modality was an MDCT of the thorax, abdomen, and pelvis (CECT TAP) in supine and right decubitus positions. An upper gastrointestinal endoscopy for disease mapping with diagnostic biopsies from the tumour was performed [17]. A pathology review was obtained at our institute for patients who had undergone a biopsy elsewhere. Patients with prior gastric interventions such as endoscopic resection, partial resection, or any other procedure that could potentially alter the native gastric wall were excluded from our analysis.

Details of CT Scan Protocol

Our institutional scans were performed using a Siemens Somatom 16-slice CT or a Siemens Somatom Sensation 16-slice Open CT (Siemens Healthcare, Erlangen, Germany) following the institutional gastric protocol. The scans were single portal venous phase CT with 1.5 mm slice thickness and axial plane acquisition using intravenous contrast (OmnipaqueTM 300, GE Healthcare, Massachusetts, USA). Patients were instructed to drink water before the scan and on the table before acquisition to ensure adequate distension. Additional lateral decubitus phase images were also obtained. Multiplanar reconstructions were made in coronal and sagittal planes. Patients who underwent CECT elsewhere with uploaded DICOM images of adequate quality (at least 1.5 mm slice thickness) available on Picture Archiving and Communication System (PACS) were also included.

I. Assigning an Initial Clinical Staging

All patients were discussed in a multidisciplinary tumour board, comprising a Gastrointestinal (GI) surgical oncologist, a GI oncoradiologist, a medical oncologist, a radiation oncologist, and a pathologist. After analysing the MDCT, each patient was assigned an initial clinical stage, and 'early-stage patients' were planned for surgical resection [18–21]. The pathology was staged according to the American Joint Committee on Cancer (AJCC) 8 th edition, and adjuvant chemotherapy or chemoradiotherapy (CRT) was offered [22].

II. Assigning a Revised Clinical Staging

Blinded CT Review

We retrospectively performed a blinded review of the preoperative images of patients who underwent a MDCT with DICOM images available on institutional PACS. The review was carried out independently by two senior gastrointestinal oncoradiologists, with at least 14 years of experience, and a revised clinical stage was assigned. Clinico-pathological correlation was performed again and with the revised clinical stage.

Method of CT Review and Reporting

The CT scans were initially reviewed for whether the lesion was appreciated on CT and the location and thickness of the lesion were entered whenever appreciated. Given that the early gastric tumours (T1, T2) may not be well discernible on imaging, the radiologist's certainty of the presence or absence of a lesion was also documented categorically as either certain or equivocal. The degree of gastric distension plays an important role in assessing early-stage lesions. Accordingly, the adequacy of gastric distension and the availability of a lateral decubitus position were noted. The presence of homogenous or heterogenous enhancement was recorded. The pattern of growth was classified as polypoidal, infiltrative, or ulcerative.

The radiological assessment of the T stage was classified as—the tumour not reaching the serosa, reaching up to/abutting the serosa and extending beyond the serosa [23]. The nodes were assessed for number, location, and size. A node was considered suspicious when the node was more than 6 mm in short axis dimension, round in shape, or was heterogeneously enhancing or necrotic. The radiologists classified the nodes as negative, suspicious, or indeterminate for metastasis.

Statistical Analysis

The tomographic staging was correlated with the post-resection histopathology results. Continuous variables were expressed as mean ± standard deviation (SD), while nominal variables were expressed as numbers and percentages. The correlations between tomographic and histopathological staging were calculated using the Spearman and Kendall methods. The association between tomographic and histopathologic staging for T, N, and clinical stage was calculated through Spearman correlation tests. All analysis was performed with Statistical Product and Service Solutions, SPSS version 26 (SPSS Inc., Chicago, IL, USA), and a p-value < 0.05 was considered statistically significant. Cohen's kappa coefficient was calculated to evaluate the interobserver agreement between radiologists for T and N stages.

Results

Three hundred and fifty-four patients of gastric adenocarcinoma underwent upfront radical curative resection between January 2010 and December 2022. Of these, 216 patients had emergency resections for complications of gastric cancer and were excluded. One hundred thirty-eight patients of localised gastric cancer underwent upfront radical resection and were analysed for clinicopathological correlation (Fig. 1).

The median age of patients was 56 years (24 to 84 years), with a male predominance (74.6%). The majority of the patients had distal tumours (50%) and underwent a subtotal/distal radical gastrectomy (78.3%) via the abdominal approach (73.9%). Almost 70% of tumours were poorly differentiated, with signet-ring cells present in one-third of all patients. Demographic, clinico-radiologic, operative, and histopathological characteristics are depicted in Table 1. An endoscopic ultrasound (EUS) was performed in only 13 (9.4%).

Performance of Initial Clinical Staging

The sensitivity, specificity, and diagnostic accuracy calculations for T, N, and clinical stage (CS) were calculated and are depicted in Table 2.

The concordance between the clinical stage and the pathological stage was found in only 55% of cases, whereas downstaging and upstaging were seen in 22.5% each. Alarmingly, one in four patients were upstaged for the T stage (24.6%), and one in three were upstaged for the N stage (33.3%). While MDCT shows higher accuracy in detecting advanced tumour stages (T4 and N2), its performance is less reliable for early stages (T1/T2 and N0).

For the T stages, there was weak agreement between tomographic and histopathological staging (tau 0.314, $p <$ 0.001 and Spearman's rho 0.327, $p < 0.001$). The agreement was also found to be weak for the N stage (tau 0.215, p 0.008 and Spearman's rho 0.229, p 0.007) and overall stage (tau 0.340, $p < 0.001$ and Spearman's rho 0.389, $p < 0.001$) (Table 3; Fig. 2) [24].

Performance of Revised Clinical Staging

Fifty-one out of 138 patients had a baseline CT study that was available for blinded review. A revised clinical stage was assigned, resulting in a significantly improved accuracy for T1/T2 disease as well as nodal staging. When the revised clinical stage was correlated with pathology, we found a moderate agreement for the T stage (tau 0.460, $p < 0.001$ and Spearman's rho 0.506, $p < 0.001$) as well as for the N stage (tau 0.454, $p < 0.001$ and Spearman's rho 0.490, $p < 0.001$) as presented in Table 3.

In 19/51 cases (37.3%), no lesion was observed on CT scan. On examining the pathology, it was found that 14/19 (73.7%) were T1, while 2/19 (10.5%) were T2 and 3/19 (15.7%) were T3 lesions. The radiologists' certainty of the presence of a lesion increased when the thickness of the lesion was more than 10 mm. However, an increase in thickness did not correlate with higher T stages. The mean thickness of lesions observed was 13.4 mm ± 5.4 mm.

Among the remaining 32/51 cases (62.7%) where a lesion was identifiable, the most common CT finding was enhancing wall thickening, present in 68.7% of cases (Figs. 3 and 4).

Suspicious nodes were detected in 33/51 (64.7%) cases, with the average size of the nodes being 7.9 mm ± 4.6 mm in short axis diameter. However, there was no statistically significant size threshold for nodal positivity on CT. The common location of the nodes was the gastrohepatic region (39.21%) followed by the perigastric region (11.7%).

The Cohen's kappa coefficient between the two radiologists for T staging ($\kappa = 0.72$, 95% CI 0.58–0.86) and N staging ($\kappa = 0.68$, 95% CI 0.53–0.83), indicated substantial agreement.

Despite standardisation, we encountered some inconsistencies in our imaging protocols. We observed that 31.4% (16/51) of cases had inadequate distension, while 45% (23/51) did not have a lateral decubitus available. In cases where a decubitus was available, the radiologists found it useful in 93% of cases. However, there was no significant

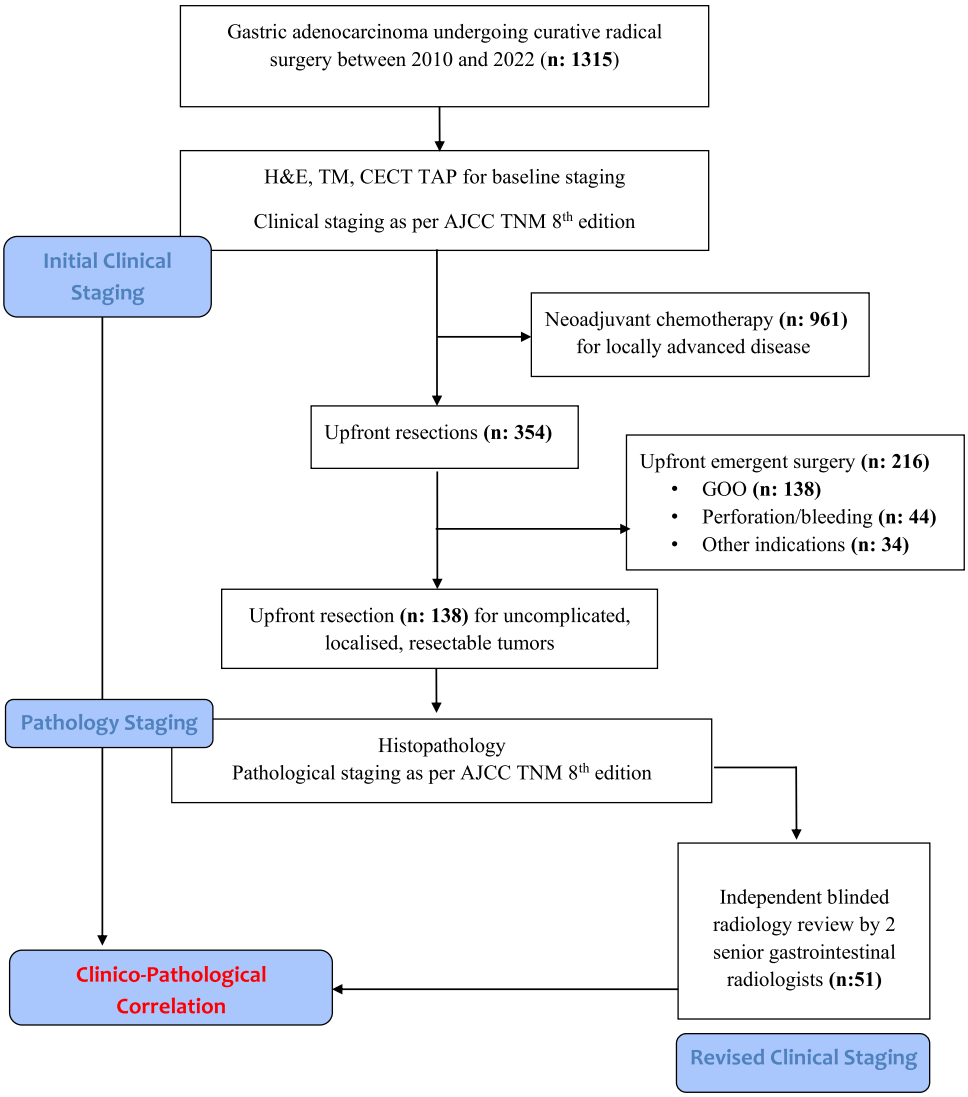

Fig. 1 Flow diagram depicting the process of inclusion, methodology and exclusion, and analysis of gastric cancer patients undergoing curative resection (H&E: history and examination, CECT TAP: contrast-enhanced computerised tomography thorax–abdomen–pelvis, AJCC: American Joint Committee on Cancer, GOO: Gastric Outlet Obstruction)

association between the adequacy of distension or the availability of a lateral decubitus with the discernibility or radiologists' certainty of the lesion.

Discussion

This study revealed that the accuracy of initial stage assignment on tomography ranged from 64.6 to 87.2% for the T stage, 60.8 to 63.7% for the N stage, and 70.67 to 79.6% for the overall stage. However, there was only weak agreement between tomography and histopathology for the T, N, and overall stages. It is concerning that one in four patients (24.6%) were upstaged for the T stage, and one in three (33.3%) were upstaged for the N stage.

In the current era of perioperative chemotherapy, we revisit the accuracy and limitations of MDCT in diagnosing truly clinically early-stage gastric cancers. With perioperative chemotherapy demonstrating a survival benefit, it is unfortunate that up to 40% of clinical early-stage disease are still inadequately staged on MDCT. As a result, approximately half of these patients do not receive appropriate chemotherapy [7]. Patients who are inadvertently understaged on tomography may receive inadequate treatment and experience compromised oncological outcomes.

To address this limitation, Endoscopic ultrasound (EUS) has been shown to have a higher predictive value for T staging of gastric cancer, thus making it a valuable complement to tomography [25]. According to the Indian Council of Medical Research (ICMR), EUS is considered 'desirable' in patients with early gastric cancer [17]. Additionally, as per the NCCN guidelines, EUS should be 'preferred' when distinguishing between early-stage and locally advanced disease [22]. However, EUS remains operator-dependent, with an accuracy of 46.2%

Table 1 Patient demographics, operative, and histopathological characteristics

Variable		Numbers (Percentages)
Patient demographics		
Median age (years)	56 years (range 24 to 84 years)	
Sex	Male	103 (74.6%)
	Female	35 (25.4%)
ASA	1	59 (42.8%)
	2	70 (50.7%)
	3	9 (6.5%)
Operative characteristics		
Surgery type of gastrectomy	Total	19 (13.8%)
	Proximal	9 (6.5%)
	Esophago-gastrecctomy	1 (.7%)
	Distal/subtotal	108 (78.3%)
	Wedge/sleeve resection	1 (.7%)
Surgical approach	Abdominal	102 (73.9%)
	Thoraco-abdominal	2 (1.4%)
	Laparoscopic assisted	27 (19.5%)
	Robotic assisted	7 (5%)
Tumor clinico-radiological characteristics		
GE junction involvement	No	133 (96.4%)
	Yes	5 (3.6%)
Tumor epicentre	Proximal	8 (5.8%)
	Distal	68 (49.3%)
	Body	58 (42%)
	GE junction	3 (2.2%)
	Linitis	1 (.7%)
Clinical stage (AJCC 8th edition)	1	64 (46.4%)
	2	43 (31.2%)
	3	31 (22.5%)
	4	0
EUS	Yes	13 (9.4%)
	No	125 (90.5%)
Tumour histopathological characteristics		
Pathological Stage (AJCC 8th edition)	CIS/dysplasia	5 (3.6%)
	1	62 (44.9%)
	2	38 (27.6%)
	3	33 (23.9%)
Perinodal extension (PNE)	No	35 (25.4%)
	Yes	31 (22.5%)
	N0	72 (52.2%)
Perineural invasion (PNI)	No	120 (87%)
	Yes	15 (10.9%)
	NK	3 (2.2%)
Lymphovascular invasion (LVI)	No	94 (68.1%)
	Yes	35 (25.4%)
	NA	9 (6.5%)
Margins	Free	128 (92.8%)
	Positive	1 (0.7%)
	Close	9 (6.5%)
Histology	Well	8 (5.8%)
	Moderately	31 (22.5%)
	Poorly	94 (68.1%)
	NK	5 (3.6%)
Signet cells	No	93 (67.4%)
	Yes	45 (32.6%)

ASA; American Society of Anaesthesiologists, *GE*; gastro-oesophageal, *LN*; lymph node, *EUS*; endoscopic ultrasound, *NK*; not known, *NACT*; neoadjuvant chemotherapy, *NA*; details not available

Table 2 Sensitivity, specificity and diagnostic accuracy by CT compared with histopathologic results for T, N, and clinical stage in gastric cancer as per the AJCC 8 th edition. Numbers in parentheses represent revised clinical staging

		pT stage									
		n: Initial stage (revised stage)				Sensitivity		Specificity		Accuracy	
cT stage		T1/T2	T3	T4		Initial	Revised	Initial	Revised	Initial	Revised
Initial (Revised)	T1/T2	58 (21)	19 (2)	7 (0)		69%	91.3%	–	–	66.9%	70.5%
	T3	18 (11)	20 (4)	10 (6)		41.67%	19%	75.64%	82.1%	64.66%	56.8%
	T4	0 (2)	0 (3)	1 (2)		–	28.5%	82.1%	80.6%	87.2%	78.4%
		pN stage									
		n: Initial stage (revised stage)				Sensitivity		Specificity		Accuracy	
cN stage		N0	N1	N2	N3	Initial	Revised	Initial	Revised	Initial	Revised
Initial (Revised)	N0	65 (26)	26 (5)	11 (1)	4 (1)	61.32%	78.78%	41.67%	45.5%	60.86%	74.5%
	N1	13 (3)	7 (3)	6 (1)	5 (0)	22.58%	42.85%	71.74%	80%	63.77%	78.4%
	N2	0 (2)	0 (2)	1 (2)	0 (3)	–	22.22%	–	90.63%	–	80.39%
	N3	0 (1)	0 (0)	0 (1)	0 (0)	–	–	–	88.57%	–	88.23%
		Pathological Stage				Sensitivity		Specificity		Accuracy	
Clinical stage		I	II A	II B	III						
	I	48	10	5	10	65.74%		78.65%		70.67%	
	II A	2	3	1	5	27.27%		76.47%		78.94%	
	II B	6	5	8	9	28.57%		89.55%		79.69%	
	III	6	5	1	9	42.85%		71.08%		72.9%	

AJCC; American Joint Committee on Cancer, *CT*; Computerised Tomography

for the T category and 66.7% for the N category [26]. In a multi-centre study from a high-income economy, it was found that less than one-quarter of patients with gastric adenocarcinoma underwent EUS, and among those who did, the EUS stage often did not correlate with the final pathological analysis [26]. The limited use of EUS (9.4%) reflects the challenges encountered in terms of limited availability of equipment and expertise, substantial additional cost, long waiting periods that can delay treatment initiation, and a perceived limited additional benefit when MDCT already suggests early-stage disease. A selective approach to EUS utilisation in cases with equivocal CT findings, particularly in proximal gastric tumours, represents a pragmatic strategy in settings where universal EUS implementation is not feasible due to resource constraints.

Table 3 Correlation between the preoperative clinical staging (tomographic staging) and the definitive histopathologic report

Variable name	Kendall's tau method		Spearman's rho method	
	Correlation coefficient	*p*-value	Correlation coefficient	*p*-value
Initial clinical staging				
cT and pT stage	0.314	< 0.001	0.327	< 0.001
cN and pN stage	0.215	0.008	0.229	0.007
Clinical stage and pathological stage (AJCC 8 th ed.)	0.340	< 0.001	0.389	< 0.001
Revised clinical staging				
cT and pT stage	0.460	< 0.001	0.506	< 0.001
cN and pN stage	0.454	< 0.001	0.490	< 0.001

c; clinical, *p*; pathologic, *AJCC*; American Joint Committee on Cancer

With surgery being a mainstay in the management of localised tumours, it may be argued that offering upfront resection to clinical early-stage patients may provide definitive staging whilst being curative. We have previously reported equivalent long-term outcomes for distal gastric cancers with either upfront surgery followed by adjuvant chemotherapy or perioperative chemotherapy followed by surgery [27]. In the current study, almost 50% (68/138) of tumours were located in the distal stomach. However, neoadjuvant chemotherapy is known to improve the likelihood of achieving margin-negative resection, pathological complete response, and biological selection, with improved survival [9, 28].

Our study indicates that conducting a comprehensive and objective review of radiology can independently improve the accuracy of CT staging and its correlation with pathology, beyond the standard assessment. The accuracy of detection of T1/T2 lesions improved to 70.5% (versus 66.9%) and ranged from 74.5 to 88.2% across different N stages. On using tests of correlation, we found a moderate agreement for both the T and N stages.

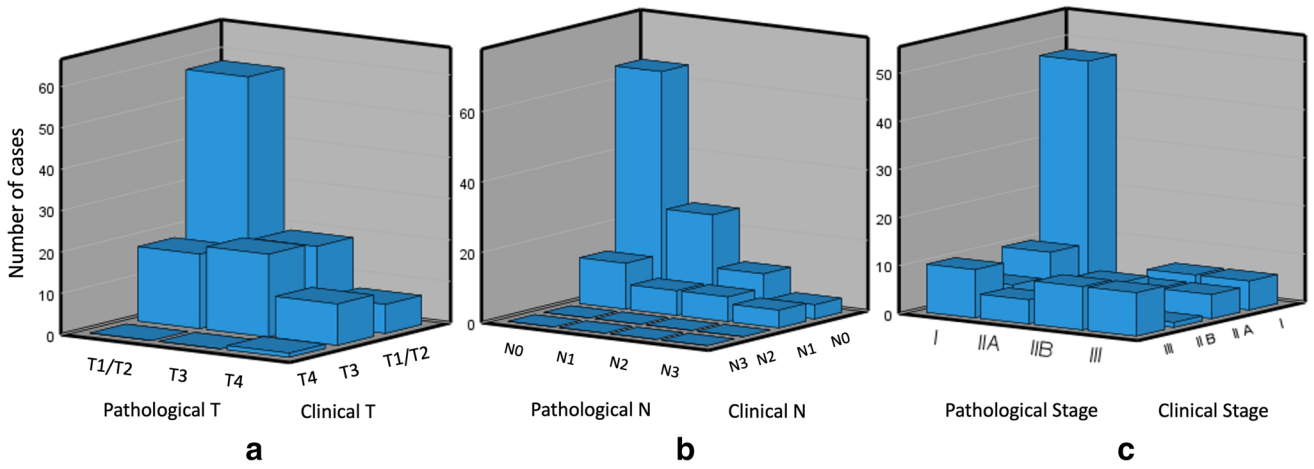

Fig. 2 Bar graphs representing the greater correlation between the preoperative tomographic staging and the definitive histopathologic results for the **a** T stage, **b** N stage, and **c** overall stage

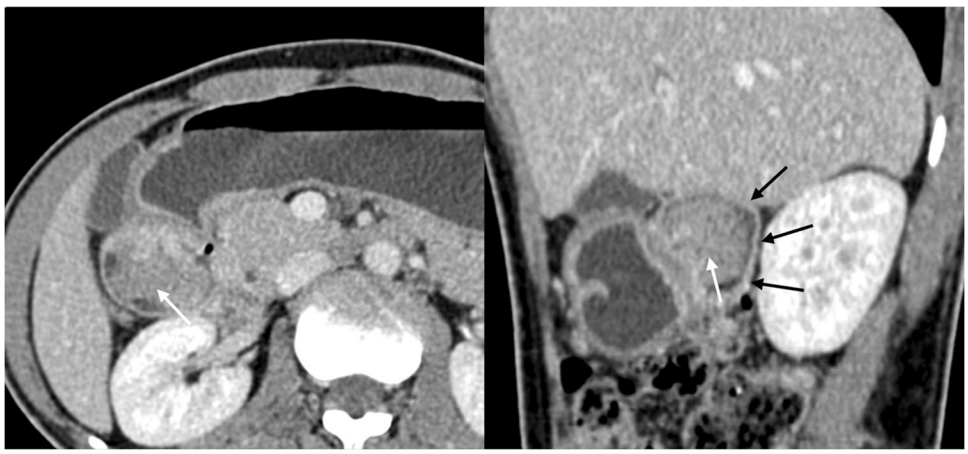

Fig. 3 CECT abdomen shows a heterogeneously enhancing polypoidal lesion (arrow) in the antro-pyloric region of the stomach. The lesion is seen away from the serosa (black arrows). It was T2 on pathology

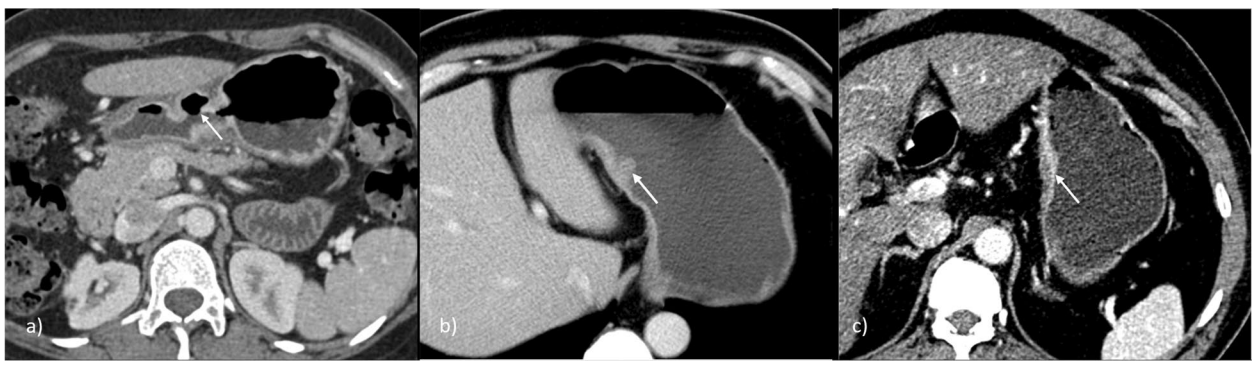

Fig. 4 CECT images demonstrate gastric cancers presenting as an ulcerative growth (**a**), polypoidal lesion (**b**), or wall thickening without a focal ulcerative or polypoidal lesion (**c**)

Several studies have compared tomographic and histopathologic results and reported staging accuracy with multi-detector CT for the T and N stages. Stagewise accuracy is depicted in Table 4 [13–16, 29]. Although our accuracy across N stages is comparable, the accuracy for the T stage is lower. The likely reasons for that are a predominance of T1/T2 lesions and the lack of dedicated gastric distention performed in our retrospective dataset.

The improved staging accuracy through expert radiological review directly impacts treatment sequencing decisions. Based on our findings, we propose that patients with equivocal T3/T4 or N + disease on initial review should undergo a second expert radiological opinion before finalising treatment plans. This approach could help identify patients who would truly benefit from neoadjuvant chemotherapy while preventing overtreatment in those with early-stage disease. While understaging deprives patients of the potential benefits of neoadjuvant therapy, overstaging carries its own set of clinical consequences. In our cohort, two patients radiologically classified as T4 were pathologically confirmed as T2 disease. On imaging, the lesion appeared to extend beyond the gastric wall and invade the serosa, leading to a radiological staging of T4a (Fig. 5). However, on pathology, it was identified as T2, indicating that the entire extramural portion of the lesion remained sub-serosal. This discrepancy may be attributed to variations in the thickness of sub-serosal fat among individuals [30]. Considering that the pathological complete response rate after neoadjuvant therapy is only 10% in gastric cancer [9], the majority of overstaged patients would eventually require surgery, albeit after enduring possible chemotherapy toxicities and potential decline in performance status. Additionally, approximately 15–20% of patients might develop disease progression during neoadjuvant treatment, which could potentially render initially resectable disease unresectable in falsely overstaged patients. This underscores the importance of accurate staging to avoid both undertreatment and overtreatment.

In a recent report, the 'radiological serosal invasion sign' was defined, in which the lesion was considered T4a if it extends beyond the perigastric vessels [31]. Although we found this concept useful, it was difficult to apply it in these two cases. It is important to consider this as it could result in an incorrect higher staging of the patient.

Recently, advances such as radiomics-based machine learning and deep learning models have been explored for assessing the T stage of gastric carcinoma. A study from 2020 reported an area under the curve (AUC) of 0.899 for a radiomics-based machine learning model that differentiates T2 from T3 and T4 stages, [32] while a 91.4 to 94.6% accuracy was reported by a ResNet-based AI classifier that distinguished T1 from T2 [33]. In addition to T staging, radiomics and deep learning models have also shown potential in differentiating adenocarcinoma from other neoplasms, such as lymphoma and neuroendocrine tumours, as well as in predicting serosal invasion and lymph node metastasis [34–37]. However, these models have yet to be integrated into routine clinical practice, and there are likely data biases between the training data and real-world data, which can lead to incorrect predictions. Development of region-specific AI algorithms can assist in initial screening and identify cases requiring

Table 4 Studies comparing tomographic and histopathologic results and reported staging accuracy with multi-detector CT for the T and N stages

		n	T1	T2	T3	T4	N0	N1	N2
1	Chen et al. (2007) [13]	55	89%	85%	84%	96%	84%	75%	85%
2	Yan et al. (2009) [14]	790	45.9%	53.03%	86.5%	85.8%	76.17%	68.8%	80.6%
3	Makino et al. (2011) [29]	616	95%	76%	76%	92%:T4a 75%:T4b	–	–	–
4	Barros et al. (2015) [15]	54	88–92%	74–82%	80–82%	86–96%	79%	55–73%	76–82%
5	Lopez-Ramirez (2017) [16]	67	94%	93%	67%	67%	72%	73%	70%
6	Our study (2024)	138	70.5%		56.8%	78.4%	74.5%	78.4%	80.4%

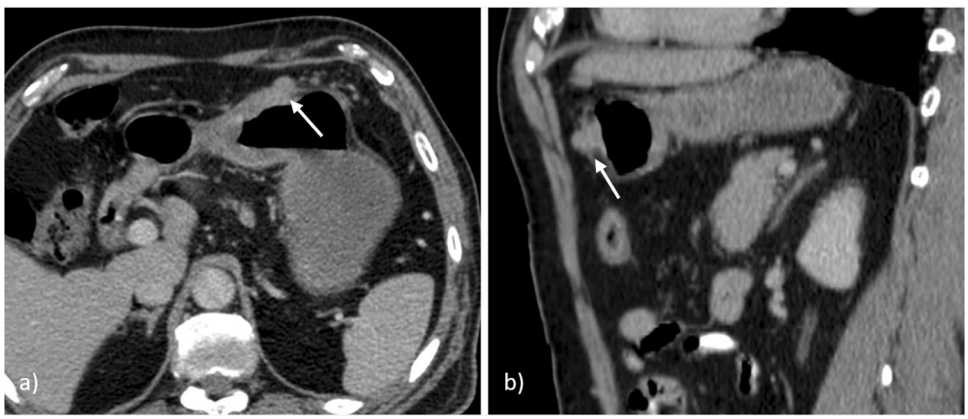

Fig. 5 CT abdomen shows focal wall thickening that appears to extend beyond the serosa into the adjacent fat. The lesion was called T4a on radiology but was T3 on pathology, with the lesion in the sub-serosal fat. Note the lesion shows a radiologic serosal invasion sign positive [31]

expert review, with a hub-and-spoke model for expertise sharing via digital platforms.

In resource-constrained low- and middle-income countries, cost-effective interventions become essential. These include focused training modules and workshops designed for early gastric cancer diagnosis and staging. The implementation of structured reporting templates and multidisciplinary team discussions can improve consistency and staging accuracy.

The study is limited by its retrospective design and its potential selection bias. Our cohort represents patients who were clinically deemed appropriate for upfront surgery based on MDCT findings, and may have led to the selection of patients with smaller disease and less obvious radiological signs of advanced disease. The exclusion of emergency resections may have eliminated cases with more advanced disease, potentially skewing our cohort towards less aggressive tumours. The blinded review was limited to 51 patients, and a single-centre experience may not represent the typical patient population. Our results, although may not be generalisable, need to be evaluated in a larger, preferably multicentre cohort for further validation. We recognise the limited use of EUS and our reliance on cross-sectional imaging to guide upfront surgery. Nevertheless, this approach overcomes the logistical challenges associated with EUS and reflects the practical reality in resource-constrained settings and low-income economies.

As a comprehensive cancer centre, most treatment decisions were guided by discussions in a multi-disciplinary tumour board. Although fewer than half of our cases underwent a blinded radiology review, this was performed by gastrointestinal oncoradiologists with extensive experience. Our study is one of the first to demonstrate the incremental accuracy of review by radiology alone as a targeted intervention, leading to improved correlation with histopathological findings beyond the standard multidisciplinary clinic assessment.

Conclusions

Although MDCT is a valuable initial staging tool for gastric cancer, we found weak agreement between the clinical and the pathological stages in upfront resected gastric cancers. MDCT is more accurate in detecting advanced tumour stages (T4 and N2), but its performance is less reliable for early stages (T1/T2 and N0). By implementing an expert radiology review and standardising scanning and reporting protocols, we can significantly improve the accuracy and correlation of MDCT with pathology, even for T1/T2 disease. This may help in better selecting patients for upfront surgery versus perioperative chemotherapy, especially in resource-constrained settings.

Author Contribution SP conceptualized the work that led to the submission, project administration, reviewing and editing the manuscript, and approval of the final version. KG and ASR acquired and curated data, and investigation, played an important role in formal analysis, wrote the original draft and edited the manuscript. RC played a role in data curation and in formal analysis. AB/PH reviewed and edited the manuscript, provided radiology review with representative images, and approved the final version. MK played an important role in formal analysis. AB/PH/MB/VC/SVS reviewed and edited the manuscript and approved the final version. All co-authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Ethics Approval and Consent to Participate The data of the present study were collected in the course of common clinical practice, and accordingly, the signed informed consent was obtained from each patient for any surgical and clinical procedure. The study protocol was in accordance with the ethical standards of the institutional research committee and the 1964 Helsinki Declaration and its later amendments.

Consent for Publication Data was collected retrospectively, and all reasonable measures were taken to protect patient anonymity.

Competing Interests The authors declare no competing interests.

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References

1. Deo SV, Sharma J, Kumar S. GLOBOCAN 2020 report on global cancer burden: challenges and opportunities for surgical oncologists. Ann Surg Oncol. 2022;29(11):6497–500.
2. Morgan E, Arnold M, Camargo MC, Gini A, Kunzmann AT, Matsuda T, Meheus F, Verhoeven RH, Vignat J, Laversanne M, Ferlay J. The current and future incidence and mortality of gastric cancer in 185 countries, 2020–40: a population-based modelling study. EClinicalMedicine. 2022;1:47.
3. Hamashima C. Cancer screening guidelines and policy making: 15 years of experience in cancer screening guideline development in Japan. Jpn J Clin Oncol. 2018;48(3):278–86.

4. Hamashima C, Systematic Review Group and Guideline Development Group for Gastric Cancer Screening Guidelines. Update version of the Japanese guidelines for gastric cancer screening. Japanese journal of clinical oncology. 2018;48(7):673–83.
5. Yao K, Uedo N, Kamada T, Hirasawa T, Nagahama T, Yoshinaga S, Oka M, Inoue K, Mabe K, Yao T, Yoshida M. Guidelines for endoscopic diagnosis of early gastric cancer. Dig Endosc. 2020;32(5):663–98.
6. Servarayan Murugesan C, Manickavasagam K, Chandramohan A, Jebaraj A, Jameel AR, Jain MS, Venkataraman J. Gastric cancer in India: epidemiology and standard of treatment. Updat Surg. 2018;70:233–9.
7. Ju MR, Karalis JD, Blackwell JM, Mansour JC, Polanco PM, Augustine M, Yopp AC, Zeh HJ, Wang SC, Porembka MR. Inaccurate clinical stage is common for gastric adenocarcinoma and is associated with undertreatment and worse outcomes. Ann Surg Oncol. 2021;28:2831–43.
8. Shen L, Shan YS, Hu HM, Price TJ, Sirohi B, Yeh KH, Yang YH, Sano T, Yang HK, Zhang X, Park SR. Management of gastric cancer in Asia: resource-stratified guidelines. Lancet Oncol. 2013;14(12):e535–47.
9. Bhandare MS, Gundavda KK, Yelamanchi R, Chopde A, Batra S, Kolhe M, et al. Impact of pCR after neoadjuvant chemotherapy and radical D2 dissection in locally advanced gastric cancers: analysis of 1001 cases. Euro J Surg Oncol. 2024;108343.
10. Al-Batran SE, Hofheinz RD, Pauligk C, Kopp HG, Haag GM, Luley KB, et al. Histopathological regression after neoadjuvant docetaxel, oxaliplatin, fluorouracil, and leucovorin versus epirubicin, cisplatin, and fluorouracil or capecitabine in patients with resectable gastric or gastro-oesophageal junction adenocarcinoma (FLOT4-AIO): results from the phase 2 part of a multicentre, open-label, randomised phase 2/3 trial. Lancet Oncol. 2016;17(12):1697–708.
11. Cunningham D, Allum WH, Stenning SP, Thompson JN, Van de Velde CJH, Nicolson M, et al. Perioperative chemotherapy versus surgery alone for resectable gastroesophageal cancer. N Engl J Med. 2006;355(1):11–20.
12. Ychou M, Boige V, Pignon JP, Conroy T, Bouché O, Lebreton G, et al. Perioperative chemotherapy compared with surgery alone for resectable gastroesophageal adenocarcinoma: an FNCLCC and FFCD multicenter phase III trial. J Clin Oncol. 2011;29(13):1715–21.
13. Chen CY, Hsu JS, Wu DC, Kang WY, Hsieh JS, Jaw TS, et al. Gastric cancer: preoperative local staging with 3D multi–detector row CT—correlation with surgical and histopathologic results. Radiology. 2007;242(2):472–82.
14. Yan C, Zhu Z, Yan M, Zhang H, Pan Z, Chen J, et al. Value of multidetector-row computed tomography in the preoperative T and N staging of gastric carcinoma: a large-scale Chinese study. J Surg Oncol. 2009;100(3):205–14.
15. Barros RH, Penachim TJ, Martins DL, Andreollo NA, Caserta NM. Multidetector computed tomography in the preoperative staging of gastric adenocarcinoma. Radiol Bras. 2015;48(2):74–80.
16. Lopez-Ramirez MA, Lever-Rosas CD, Motta-Ramirez GA, Rebollo-Hurtado V, Guzman-Barcenas J, Fonseca-Morales JV, et al. Correlation between preoperative tomographic staging and definitive histopathologic results in gastric cancer at the Hospital Central Militar. Revista de Gastroenterología de México (English Edition). 2017;82(3):210–6.
17. Shrikhande SV, Sirohi B, Barreto SG, Chacko RT, Parikh PM, Pautu J, et al. Indian Council of Medical Research consensus document for the management of gastric cancer. Indian Journal of Medical and Paediatric Oncology. 2014;35(04):239–43.
18. Bhandare MS, Chaudhari V, Shrikhande S V. Surgery for gastric cancer: State of the art. Indian Journal of Surgery. 2020;1–11.
19. Bhandare MS, Kumar N, Batra S, Chaudhari V, Shrikhande SV. Radical gastrectomy for gastric cancer at Tata Memorial Hospital. Indian J Cancer. 2017;54(4):605–8.
20. Sugoor P, Shah S, Dusane R, Desouza A, Goel M, Shrikhande SV. Proximal gastrectomy versus total gastrectomy for proximal third gastric cancer: total gastrectomy is not always necessary. Langenbecks Arch Surg. 2016;401:687–97.
21. Shrikhande SV, Barreto SG, Talole SD, Vinchurkar K, Annaiah S, Suradkar K, et al. D2 lymphadenectomy is not only safe but necessary in the era of neoadjuvant chemotherapy. World J Surg Oncol. 2013;11:1–10.
22. Ajani JA, D'Amico TA, Bentrem DJ, Chao J, Cooke D, Corvera C, et al. Gastric cancer, version 2.2022, NCCN clinical practice guidelines in oncology. J Nati Comprehensive Cancer Network. 2022;20(2):167–92.
23. Lee IJ, Lee JM, Kim SH, Chang S, Han JK, Choi BI, et al. Helical CT evaluation of the preoperative staging of gastric cancer in the remnant stomach. Am J Roentgenol. 2009;192(4):902–8.
24. Schober P, Boer C, Schwarte LA. Correlation coefficients: appropriate use and interpretation. Anesth Analg. 2018;126(5):1763–8.
25. Lee KG, Shin CI, Kim SG, Choi J, Oh SY, Son YG, et al. Can endoscopic ultrasonography (EUS) improve the accuracy of clinical T staging by computed tomography (CT) for gastric cancer? Eur J Surg Oncol. 2021;47(8):1969–75.
26. Spolverato G, Ejaz A, Kim Y, Squires MH, Poultsides GA, Fields RC, et al. Use of endoscopic ultrasound in the preoperative staging of gastric cancer: a multi-institutional study of the US gastric cancer collaborative. J Am Coll Surg. 2015;220(1):48–56.
27. Singh HK, Chaudhari V, Batra S, Ostwal V, Ramaswamy A, Mokal S, et al. Radical D2 gastrectomy with adjuvant chemotherapy for stage IB/II/III distal gastric cancers in the era of perioperative chemotherapy: a propensity matched comparison. The American Journal of Surgery. 2022;223(6):1055–62.
28. Kaltenmeier C, Althans A, Mascara M, Nassour I, Khan S, Hoehn R, Zureikat A, Tohme S. Pathologic complete response following neoadjuvant therapy for gastric adenocarcinoma: a national cancer database analysis on incidence, predictors, and outcomes. Am Surg. 2021;87(7):1145–54.
29. Makino T, Fujiwara Y, Takiguchi S, Tsuboyama T, Kim T, Nushijima Y, et al. Preoperative T staging of gastric cancer by multidetector row computed tomography. Surgery. 2011;149(5):672–9.
30. Lee MH, Choi D, Park MJ, Lee MW. Gastric cancer: imaging and staging with MDCT based on the 7th AJCC guidelines. Abdom Imaging. 2012;37:531–40.
31. You MW, Park S, Kang HJ, Lee DH. Radiologic serosal invasion sign as a new criterion of T4a gastric cancer on computed tomography: diagnostic performance and prognostic significance in patients with advanced gastric cancer. Abdominal Radiology. 2020;45(10):2950–9.
32. Wang Y, Liu W, Yu Y, Liu JJ, Jiang L, Xue HD, et al. Prediction of the depth of tumor invasion in gastric cancer: potential role of CT radiomics. Acad Radiol. 2020;27(8):1077–84.
33. Zeng Q, Feng Z, Zhu Y, Zhang Y, Shu X, Wu A, et al. Deep learning model for diagnosing early gastric cancer using preoperative computed tomography images. Front Oncol. 2022;30:12.
34. Feng B, Huang L, Liu Y, Chen Y, Zhou H, Yu T, et al. A transfer learning radiomics nomogram for preoperative prediction of Borrmann type IV gastric cancer from primary gastric lymphoma. Front Oncol. 2022;11:11.
35. Dong D, Fang MJ, Tang L, Shan XH, Gao JB, Giganti F, et al. Deep learning radiomic nomogram can predict the number of

lymph node metastasis in locally advanced gastric cancer: an international multicenter study. Ann Oncol. 2020;31(7):912–20.
36. Gao X, Ma T, Cui J, Zhang Y, Wang L, Li H, et al. A radiomics-based model for prediction of lymph node metastasis in gastric cancer. Eur J Radiol. 2020;129:109069.
37. Wang L, Zhang Y, Chen Y, Tan J, Wang L, Zhang J, et al. The performance of a dual-energy CT derived radiomics model in differentiating serosal invasion for advanced gastric cancer patients after neoadjuvant chemotherapy: iodine map combined with 120-kV equivalent mixed images. Front Oncol. 2021;11:10.

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