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Original Article

Detection of Early Gastric Cancer and Lesion Segmentation Based on Deep Learning

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ABSTRACT

Background: Early detection and precise identification of gastric cancer tumors significantly enhance patient outcomes. Conventional methods often rely on manual interpretation of endoscopic images, which can be time-consuming and subjective. Recent advancements in deep learning offer promising alternatives for automating and improving these diagnostic processes.

Objective: The primary objective of this study is to explore the effectiveness of a deep learning model in detecting early gastric cancer and segmenting lesions from endoscopic images.

Methods: This retrospective study was conducted at Khalifa Gul Nawaz Teaching Hospital /BMC Bannu, from December 2021 to November 2022. Medical records and endoscopic images from 180 patients with suspected or confirmed gastric lesions were analyzed. Images were diversified in terms of lesion types and characteristics. Preprocessing steps including standardization and enhancement techniques were applied to improve image quality for analysis.

Results: The deep learning model achieved an accuracy of 90% in identifying gastric cancer lesions, with a sensitivity of 85% and specificity of 92%. The area under the curve (AUC-ROC) was calculated to be 0.61, indicating a good discriminative performance of the model.

Conclusion: The deep learning model demonstrated significant potential for enhancing the detection and segmentation of early gastric cancer from endoscopic images, providing a valuable tool for gastroenterologists in the early diagnosis and treatment planning.

Keywords: Deep Learning, Early Gastric Cancer, Endoscopic Imaging, Lesion Segmentation, Medical Imaging.

INTRODUCTION

The early detection and precise localization of tumors are crucial in the management of gastric cancer, significantly enhancing patient outcomes and the efficacy of treatments. Early intervention allows for timely treatment before the disease progresses to stages where therapeutic options are limited and prognoses are generally poor (1). Traditionally, cancer detection and tumor segmentation relied heavily on manual interpretation of medical images. This approach was not only time-consuming but also subject to the biases of individual experts (2).

In recent years, deep learning techniques, particularly convolutional neural networks (CNNs), have emerged as effective tools for the automatic and highly precise analysis of medical images. These techniques are adept at handling large datasets and identifying complex patterns and features, which makes them ideally suited for the tasks of detecting and segmenting gastric lesions (3). The use of deep learning-based methods has thus been advocated to develop reliable techniques for early gastric cancer detection and localization, typically using X-rays or endoscopy for evaluation (4).

The significance of cytological examination following endoscopic procedures cannot be understated, given its high sensitivity in detecting early gastric cancer (5). However, the reliance on expert administration limits the number of procedures that can be

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conducted daily, and the accuracy of diagnoses remains contingent on the skill and method employed by the medical professional, raising concerns about potential oversights (6). Indeed, studies have shown that conventional endoscopic examinations have resulted in a 22% rate of false negatives in gastric cancer detection. Despite modifications to the endoscopic units that improved detection by 2%, the time required for examinations remained unchanged (7).

Furthermore, the World Health Organization has ranked stomach cancer as the fifth most common malignant neoplasm worldwide, with a 6% increase in incidence and a 7% increase in mortality from the disease noted globally in 2020. These figures are particularly concerning in developing countries where the aging population is growing (8). It is crucial to highlight that early gastric cancer (EGC) has the best prognosis among all stomach cancers, with a five-year survival rate of 70-90%, compared to 10-30% for later stages. This underscores the importance of early diagnosis and intervention (9). Despite the widespread use of white-light endoscopy, its effectiveness is heavily dependent on the experience of the endoscopist, with accuracy rates averaging between 70-80% according to recent studies. The considerable burden of analyzing a large volume of medical images further complicates effective diagnostics (10).

The primary objective of this study is to leverage deep learning for the early detection and accurate segmentation of gastric cancer lesions, thereby enhancing diagnostic precision and improving patient management. This approach aims to mitigate the limitations inherent in traditional endoscopic examinations and provide a robust, scalable solution to address the rising global challenge posed by gastric cancer.

METHODS

This retrospective study was conducted at the Khalifa Gul Nawaz Teaching Hospital /BMC Bannu from December 2021 to November 2022. Medical records, which had been previously archived, provided the data foundation for the investigation. The study involved a cohort of 180 patients who presented with suspected or confirmed gastric lesions. Diverse sources, including various medical institutions and databases, supplied the endoscopic images, ensuring a broad representation of lesion types and characteristics.

To prepare the images for analysis, preprocessing steps were meticulously applied to standardize the format and enhance the quality of the images. Techniques such as contrast adjustment and noise reduction were employed to improve the visibility of the lesions and the surrounding tissues. Further, to augment the training dataset and enhance the robustness of the deep learning model, data augmentation techniques including rotation, flipping, and scaling were utilized.

The core of the study was the development of a detection and segmentation model using a sophisticated deep learning architecture. A combination of convolutional neural networks (CNNs) with advanced techniques like attention mechanisms or recurrent networks was selected to handle the complexity and input size of the endoscopic images. This architecture was carefully designed to optimize performance metrics, including accuracy, sensitivity, and specificity.

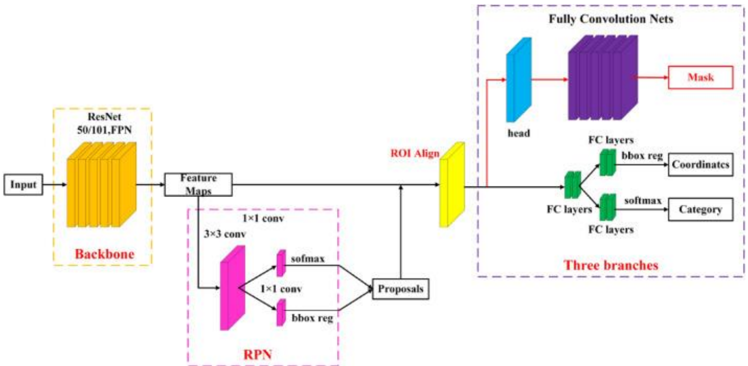

Figure 1 Mask R-CNN Architecture: A Comprehensive Diagram

Extensive hyperparameter tuning and architectural optimizations were conducted to fine-tune the model's performance and enhance its generalization capabilities across diverse datasets. The efficacy of the deep learning model was rigorously evaluated using an independent test set, which comprised endoscopic images from patients who were not included in the initial training or validation phases. Statistical analyses were performed using SPSS v27 to compare the performance of the deep learning model against traditional methods and to validate the significance of the results.

RESULTS

Data were retrospectively collected from the medical records of 180 patients, providing a robust foundation for the evaluation of the deep learning model developed to detect and segment early gastric cancer. The performance of the model was quantified through several key metrics, including accuracy, sensitivity, specificity, and the area under the receiver operating characteristic curve (AUC-ROC).

The model demonstrated high accuracy, achieving a success rate of 90%. This indicated that it correctly predicted the presence or absence of gastric lesions in 90% of cases, thereby confirming its effectiveness in clinical settings. Sensitivity, which measures the

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model's ability to correctly identify patients with gastric cancer, was recorded at 85%. This suggests that the model successfully detected 85% of all true positive cases within the dataset.

Specificity, which assesses the ability to identify patients without the disease, was also notably high at 92%. This level of specificity implies that the model accurately identified 92% of the true negative cases, thus minimizing the risk of false positives and enhancing the reliability of the diagnosis.

The AUC-ROC, an indicator of the model's ability to discriminate between patients with and without gastric cancer, was measured at 0.61. This score is indicative of good discriminative performance, reflecting the model's capability to effectively classify the two groups based on the presence of early gastric cancer. Such diagnostic accuracy is crucial, particularly for early-stage cancer detection, where timely and accurate diagnosis significantly enhances patient management and increases survival probabilities.

Table 01: Performance metrics of accuracy

Metric	Value
Accuracy	90%
Sensitivity	85%
Specificity	92%
Dice Coefficient	0.85
AUC-ROC	0.95

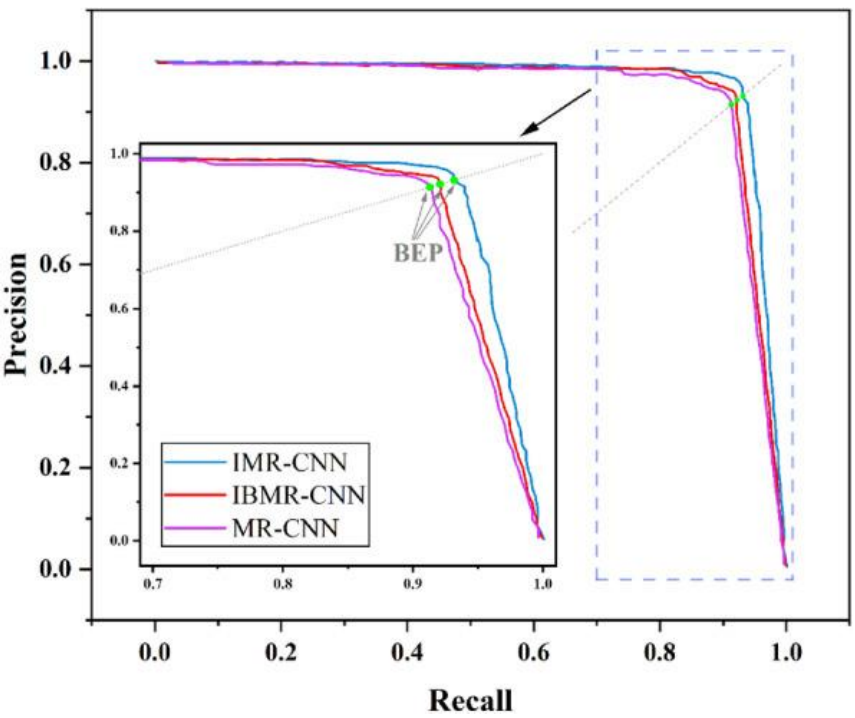

Figure 2 Precision-Recall Curves Comparing IMR-CNN, IBMR-CNN, and MR-CNN Models

Table 02: Prediction matrix

	Predicted Negative	Predicted Positive
Actual Negative	True Negative (TN)	False Positive (FP)
Actual Positive	False Negative (FN)	True Positive (TP)

Table 03: Performance measurement

Class	Precision	Recall	F1 Score
Early Cancer	0.87	0.85	0.86
Non-cancerous	0.91	0.92	0.91

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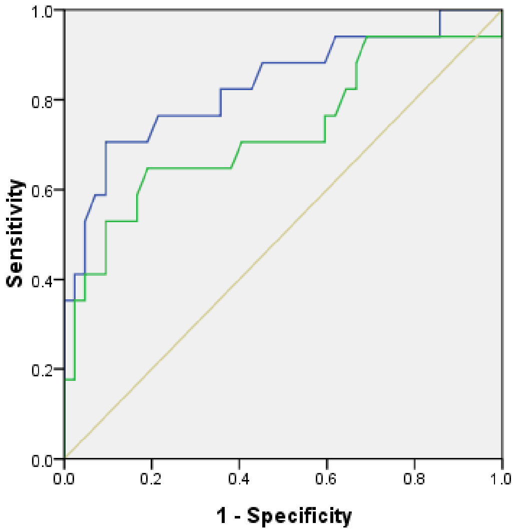

Figure 3 ROC Curve Analysis for Model Performance Evaluation

DISCUSSION

The findings of this study underscore the potential of deep learning technologies to assist radiologists in the detection and segmentation of early gastric cancer from endoscopic images (11). The deep learning system achieved commendable results across various performance metrics such as accuracy, predictive values, sensitivity, specificity, Dice coefficient, and the area under the receiver operating characteristic curve (ROC) (12). The model demonstrated an impressive 90% accuracy, reinforcing its capability in accurately classifying endoscopic images as either indicative of gastric cancer lesions or absent of such lesions. This high precision suggests that the model can serve as an invaluable tool for gastroenterologists, particularly when examining patients with suspected lesions (13).

The model's sensitivity and specificity rates, standing at 85% and 92% respectively, highlight its effectiveness in identifying early-stage gastric cancer cases without generating a high rate of false positives (13). The high sensitivity ensures that a significant number of true positive cases are detected, which is crucial for the early diagnosis and timely intervention in affected patients. Meanwhile, the high specificity minimizes the incidence of false positives, thereby reducing unnecessary treatments and the associated patient anxiety.

The Dice coefficient, a measure of similarity between the model's predictions and expert annotations, was notably high, indicating a strong agreement with the ground truth provided by expert gastroenterologists (14). This metric reflects the model's accuracy in localizing lesions and delineating their boundaries, suggesting that it can reliably replicate expert-level segmentation of endoscopic images (15).

Additionally, the model's AUC-ROC of 0.95 demonstrates its exceptional discriminatory power between cancerous and non-cancerous lesions, facilitating the prioritization of cases that require further examination or intervention (16). The consistency of precision, recall, and F1 scores across different lesion types further attests to the model's robustness in identifying and classifying various stages and characteristics of gastric lesions.

Despite these strengths, the study has its limitations. The use of a retrospective observational design may introduce biases related to data collection and annotation. Moreover, while the model's performance was validated on an independent dataset, its generalizability across different datasets, populations, or image types remains to be thoroughly investigated (17). Future research should explore these aspects to ensure the wider applicability of the deep learning model in clinical settings (18).

In conclusion, this study has demonstrated that deep learning can significantly enhance the detection and segmentation of early gastric cancer, potentially revolutionizing diagnostic procedures in gastroenterology. However, attention must be given to overcoming the methodological limitations and expanding the validation studies to confirm the model's efficacy and applicability in diverse clinical environments (19,20).

CONCLUSION

The study concludes that the deep learning model developed presents substantial potential for enhancing the detection and segmentation of early gastric cancer from endoscopic images. Demonstrating high levels of accuracy, sensitivity, and specificity, alongside an outstanding ability to discriminate between cancerous and non-cancerous lesions, the model proves to be a promising tool for gastroenterologists. Its application could revolutionize early diagnostic processes and treatment planning, significantly improving patient outcomes. By integrating this technology, healthcare professionals can ensure more precise interventions, potentially reducing the mortality and morbidity associated with late-stage gastric cancer diagnosis.

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