Gastric morphological type: A supplementary addition for the evaluation of gastric cancer

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Abstract. Clinical and pathological features are important factors that affect the prognosis and treatment strategies of patients with gastric cancer (GC). An upper gastrointestinal barium X-ray examination is commonly used to show gastric mucosa and morphological changes. The aim of the present study was to evaluate the association between gastric morphological type and the clinicopathological features of patients with GC, based on double-contrast barium X-ray imaging. A total of 329 patients with GC who underwent upper gastrointestinal barium X-ray examination were analyzed. The gastric morphological type was divided into four types on barium X-ray images: Horn-type, hook-type, weak-type and waterfall-type stomach. The χ^2 test or Fisher's exact test was used to assess the association between gastric morphological type and the clinicopathological features. There was a statistically significant difference in the location of GC between different types of gastric morphology. Hook-type and horn-type GC were commonly present in the lower region of the stomach, while waterfall-type GC was mainly located in the upper region of the stomach. The incidence of waterfall-type non-poorly differentiated GC was higher than that of other gastric types. The incidence of waterfall-type intestinal-type GC was higher than that of other gastric types, and horn-type GC was more common in mixed-type GC. There was a statistically significant difference in the T-staging of GC between different types of gastric morphology. In conclusion, gastric morphological type correlates with the location and T-stage distribution of GC.

Introduction

As a major cause of cancer-related death in the world, gastric cancer (GC) remains the third most frequent cause of cancer-related death worldwide, resulting in 782,685 deaths annually, with a 5-year survival rate of only 20-30% after curative resection (1). Radical surgical resection is the preferred treatment for GC, supplemented by combined perioperative radiotherapy, chemotherapy and biotherapy. It is worth mentioning that numerous factors affect the prognosis and treatment strategies of patients with GC (1,2), such as Lauren classification, degree of differentiation and TNM staging, and the clinical and pathological features of GC are an important consideration. Accurate preoperative evaluation of the clinical and pathological features of GC is conducive to treatment plan formulation and prognosis evaluation (2). At present, as a common screening method for clinically suspicious gastric space-occupying lesions, upper gastrointestinal barium X-ray examination is especially suitable for patients who have suspicious gastric mucosa and morphological changes (3). There have been few clinical studies based on upper gastrointestinal barium X-ray examination, and to the best of our knowledge, the associations between the gastric morphological types and clinicopathological features of GC have not been reported in the literature. Given this, the present study analyzed the association between gastric morphological type, and the clinical and pathological features of GC in order to provide a clinical reference.

Patients and methods

Patients and study design. The study was approved by the Institutional Review Board of The First Hospital of Zhengzhou University (Zhengzhou, China; approval no. 2021-KY-1070-002). The requirement for written informed consent was waived by the Institutional Review Board due to the retrospective nature of the study. A total of 329 patients with GC who had undergone radical surgical resection in the First Affiliated Hospital of Zhengzhou University between January 2020 and April 2021 were retrospectively selected following application of inclusion and exclusion criteria. There were 245 males and 84 females, with a male-to-female ratio of ~3:1. The mean age (±SD) was 65±14 years (age range, 28-86 years). The medical history of all patients in this study included the following: Hypertension (n=42), diabetes (n=16), cholecystectomy for cholecystolithiasis (n=6), hepatitis B (n=3), chronic gastritis (n=8), herpes zoster (n=1), polypectomy of the colon (n=1), lymphoma of the bile duct (n=1), rheumatoid arthritis (n=1), hysteromyoma surgery (n=6), coronary heart disease (n=7),

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appendicectomy for appendicitis (n=2), parotid adenoma surgery (n=1), thyroid cancer resection (n=1), pneumoconiosis (n=1), ovarian tumor removal (n=1), pulmonary tuberculosis (n=1), pulmonary heart disease (n=1), prostate surgery (n=1), rectal cancer resection (n=1) and lipoma resection (n=1). The ICD-10 classification codes of the cancer types included in this study were C15-C26 (4).

The inclusion criteria were as follows: i) Newly diagnosed patients without any preoperative antitumor therapy; ii) upper gastrointestinal barium X-ray examination acquired within 2 weeks of surgery; iii) patients were highly cooperative in order to complete the examination; and iv) gastric adenocarcinoma confirmed by surgery and pathology data. The exclusion criteria were as follows: i) Poor respiratory control and poor image quality observed in the images; and ii) patients who had gastric surgery history, torsion or dysplasia. The flow chart for the study population recruitment is shown in Fig. 1.

Upper gastrointestinal barium X-ray examination. The upper gastrointestinal barium X-ray examination was performed using the Shimadzu digital gastrointestinal machine (Social Vision SafireII; Shimadzu Corporation). The 'automatic' option was selected for gastrointestinal fluoroscopy. Before the examination, the patients fasted for 10-12 h, and oral doses of barium were administered at 150-250 ml immediately before examination. The mucosa, filling and pressure phases were observed. The shape, outline, position, size, peristalsis and pylorus opening of the stomach were observed in different body positions and filling states, and X-ray films were taken. According to the different morphological features, the gastric morphology was divided into four types (Fig. 2): The horn-type, hook-type, weak-type and waterfall-type stomach. The horn-shaped stomach has a high position and tension, is horizontal, wide in the upper part and narrow in the lower part, and the stomach angle is not obvious. This type of gastric morphology is commonly seen in obese people. The hook-shaped stomach has a moderate position and tension, an obvious gastric angle and the lower gastric pole is roughly at the level of the iliac crest. The weak-type stomach has a low position and tension. The upper stomach cavity is narrow and wide like a water bag, while the lower part of the stomach is often below the level of the iliac crest. This type of gastric morphology is commonly seen in slender people. In the waterfall-type stomach, the fundus of the stomach is in the shape of a sac, the stomach is large, the body of the stomach is small and the tension is high. The gastric morphological type was analyzed by two senior physicians, with 4 and 10 years of experience in abdominal radiology, respectively, who were blinded to the clinical information and pathological results.

Statistical analysis. Statistical analyses were performed using SPSS software version 23.0 (IBM Corp.). The categorical variables are presented as frequencies and percentages. The χ^2 test or Fisher's exact test were used to assess categorical variables (gastric types of GC and age, sex, site, differentiation degree, Lauren classification and T staging). Two-sided $P<0.05$ was considered to indicate a statistically significant difference.

Results

In this study of 329 patients with GC, 160 cases (48.63%) were of the hook-type stomach, 12 cases (3.65%) were of the horn-type stomach, 91 cases (27.66%) were of the weak-type stomach and 66 cases (20.06%) were of the waterfall-type stomach. Among the 245 male patients, there were 10 cases of the horn-type stomach, 123 cases of the hook-type stomach, 45 cases of the weak-type stomach and 67 cases of the waterfall-type stomach. Among the 84 female cases, there were 2 cases of the horn-type stomach, 37 cases of the hook-type stomach, 21 cases of the weak-type stomach and 24 cases of the waterfall-type stomach. The classification and distribution in patients with GC of different sexes were similar, and the most common type was the hook-type stomach, followed by the waterfall-type stomach. A total of 134 cases (40.73%) of GC were located in the upper stomach, 74 cases (22.49%) in the middle stomach and 121 cases (36.78%) in the lower stomach, with the hook-type and horn-type GC being more common in the lower stomach, and the waterfall-type GC being mainly located in the upper stomach. There were 156 cases of poorly differentiated GC (47.42%) and 173 cases of non-poorly differentiated GC (52.58%), among which the incidence of non-poorly differentiated GC in the waterfall-type stomach was higher than that in other gastric types and the incidence of poorly differentiated GC in the horn-type stomach was more common. There were 73 cases of diffuse-type GC (22.19%), 131 cases of intestinal-type GC (39.82%), and 125 cases of mixed-type GC (37.99%), among which the incidence of intestinal-type GC in the waterfall-type stomach was higher than that in the other gastric types and the incidence of mixed-type GC in the horn-type stomach was more common. There were 76 cases of T1 + T2 GC (23.10%), 163 cases of T3 GC (49.54%) and 90 cases of T4 GC (27.36%). There was a statistically significant difference in the T-staging of GC between different gastric morphological types. The incidence of T1 + T2 GC in the hook-type stomach was higher than that in other gastric morphological types and T3 GC was present at the highest proportion among the four gastric morphological types. Overall, there were statistically significant differences in the site and T stage of GC classified by different gastric morphological types (Figs. 3 and 4), as shown in Table I.

Discussion

Compared with electronic gastroscopy, ultrasound endoscopy and CT gastric reconstruction, upper gastrointestinal barium X-ray examination in clinical application is less commonly used. However, upper gastrointestinal barium X-ray examination is still a necessary examination before the surgery for gastric space-occupying lesions, as it can provide images of gastric motility that other examination techniques cannot show, in addition to the morphological changes; it is a simple, easy, non-invasive and less painful technique, and the interpretation and judgment of the results is intuitive (5). Upper gastrointestinal barium X-ray examination can show the location, shape, depth and size of GC, as well as the relationship between adjacent organs and tissues (5). At the same time, the peristalsis and softness of the gastric wall at the site of the

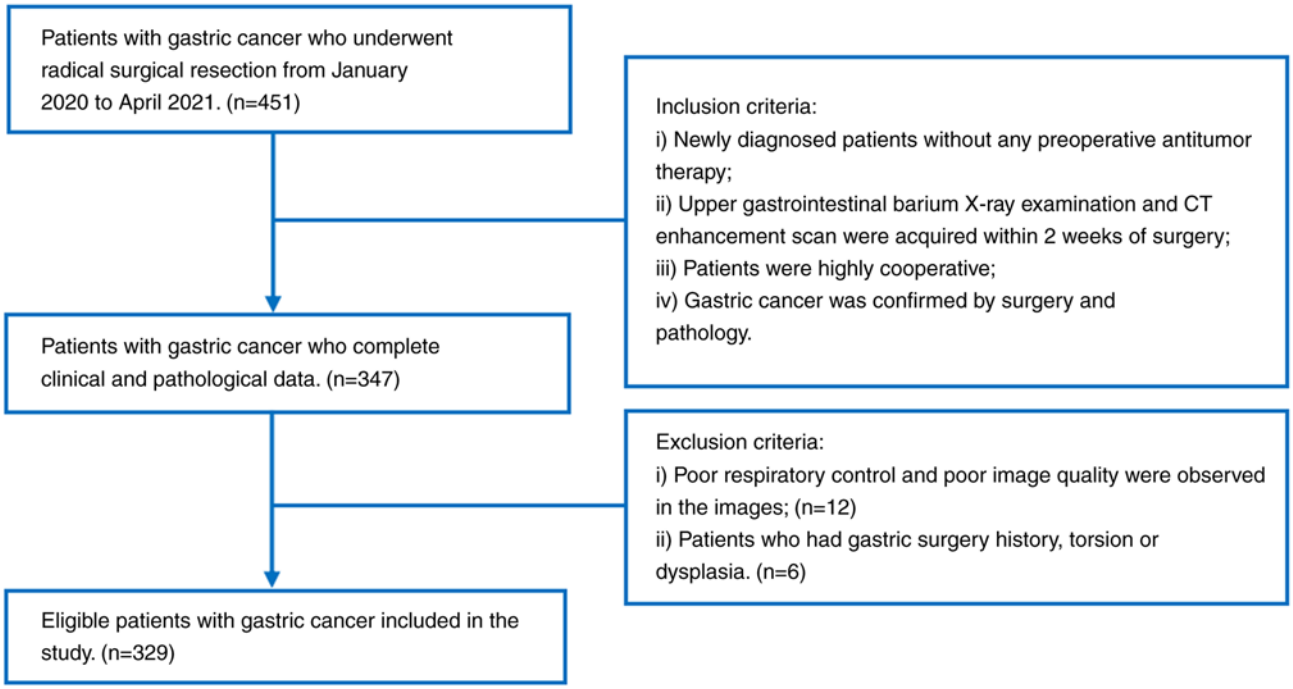

Figure 1. Flow chart of the study population recruitment.

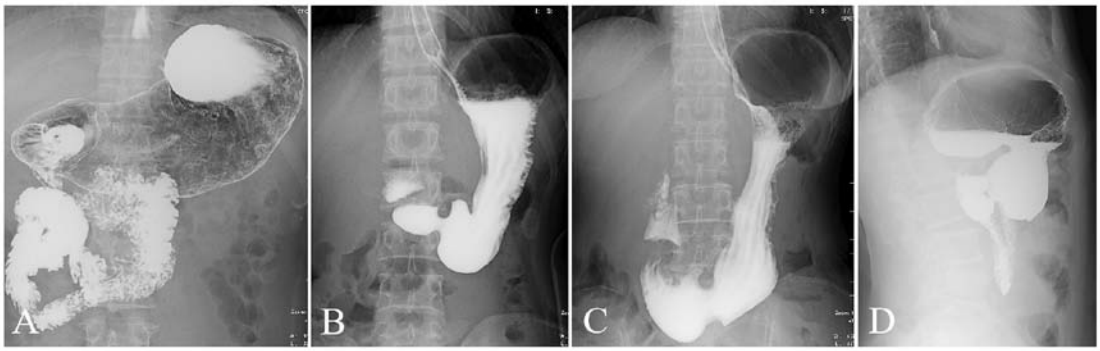

Figure 2. Different types of gastric morphological type based on upper gastrointestinal barium X-ray examination. According to upper gastrointestinal barium X-ray examination, the gastric morphology was divided into four types: (A) Horn-type stomach, (B) hook-type stomach, (C) weak-type stomach and (D) waterfall-type stomach.

lesion can be observed to determine whether there are functional abnormalities (5).

The value of upper gastrointestinal barium X-ray examination in the diagnosis of disease has always been a knowledge point that must be mastered during the training period in higher medical education. Therefore, the importance and particularity of upper gastrointestinal barium X-ray examination in clinical work and personnel training can be seen. Given this, we consider that upper gastrointestinal barium X-ray examination in gastric disease should be fully explored in terms of its clinical value, so that the clinical application of this technology can be awarded greater value. The clinical application value of upper gastrointestinal barium X-ray examination has been reported in the literature, such as its ability to differentially diagnose the waterfall-type stomach and gastric torsion (6), and the weak-type stomach and mild gastroptosis (7). It is worth mentioning that, in the past, upper gastrointestinal barium X-ray examination studies concentrated on lesion detection, and a study did analyze the invasion depth of the tumor based on upper gastrointestinal barium X-ray examination (8); however, previous studies were limited to the morphological features of pathological changes. There has been little literature about the associations between gastric morphological type and the clinicopathological features of patients with GC based on double-contrast barium X-ray imaging.

The gastric morphological type is a descriptive term based on anatomical features, which were related to the body shape, gastric cavity position and tension (3). The morphological assessment in the present study was not of the morphological changes of the GC itself, but rather the upper gastrointestinal barium X-ray examination showed the gastric morphological type, that is, the horn-type, hook-type, weak-type and waterfall-type stomach. The purpose of the present study was to expand the application value of upper gastrointestinal barium X-ray examination in patients with

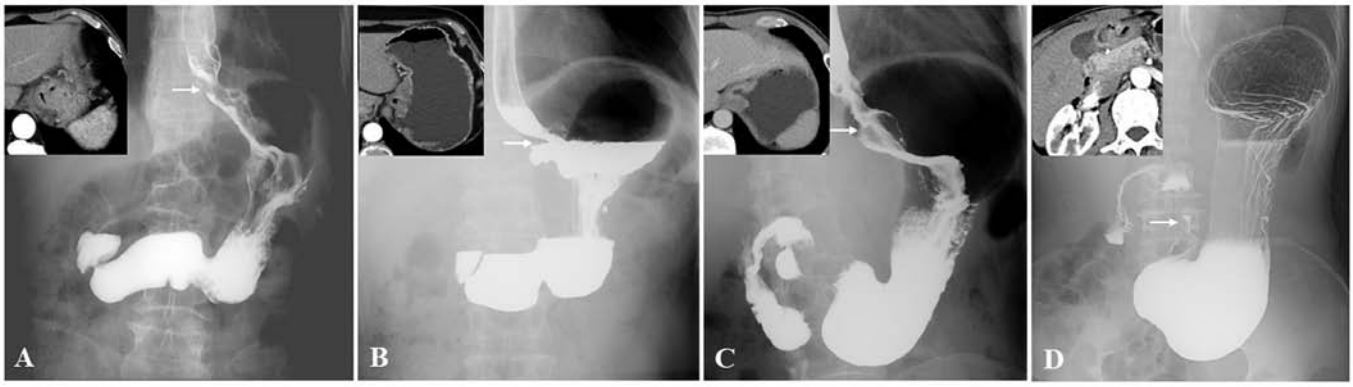

Figure 3. Different types of gastric morphological type for T3 stage and T4 stage GC. (A) Case of a 76-year-old male with GC located at the upper segment (arrow) based on upper gastrointestinal barium X-ray image. The inset image is the CT image. Upper gastrointestinal barium X-ray examination diagnosed a hook-type stomach. The postoperative pathology data proved to be of a moderately differentiated adenocarcinoma, intestinal-type GC and T4 stage disease. (B) Case of a 39-year-old female with GC located at the upper segment (arrow) based on upper gastrointestinal barium X-ray image. The inset image is the CT image. Upper gastrointestinal barium X-ray examination diagnosed a waterfall-type stomach. The postoperative pathology data proved to be of a poorly differentiated adenocarcinoma, diffuse-type GC and T3 stage disease. (C) Case of a 55-year-old male with GC located at the upper segment (arrow) based on upper gastrointestinal barium X-ray image. The inset image is the CT image. Upper gastrointestinal barium X-ray examination diagnosed a horn-type stomach. The postoperative pathology data proved to be of a moderately differentiated adenocarcinoma, intestinal-type GC and T4 stage disease. (D) Case of a 55-year-old male with GC located at the lower segment (arrow) based on upper gastrointestinal barium X-ray image. The inset image is the CT image. Upper gastrointestinal barium X-ray examination diagnosed a weak-type stomach. The postoperative pathology data proved to be of a poorly differentiated adenocarcinoma, mixed-type GC and T4 stage disease. GC, gastric cancer.

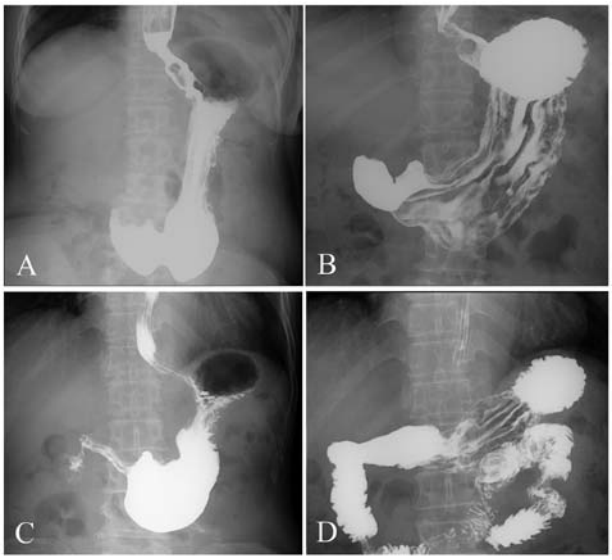

Figure 4. Different types of gastric morphological type for T1 stage and T2 stage GC. (A) Filling image and (B) mucosal image for the case of a 58-year-old female with GC located at the upper segment; Upper gastrointestinal barium X-ray examination diagnosed a weak-type stomach. The postoperative pathology data proved to be of a moderately differentiated adenocarcinoma, intestinal-type GC and T2 stage disease. (C) Filling image and (D) mucosal image for the case of a 73-year-old male with GC located at the lower segment; Upper gastrointestinal barium X-ray examination diagnosed a hook-type stomach. The postoperative pathology data proved to be of a moderately differentiated adenocarcinoma, mixed-type GC and T1 stage disease. GC, gastric cancer.

GC, that is, in addition to the conventional display of mucosal changes, ulcers and peripheral mucosal lesions, the purpose of this study was to demonstrate the biological behavior of GC. Upper gastrointestinal barium X-ray examination has played a very important role in clinic. For medical institutions without CT equipment or contrast-enhanced ultrasound examination, the more popular upper gastrointestinal barium X-ray examination can be applied, and the detection, diagnosis, and preliminary analysis of biological behavior of gastric space-occupying lesions can be performed to improve clinical treatment. As an upper gastrointestinal barium X-ray examination is a necessary examination before surgery in The First Affiliated Hospital of Zhengzhou University, if the value of this technique is expanded, the biological behavior of gastric space-occupying lesions can be investigated preliminarily, which can be confirmed by CT equipment or contrast-enhanced ultrasonography at a later stage, and has great clinical application value.

Among the gastric morphological types, the hook-type stomach is the most common, followed by the horn-type stomach. The present study showed that there were 160 cases of hook-type stomach, accounting for 48.63% of all cases (160/329), which was higher than the number of the other three types. TO the best of our knowledge, a study on the relationship between gastric morphological type and sex in patients with GC has not been reported. In the present study, it was found that the classification and the distribution of the gastric morphological type among the different sexes were similar, with the hook-type stomach being the most common, followed by the waterfall-type stomach.

In a previous study, the site of GC was recorded as an independent risk factor for the prognosis of patients with GC, and the prognosis of GC at different sites varied (9). Therefore, it is of great clinical importance to compare the clinicopathological characteristics of GC at different sites. With the change of lifestyle and the influence of natural environmental factors, epidemiological studies on the occurrence site of GC have shown that compared with that of distal GC, the incidence of proximal GC is on the rise, and the incidence of the cancer in the cardia and gastric body is common (10). In the present study, the occurrence site of GC was the upper stomach in 134 cases (40.73%), the middle stomach in 74 cases (22.49%) and the lower stomach in 121 cases (36.78%). The study further

Table I. Comparison of clinicopathological features of patients with gastric cancer and different gastric morphological types.

Variables	Hook-type stomach, n	Horn-type stomach, n	Waterfall-type stomach, n	Weak-type stomach, n	χ^2	P-value
Age, years					3.40	0.334
≤60	76	3	45	27		
>60	84	9	46	39		
Sex					2.39	0.496
Male	123	10	67	45		
Female	37	2	24	21		
Site					14.72	0.023
Upper	54	8	46	26		
Middle	37	2	23	12		
Lower	69	2	22	28		
Differentiation					3.93	0.267
Poorly differentiated	77	8	37	34		
Non-poorly differentiated	83	4	54	32		
Lauren classification					7.44	0.282
Diffuse type	36	4	18	15		
Intestinal type	63	1	43	24		
Mixed type	61	7	30	27		
T staging					16.87	0.010
T1 + T2	52	1	12	11		
T3	68	7	54	34		
T4	40	4	25	21		

T, tumor.

analyzed the association between gastric morphological types and the site of GC. The results showed that there were differences in terms of the site of GC in patients with different gastric morphological types, with the hook-type and horn-type being most common in the lower stomach, while the upper stomach mainly contained waterfall-type GC.

Accurate preoperative assessment of GC differentiation is of great importance for the selection of individualized treatment and prognosis evaluation (11). Studies have pointed out that the enhancement mode of GC is closely related to the pathological basis and microvascular structure (12-14). GC with a low differentiation degree has dense and regular surface blood vessels and more deep fibrous connective tissue, which is more likely to show continuous enhancement (12). Therefore, it is difficult to evaluate the differentiation degree of GC by gastric barium X-ray radiography. In more recent years, relevant imaging literature reports have mostly been based on CT enhanced examination, such as three-stage CT enhanced imaging (12), CT perfusion imaging (13) and CT energy imaging (14). The present study showed that the incidence of non-poorly differentiated GC in the waterfall-type stomach was higher than that in other gastric types, and the incidence of poorly differentiated GC in the horn-type stomach was common.

In the past, it was considered that an upper gastrointestinal barium X-ray examination could not diagnose the depth of invasion and the metastasis of the surrounding lymph nodes and distant organs, so it could not be used for the evaluation of GC staging. However, the deeper the degree of invasion of GC, the more significant the degree of gastric wall stiffness in the upper gastrointestinal barium X-ray examination (15). Given this, the stiffness of the gastric wall can provide a preliminary reference for the clinical evaluation of surgical indications. It is worth mentioning that, to the best of our knowledge, there has been no correlation study between gastric morphological types and T staging. The present study showed that there were statistically significant differences in the T-stage distribution of GC according to the gastric morphological types. The incidence of stage T1+T2 GC in the hook-type stomach was higher than that in other gastric types, and the proportion of stage T3 GC was the highest among the gastric morphological types.

The 2010 World Health Organization classification recognizes four major histological patterns of GC (16,17): Tubular, papillary, mucinous and poorly cohesive (including signet ring cell carcinoma), plus an uncommon histological variant. As the pathological examination of The First Affiliated Hospital of Zhengzhou University did not distinguish between tubular and papillary adenocarcinoma, all cases were reported as just adenocarcinoma. In this retrospective study, the distribution characteristics of the samples were carefully checked, and of the 329 patients, 256 were pathologically reported as cases of adenocarcinoma, 20 as cases of mucinous adenocarcinoma and 53 as cases of signet ring cell carcinoma. Further analysis of the association between the four major histological patterns

of GC and the gastric morphological types may be helpful to further expand the scope of application and the clinical value of examination, which will be analyzed in future research.

There are a number of limitations to the present study. As a preliminary screening method, the upper gastrointestinal barium X-ray examination lacks quantitative parameters, which makes it difficult to conduct an in-depth comparative analysis with pathology data. There are also certain differences in the number of samples among gastric morphological types, which need to be further assessed using large sample data. Furthermore, T1 and T2 stage GC were not separately discussed. The reasons for combining the T1 and T2 stages are as follows: i) T1 stage GC is rare, which can be confirmed from the previously published studies on early GC and clinical work; and ii) in clinical work, most of the patients with T1 and T2 stage GC can be treated by radical resection. In order to be closer to the situation in the clinic, these two groups of patients with GC should be combined to improve the value of upper gastrointestinal barium X-ray examination. Furthermore, prognostic information was not available for the patients in the study. The follow-up observations have been made for the patients included in this study, but it should be noted that the lack of contact information in some patients affected the observations in this study. In addition, the focus of this study was to observe the relationship between the gastric morphological type on upper gastrointestinal barium X-ray examination and its biological behavior. In the follow-up study, focus will be placed on the patient's prognostic information.

In conclusion, the present study found an association between gastric morphological type, and the clinical and pathological features of patients with GC on upper gastrointestinal X-ray imaging. There were differences with regard to incidence site and T-stage distribution of gastric morphological types, which may be used as a supplementary factor for making a diagnosis.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

PL is the primary author. PL and JBG designed the study. JBG critically reviewed the paper and revised it. PL, BZ, XCR, DL and MC performed the database search and literary review. BZ performed the statistical analysis. PL, BZ, XCR, DL and MC analysed the data. PL and JBG confirm the authenticity of all the raw data. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Institutional Review Board of The First Affiliated Hospital of Zhengzhou University (approval no. 2021-KY-1070-002). The requirement for written informed consent was waived by the Institutional Review Board due to the retrospective nature of the study.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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