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Comparison of clinical value and diagnostic rate between barium meal radiography and spectral CT scan in the diagnosis and treatment of gastric cancer and benign gastric tumor

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#Equal contributions to this study.

ABSTRACT

***Background*:** Background: To investigate the clinical and diagnostic value of X-ray examination and computed tomography (CT) imaging for gastric cancer (GC) and benign gastric tumors. ***Materials and Method*:** Totally 160 patients with gastric tumors treated in Baoding First Central Hospital from October 2016 to December 2017 participated in this study and randomized into the control group and observation group (n=80 per group). The control group received X-ray examination and the observation group underwent CT scan. The diagnostic rate was compared between these two modes. Receiver Operating Characteristic (ROC) curve was applied for the evaluation of the diagnostic efficacy of CT quantitative parameters in the observation group. The clinic accordance rate, clinical efficacy and life quality score in the two groups were then compared. ***Results*:** CT scan is more accurate than X-ray examination in diagnosing gastric cancer and benign tumor (P< 0.05). CT quantitative parameters were of diagnostic value in gastric cancer and benign gastric tumor. Their Area under Curve (AUC) was 0.750, 0.696, 0.676, 0.841 and 0.721, respectively. After treatment, the clinical efficacy and functional scales showed improvement in patients examined by CT imaging relative to those examined by X-ray (P<0.05). ***Conclusion*:** CT scan has a higher diagnostic accuracy than X-ray examination for gastric cancer and benign tumor. Selecting appropriate therapy after diagnosing with CT scan is beneficial for the improvement of clinical efficacy.

INTRODUCTION

Gastric tumor is a common digestive disease that can be divided into malignant and benign tumors. Malignant gastric tumors mainly include gastric cancer, malignant lymphoma and gastrointestinal stromal sarcomas, and are characterized by the high incidence and mortality [1, 2]. Either malignant or benign tumor is detrimental to patients [2, 3]. Gastric cancer is an important cancer all over the world. It is the fifth most common cancer and the fourth leading cause of cancer-related deaths, with over one million new cases and 769,000 deaths worldwide in 2020, and the incidence is two times higher in males than in females [4]. The symptoms of gastric cancer mainly include indigestion, poor appetite, early satiety, weight loss, and abdominal pain [2], which are vague and non-specific, and may be symptomatic until the late stage [5]. Currently, the treatment options such as surgery, chemotherapy, radiotherapy, targeted and immune therapy are often recommended for gastric cancer patients [5]. However, the prognosis in patients at late stage is unsatisfactory with an average survival time of under 12 months [6]. Thereby, improvement of early and accurate diagnosis are required for better outcomes and life quality of patients.

Physical examination is usually unrevealing in early stage of gastric cancer [7]. In clinical practice, endoscopic biopsy is the gold standard to distinguish benign and malignant tumors, as well as their histology type [8, 9]. However, as an invasive surgery, endoscopic biopsy has a high risk of complications, and the location and size of sampling and operating skills would all influence the positive rate of examination [10]. Compared with endoscopic biopsy, imaging techniques which mainly include X-ray examination and spectral computed tomography (CT) imaging have many advantages [11]. X-ray examination is a cost-effective, simple and suitable means for primary screening of gastric cancer [12]. As a conventional method for gastric cancer diagnosis, X-ray examination primarily showed the state of disease via the tissue absorption rate of the X-ray. It is reported that the screening of gastrointestinal X-ray can reduce the mortality rate of gastric cancer [13]. CT is characterized by high specificity and contrast and clear exhibition of the disease, which is

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conducive to the identification of the nature of cancer [14]. Spectral CT imaging refers to the application of energy information in polychromatic X-rays to optimize tissue characterization [15, 16]. Currently, the diagnostic capability difference between X-ray examination [17] and spectral CT imaging [18] in benign gastric tumor and gastric cancer diagnosis were unclarified. An accurate diagnosis can provide valid references for the treatment of patients with benign gastric tumor or gastric cancer, enable targeted therapy, improve patient survival outcomes as well as their life quality.

In this study, we performed X-ray examination or spectral CT imaging and compared their effect on the diagnostic rate of benign gastric tumor or gastric cancer and on the clinical efficacy. The findings of our work might provide evidence for the diagnosis of gastric cancer.

MATERIALS AND METHODS

Study participants

Totally 160 patients with gastric tumors treated in Baoding First Central Hospital from October 2016 to December 2017 were enrolled in this study, and their clinical information was retrospectively analyzed. Inclusion criteria: (1) 18-85 years old; (2) diagnosed of benign gastric tumor and gastric cancer by endoscopic biopsy and histopathological analysis; (3) did not receive surgery, radiotherapy and chemotherapy before X-ray examination or spectral CT imaging; (4) in good body state, and the performance status up to standards. Exclusion criteria: (1) with expected life time less than 3 months; (2) patients with history of gastrointestinal surgery and gastric tumor; (3) combine organic disease or other tumors; (4) clinical data is incomplete. Participants were randomized into the control group or observation group, and each group had 80 patients. The control group contained 61 males and 19 females, with 20 patients of benign gastric tumor, and 60 patients of gastric cancer. The age of patient ranged from 30-69, and the average was 49.84±11.88. The observation group contained 65 males and 15 females, with 22 patients of benign gastric tumor and 58 patients of gastric cancer. Their age ranged from 29-73, and the average age was 51.71±13.17 years old.

Methods

In the control group, patients received X-ray examination after fasting for 6 h. Fifteen minutes before examination, 20 mg anisodamin was given by intramuscular injection (Hangzhou Minsheng Medicine, Hangzhou, China), and then gas generating reagent was administered orally, meanwhile 10 mL warm water was treated to facilitate the full expansion of esophagus. Patients took a barium meal (Xintian Pharmaceutical, China) for 150 mL, and received gastrointestinal imaging with Shimadzu 500mA X-ray machine (Shimadzu, Japan). During diagnosis, changing the distribution of barium through altering position of patients and adjusting the height and angle of bed.

Patients in the observation group received CT scan after fasting for 8 h. Thirty min before examination, 20 mg anisodamin was given by intramuscular injection. Meanwhile 800-1000 mL warm water was drunk to fulfill the stomach cavity. GE Discovery CT 750 HD CT system was used (GE Healthcare, Milwaukee, America) for examination. Patients were maintained at supine position, and plain scan was performed from the sternum xiphoid periosteum to umbilicus. Enhanced images were acquired using a GSI imaging mode. Patients were then injected with compound meglumine diatrizoate injection (Shanghai Xudong Haipu Pharmaceutical Co., Ltd., China) via antecubital venous access at a rate of 3 mL/s for a total of 50~150 ml. The Arterial phase began after half of the drug was injected, and the portal venous phase (PP) began 30 s-1 min after termination of drug injection. Dual energy CT images were obtained by switching the single X radiation switch between 80 and 140 kVp rapidly with a speed under 5 m/s. Other imaging parameters were set as follows: 600 mA tube current, 5 mm slice thickness, 5 mm slice increment, 0.984 helical pitch, and 0.6 s rotation speed. CT images were reconstructed using a standard reconstruction kernel with 2.5 mm slice thickness. Representative CT images of patients with gastric cancer tumors were shown in figure 1.

After X-ray examination or CT imaging, patients in two groups received treatment accordingly.

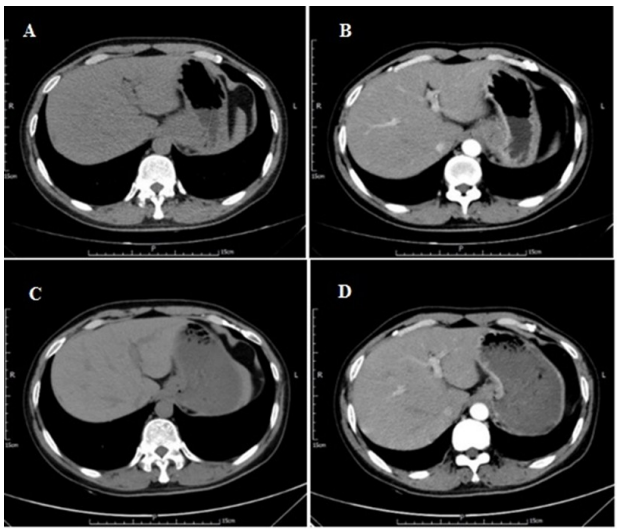


Figure 1. (A, B) gastric cancer patients and **(C, D)** healthy control.

Observational indexes

Patients were diagnosed by X-ray examination or CT scan after grouping, and the diagnostic rate of two mode was compared.

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Patients in the observation group underwent CT scan, and the quantitative parameter was compared between patients with benign or malignant gastric tumors in the observation group. Draw regions of interest (ROI) in lesions, and detect iodine concentration (IC), IC arterial phase (ICAP) and ICPP. IC was usually standardized to reduce individual differences. $NIC=IC_{lesion}/IC_{aorta}$. Slopes of spectral curve in arterial phase (AP) and venous phase were defined as λ_{AP} and λ_{PP} respectively.

Receiver Operating Characteristic (ROC) curve for CT quantitative parameters with significant differences between patients with gastric cancer and benign tumor in observation group were generated to analyze the diagnostic value of CT quantitative parameters.

After diagnosis, patients in control and observation group were treated accordingly, and their clinical efficacy was compared. Response Evaluation Criteria in Solid Tumors (RECIST) 1.1 [19] was used for the assessment of therapeutic outcomes. Patients were classified intoPartial Response (PR), Compete Response (CR), Progressive Disease (PD) and Stable Disease (SD). CR + PR= Response rate (RR), and CR + PR + SD= Disease control rate (DCR).

The quality of life (QOL) of participants in the two groups was assessed with QLQ-C30 [20]. Five items including physical, role, cognitive, emotional and social function of functional scales were scored. Scores range from 0 to 100, and higher scores indicate better QOL.

Statistical analysis

SPSS software (SPSS Inc, version 20.0, Chicago, IL, USA) was applied to conduct data analysis. The quantitative data was presented as the mean ± standard deviation (`X±SD). The intergroup analysis was subject to Mann-Whitney U test; Enumeration data were recorded as percent (%), and two-group comparisons were analyzed using Chi-squared Test. $P < 0.05$ indicated statistical significance. Graphpad Prism version 7.0 (GraphPad Software, Inc., USA) was applied for the data visualization.

RESULTS

General data of participants

Totally 160 patients participated into our study. They were randomized into 2 groups and were examined by different modes of diagnosis, and treated accordingly. The control group included 20 patients with benign gastric tumor, and 60 patients with gastric cancer. The observation group included 22 patients diagnosed of benign gastric tumor and 58 patients diagnosed of gastric cancer. The age, gender composition, BMI and tumor thickness showed no statistical differences between the two groups. The general information of patients in the two groups were comparable, as shown in table 1.

Table 1. General material of participants.

Items	Control group (n=80)	Observation group (n=80)	*P* value
Age (years)	49.84±11.88	51.71±13.17	0.347
Gender (%)			
Male	61(76.25)	65(81.25)	0.563
Female	19(23.75)	15(18.75)	
BMI (kg/m^2)	23.47±3.60	23.83±3.23	0.506
Type			
Benign gastric tumor	20(25.00)	22(27.50)	0.858
Gastric cancer	60(75.00)	58(72.50)	
Tumor thickness (cm)	3.21±1.36	3.11±1.31	0.636

BMI, body mass index.

Comparison of diagnostic rate between X-ray examination and CT imaging

According to X-ray examination, the diagnostic rate of benign gastric tumor and gastric cancer was 70% and 80% in the control group respectively. Based on the results of CT imaging, the diagnostic rate of benign gastric tumor and gastric cancer was 86.36% and 91.38% in the observation group respectively. There was a higher diagnostic rate in the control group relative to the observation group ($P<0.05$, table 2).

Table 2. Comparison of diagnostic rate between X-ray examination and CT imaging.

Group	Total number (n)	Absolute accuracy (n)%	Basic accuracy (n)%	Non-accuracy (n)%	Diagnostic rate %
Control group (benign gastric tumor)	20	10(50.00)	4(20.00)	6(30.00)	70.00
Control group (gastric cancer)	60	39(65.00)	9(15.00)	12(20.00)	80.00
Observation group (benign gastric tumor)	22	16(72.72)	3(13.64)	3(13.64)	86.36[a]
Observation group (gastric cancer)	58	46(79.31)	7(12.07)	5(8.62)	91.38[a]

aP < 0.05: Compared with control group. CT, computed tomography

Comparison of CT quantitative parameters

CT imaging was used to examine patients in observation groups, and the quantitative parameters of patients with benign or malignant gastric tumors were compared. Table 3 and figure 2 showed that ICPP, ICAP, nICAP and nICPP of patients with malignant tumors increased, while λ_{PP} was reduced compared with in patients with benign gastric tumor, though the difference showed no statistical significance ($P>0.05$).

Table 3. Comparison of CT qualitative parameters.

Parameter	Observation group (benign gastric tumor) (n=22)	Observation group (gastric cancer) (n=58)
ICAP(mg/ml)	1.17±0.13	1.31±0.18[a]
ICPP(mg/ml)	1.67±0.20	1.84±0.25[a]
nICAP	0.13±0.04	0.16±0.06[a]
nICPP	0.23±0.07	0.34±0.08[a]
λ_{AP}	2.44±0.71	2.24±0.66
λ_{PP}	2.77±0.85	2.13±0.68[a]

aP < 0.05: Compared with observation group (benign gastric tumor). CT, computed tomography; ICAP, iodine concentration during arterial phase; ICPP, iodine concentration during portal venous phase; nICAP, normalized ICAP; nICPP, normalized ICPP; AP, arterial phase; PP, portal venous phase.

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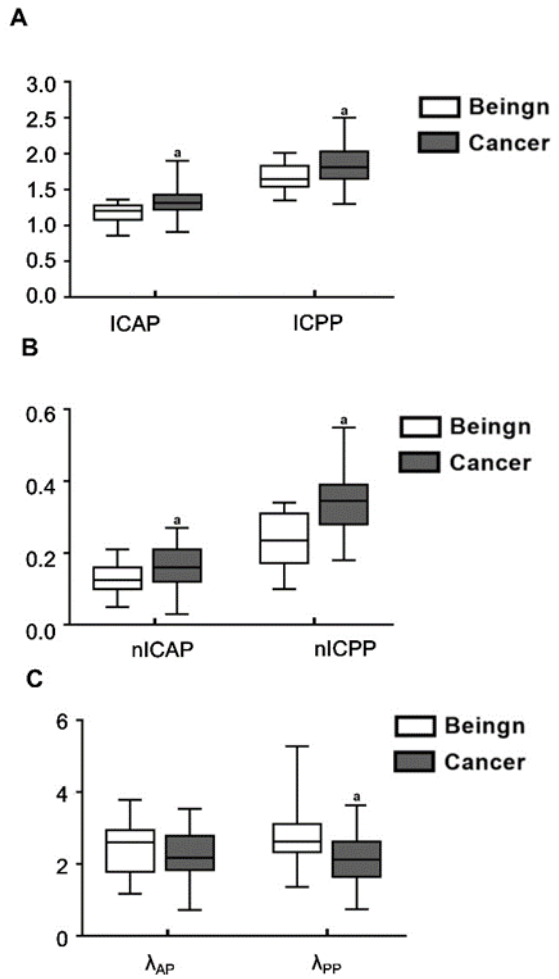


Figure 2. Comparison of CT qualitative parameters Box plot. **A:** Difference of ICAP and ICPP value between patients with benign or malignant gastric tumors; **B:** Difference of nICAP and nICPP value in patients with benign or malignant gastric tumors; **C:** Difference of λAP and λPP value between patients with benign or malignant gastric tumors. aP<0.05: Compared with observation group (benign gastric tumor).

The diagnostic capability of CT quantitative parameters

ICAP, ICPP, nICAP, nICPP and λ_{PP} are valuable in diagnosing benign gastric tumor and gastric cancer. Their AUC value was 0.750, 0.696, 0.676, 0.841 and 0.721, respectively. nICPP has the highest AUC value, with a threshold of 0.32, and its values of sensitivity, specificity and Youden index were 0. 62, 0.91 and 0.53, respectively (table 4, figure 3).

Table 4. Diagnostic capability of CT quantitative parameters.

Parameter	AUC	Threshold	Sensitivity	Specificity	Youden index
ICAP(mg/ml)	0.750	1.31	0.53	0.96	0.49
ICPP(mg/ml)	0.696	1.73	0.69	0.64	0.33
nICAP	0.676	0.14	0.64	0.68	0.32
nICPP	0.841	0.32	0.62	0.91	0.53
λ_{PP}	0.721	2.36	0.65	0.77	0.43

CT, computed tomography; AUC, area under the curve; ICAP, iodine concentration during arterial phase; ICPP, iodine concentration during portal venous phase; nICAP, normalized ICAP; nICPP, normalized ICPP; PP, portal venous phase.

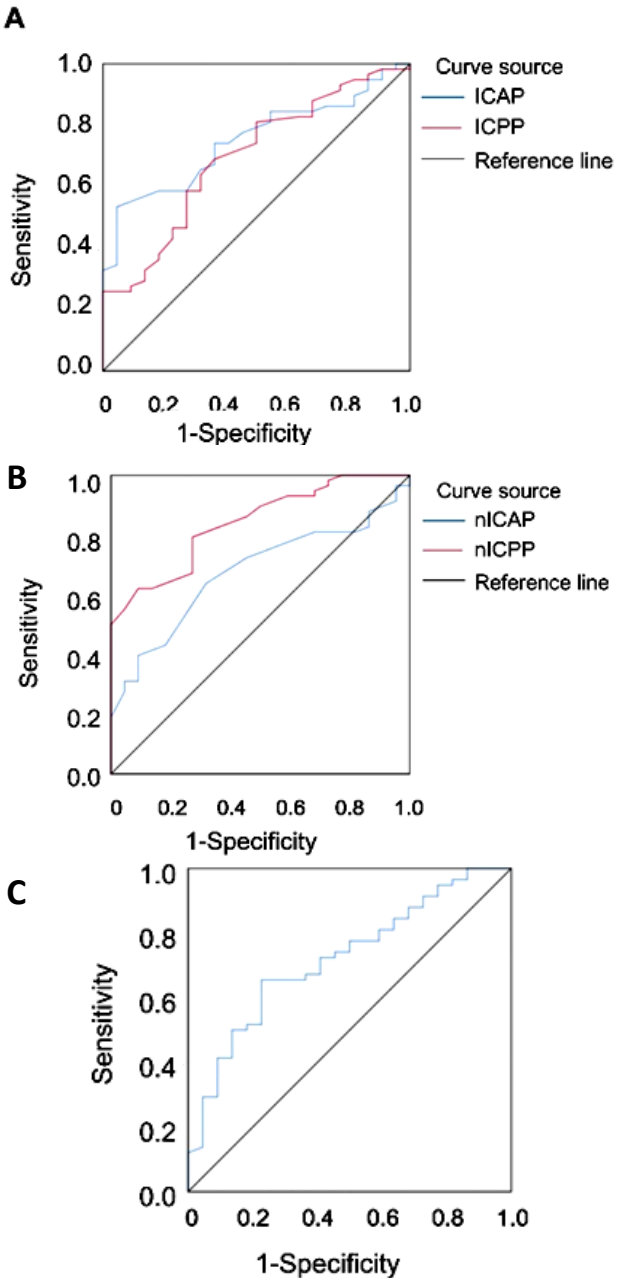


Figure 3. Diagnostic capability of CT quantitative parameters ROC curve of CT quantitative parameters. ROC curve of ICAP, ICPP**(A)**, Nicap, nICPP **(B)** and λPP**(C)** between benign gastric tumor and gastric cancer group.

Comparison of clinical efficacy between two groups

After treatment according to diagnosis, the clinical efficacy rate of control and observation group were 30% and 36.25%, respectively. The efficacy rate of the CT imaging was higher relative to the X-ray examination, though without statistical significance (P>0.05). The disease control rate of in patients after examination of CT imaging was significantly higher than those examined by X-ray, which were 55% and 72.5%, respectively (table 5).

Life quality of patients in two groups before and after treatment

Before symptomatic treatment, no difference was

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observed in the score of each item in functional scales between control and observation group (P>0.05). After symptomatic treatment according to diagnosis, each item score was increased in either group (P<0.05). Meanwhile, relative to the control group, each item score in the observation group increased (P<0.05), as exhibited in table 6 and figure 4.

Table 5. Comparison of clinical efficacy between patients examined by two modes.

Indexes	Control group (n=80)	Observation group (n=80)
CR	9(11.25)	13(16.25)
PR	15(18.75)	16(20.00)
SD	20(25.00)	29(36.25)
PD	36(45.00)	22(27.50)
RR(%)	30.00	36.25
DCR(%)	55.00	72.50[a]

PR, Partial Response; CR, Compete Response; PD, Progressive Disease; SD, Stable Disease; RR, Response rate; DCR, Disease control rate.

Table 6. Comparison of quality of life score between patients in control group and observation group before and after treatment.

Item	Control group (n=80)		Observation group (n=80)	
	Before treatment	After treatment	Before treatment	After treatment
Physical function	73.34±13.91	78.60±10.66[a]	72.41±15.88	84.28±10.21[a,b]
Role function	64.10±8.97	74.45±10.97[a]	63.61±9.09	84.25±9.24[a,b]
Cognitive function	72.84±12.84	78.77±10.67[a]	73.32±13.07	88.37±7.14[a,b]
Emotional function	70.47±12.98	76.52±10.88[a]	71.03±12.26	81.76±7.40[a,b]
Social function	62.54±9.46	75.30±9.91[a]	62.36±8.29	86.30±9.55[a,b]

PR, Partial Response; CR, Compete Response; PD, Progressive Disease; SD, Stable Disease; RR, Response rate; DCR, Disease control rate.

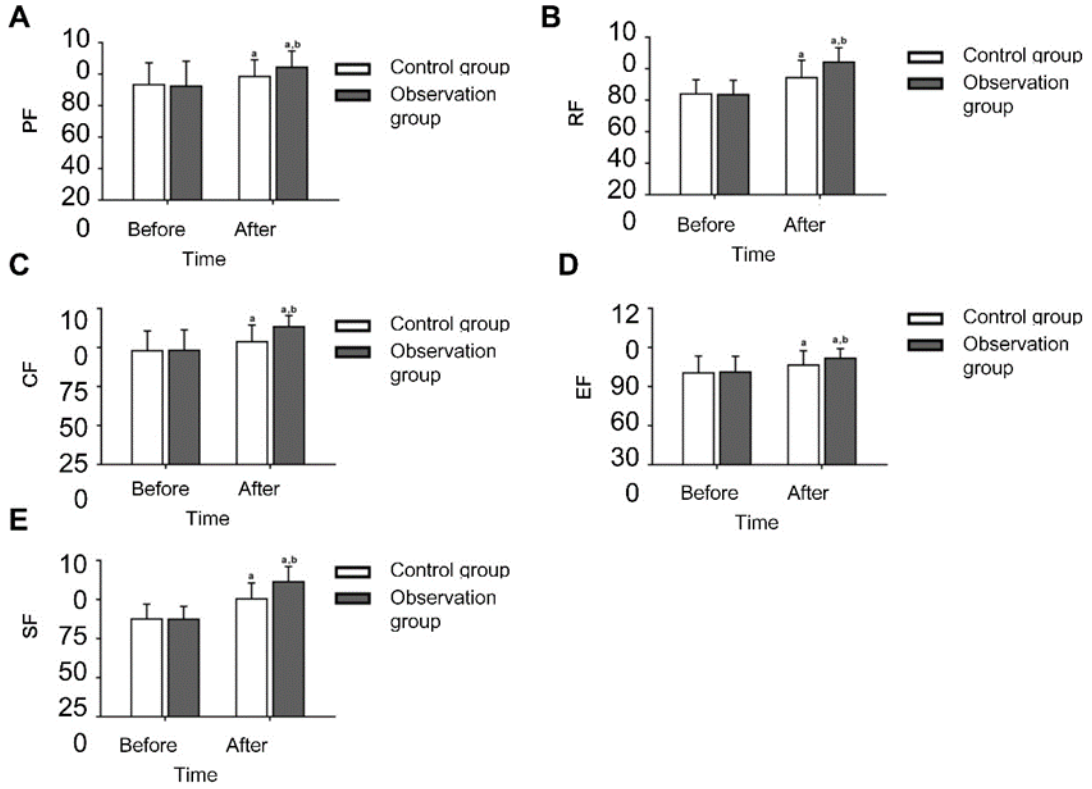


Figure 4. Comparison of quality of life score between patients in two groups before and after therapy. QLQ-C30 was applied for the assessment of the life quality of patients in control and observation group before and after definitive therapy. Five items in fucntional scales were scored. PF: Physical function **(A)**; RF:Role function **(B)**; CF: Cognitive function **(C)**; EF: Emotional function **(D)**; SF: Social function **(E)**. aP < 0.05: relative to patients before treatment; bP < 0.05: Compared with patients of the control group after treatment

DISCUSSION

Gastric tumor a common digestive disease associated with the lifestyle and diet of patients, and the efforts are needed for lifestyle interventions and H pylori screening and treatment in countries with increasing incidence of gastric cancer [21-23]. Gastric tumor includes benign and malignant tumors, and affects more men than women [2]. At the early stage, gastric tumor are asymptomatic, and have a potential transformation. When being diagnosed, patients are usually in an advanced stage [24]. It is critical for patients with gastric tumor to be diagnosed as early and accurate as possible, distinguished between benign and malignant, and treated properly. In this study, we evaluated the clinical value of X-ray examination and CT scan on the diagnosis and therapy of gastric tumors. The CT images showed higher diagnostic rate and clinical efficacy, and the life quality of patients was improved followed treatment based on diagnosis.

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Abdominal X-ray examination is one of the mostly used imaging methods in clinics, which can diagnose ileus and stones [25]. However, the density of a bdominal organs or tissues is roughly the same, and X-ray barium meal examination should be used for better diagnosis of gastric tumor [26]. Barium used for digestive tract examination is usually medicinal barium sulfate, and it reacts with X-ray to generate photoelectric effect.

Barium is insoluble in water and lipid. After entering into the digestive tract, barium coats the inside wall of the digestive tract, and is excreted without being absorbed by gastrointestinal mucosa. Therefore, digestive skeleton and lesion can be better visualized by X-ray barium meal examination [27]. The X-ray examination is a static examination with a simple operational process. However, the resolution of images generated from X-ray is lower than that of CT scan, radiologists can only diagnose through visual study and empirical analysis, which can lead to misdiagnose and missed diagnosis [28]. A previous study has demonstrated that the double-contrast barium meal is accurate to pick the lesion of gastric tumors and shows a diagnostic accuracy of 96% in the differentiation of mucosal and submucosal lesions and 63% in the type classification of gastric cancer [29].

In our work, the diagnostic rate in patients of benign or malignant gastric tumors by X-ray was 70% and 80% respectively (table 2).The difference in diagnostic accuracy with previous studies may be caused by the different procedures and contrast agent used for barium meal radiography and the different diagnostic aims.

Dual-energy spectral computed tomoraphic is a rapidly developing CT imaging technique in recent years, which expands the function of conventional CT imaging. This technique obtains a series of continuous single energy images through rapidly switching kilovoltage. Then concentration of iodine is calculated through attenuation analysis to provide various qualitative parameters [30]. The SNR and resolution ratio of image obtained from spectral CT is higher than that of conventional CT, which is helpful for observing tiny lesions [31]. Qualitative and quantitative indexes are more helpful for radiologists to make accurate diagnosis. Chest CT is indicated to detect lung metastasis more efficiently relative to X-ray examination [14]. The previous study has also revealed that the multidetector row computed tomography has a higher accuracy in the preoperative diagnosis of different gastric tumors relative to double-contrast barium meal [29]. In our study, we found that the diagnostic rate of benign gastric tumor and gastric cancer by CT imaging reached 86.36% and 91.38%, which was higher than those by the X-ray examination ($P < 0.05$, table 2). The results suggested that CT imaging was more accurate in the preoperative diagnosis of gastric cancer, which was consistent with the previous findings.

Iodine is the main ingredient of contrast agent, and its concentration can reflect the blood supply of lesions [32]. This study drew region of interest in lesions, and measured ICAP and ICPP. To eliminate the effect of individual difference and circulating blood, aorta abdominalis in the same layer were selected as reference, and iodine concentration was normalized. In addition, slope of spectral curve was used to evaluate the attenuation of contrast agent. Blood vessel in lesions of gastric cancer patients were more abundant with a fast blood flow velocity and higher permeability of vascular wall, which would accelerate the permibilization of contrast agent and cut off the washout time [33].

In this study, compared with X-ray examination, spectral CT imaging not only provided more stereo images but also applied multiple quantitative parameters to enhance diagnostic accuracy. Compared with patients with gastric benign tumor, parameters such as ICPP, ICAP, nICAP and nICPP of patients with malignant gastric tumors increased, and λ_{PP} decreased with a significant difference (table 3, figure 2). To further analyze the diagnostic capabilities of quantitative parameters ICAP, ICPP, nICAP, nICPP and λ_{PP}, which showed remarkable differences, ROC curve was generated. Results indicated that ICAP, ICPP, nICAP, nICPP and λ_{PP} are valuable in diagnosing benign gastric tumor and cancer, and their AUC value was 0.750, 0.696, 0.676, 0.841 and 0.721, respectively. The AUC of nICPP was the highest (table 4 and figure 3), and our findings were in line with the previously reported results [11]. Definitive therapy was designed for patients according to diagnosis. The score of each item in functional scales was increased in patients of both groups after treatment. Meanwhile, relative to the control group, the score of each item in functional scales and disease control rate showed an increase in patients examined by CT imaging. These results suggested that diagnosing patients with benign or malignant gastric tumors by CT imaging before treatment is beneficial for making suitable treatment plan, thereby improving clinical efficacy.

In conclusion, the diagnostic accuracy of spectral CT imaging was higher for benign gastric tumor and gastric cancer than that of X-ray examination. The application of CT scan for preoperative diagnosis is beneficial to improve the therapeutic efficiency and the quality of life of patients.

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***Conflicts of interests*:** The authors have no conflicts of interest to declare.

***Availability of data and materials*:** The datasets

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

***Ethical consideration*:** The present study was approved by the Ethics Committee of Maternity and Baoding First Central Hospital (approval number: BD (2016)002L) and written informed consent was provided by all patients prior to the study start. All procedures were performed in accordance with the ethical standards of the Institutional Review Board and The Declaration of Helsinki, and its later amendments or comparable ethical standards.

***Author contribution*:** Conceptualization: G-N.Z., X-S.D.; methodology and validation: G-N.Z., X-S.D., P-Z.Z., L. G.; Writing: G-N.Z., X-S.D.; Review and editing: P-Z.Z., L.G.. All authors have read and approved the final version of the manuscript.

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