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Original Article

Applications of computed tomography pelvimetry and clinical-pathological parameters in sphincter preservation of mid-low rectal cancer

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Abstract: Background: This study aims to evaluate the predictive value of pelvic anatomical and clinical-pathological parameters that influence the success of sphincter preservation procedure (SPP). Methods: We studied 42 consecutive patients who underwent low anterior resection (LAR) with double stapling technique (DST) anastomosis or abdominoperineal resection (APR) for mid-low rectal cancer between June 2009 and April 2014. The surgical procedures were performed by the same surgeon and surgical team at the Department of Surgery of Wenzhou Central Hospital. Pelvic dimensions and angles were measured using three-dimensional reconstruction of spiral computed tomography (CT) images. A number of clinical-pathological parameters were also examined. Univariate and multivariate analyses were performed to determine the predictive significance of these variables that might affect a successful SPP for mid-low rectal cancer. Results: Body mass index (BMI), distance of tumor from anal verge, and diameter of upper pubis to coccyx affected the success of SPP. It was the higher distance of tumor from anal verge, the higher BMI, and the larger diameter of upper pubis to coccyx contributed most to the success of SPP. Conclusions: Diameter of upper pubis to coccyx is the only one of the pelvic anatomical parameters that could affect the success of SPP for mid-low rectal cancer patients. Furthermore, within the normal BMI range, higher BMI seemed to be a favorable factor for the success of SPP.

Keywords: Computed tomography, pelvimetry, three-dimensional reconstruction, sphincter preservation, mid and low rectal cancer

Introduction

Rectal cancer is one of the most common malignant neoplasm in the world. Its incidence has been increasing for many decades. Compared with western countries, the incidence of rectal cancer is higher than that of colon cancer, and 65%~75% of rectal cancer located at the mid and low rectum in China [1].

Because of its special anatomical position and close relationship with the surrounding tissue, the curative operation for mid-low rectal cancer is relatively difficult to perform. Especially for some patients with lower rectal cancer, it is difficult to perform a SPP, usually because of the narrow and deep pelvic cavity. Some studies have also suggested that the quality of open rectal surgery is influenced not only by the surgeon's skill but also by the patient's clinical and anatomical factors, such as gender, BMI, distance of tumor from anal verge, and pelvic size [2-5].

Total mesorectal excision (TME) has been a common procedure used in the treatment of rectal cancer since Heald et al. reported TME in 1982 [6]. TME principle was wildly applied, which has significantly reduced the local recurrence rate for rectal cancer [7]. As a standard procedure, a surgical margin of 1 to 2 cm in the bowel wall and a 5-cm mesorectal margin should be obtained by a SPP, or the patient may have to receive APR [3]. With the application of surgical anastomat and preoperative neoadjuvant chemoradiotherapy in recent years, the SPP rate of mid-low rectal cancer, especially lower rectal cancer, has increased. Even so, there are still a significant portion of patients with rectal cancer who unfortunately fail a SPP [8, 9]. It is well known that pelvis anatomy is a very important factor affecting surgical procedure selection. Sometimes surgeons contribute failure of a SPP to a limitation of pelvis anatomy besides the clinical factors, but there was no consensus on which pelvic diameter and angle interfered with the procedure. The aim of this study is to evaluate the predictive value of pelvic anatomical and clinical-pathological parameters, particularly pelvic anatomical parameters, which influence the success of sphincter preservation procedure for mid-low rectal cancer.

Materials and methods

Patients and surgical procedures

We studied 42 consecutive patients who underwent LAR with DST anastomosis or APR for mid-low rectal cancer located within 7 cm of the anal verge between June 2009 and April 2014. The distance from the anal verge to the lower margin of the tumors (distance of tumor from anal verge) was measured by digital rectal examination and/or colonoscopy. All cases were confirmed to be adenocarcinoma by biopsy before operations. The surgical procedures were performed by the same surgeon and surgical team who were experienced in TME techniques at the Department of Surgery of Wenzhou Central Hospital.

Patients who had previous abdominal surgery through a laparotomy, had a history of pelvic fracture and underwent neoadjuvant chemoradiotherapy, or with locally recurrent disease were excluded from this study. Cases were also excluded if tumors had infiltrated to the organs adjacent to the rectal cancer or had metastasized to the lateral pelvic wall lymph nodes and distant regions of the body. The preoperative clinical stage of rectal cancer was assessed by contrast-enhanced CT.

Data for age, gender, BMI, the maximum diameter of the tumor, distance of tumor from anal verge, tumor invasive depth, lymph node metastasis and tumor staging were collected prospectively. Tumors were staged according to the seventh tumor-node-metastasis (TNM) classification of the International Union against Cancer (UICC) on the basis of the histological findings of the surgical specimens. Written informed consent for participation in the study was obtained from participants or their parent or guardian. None of the children were included in this study. This study was approved by the Institutional Review Board of Wenzhou Central Hospital, Wenzhou, Zhejiang, P.R. China.

Pelvimetry

All patients underwent contrast-enhanced abdominopelvic CT. Three-dimensional reconstruction of the pelvis was performed on a workstation by using an image program with a scanning slice thickness of 1.0 mm and interslice interval of 1.0 mm. Pelvic dimensions and angles were obtained using mid-sagittal and axial sections of the pelvis.

All measurements were made by a single observer who blinded to all clinical informations regarding the patients. Fourteen pelvic parameters, including twelve dimensions and two angles, were measured:

1. Anteroposterior diameter of the pelvic inlet (AB): a line from the superior, middle aspect of the pubic symphysis to the sacral promontory.

2. Anteroposterior diameter of the mid-pelvis (CD): a line from the inferior, middle aspect of the pubic symphysis to the sacrococcygeal junction.

3. Anteroposterior diameter of the pelvic outlet (CE): a line from the inferior, middle aspect of the pubic symphysis to the tip of the coccyx.

4. The interspinous diameter.

5. The intertuberous diameter.

6. The height of pubic symphysis (AC).

7. The sacrococcygeal distance (BE): distance from the sacral promontory to the tip of the coccyx.

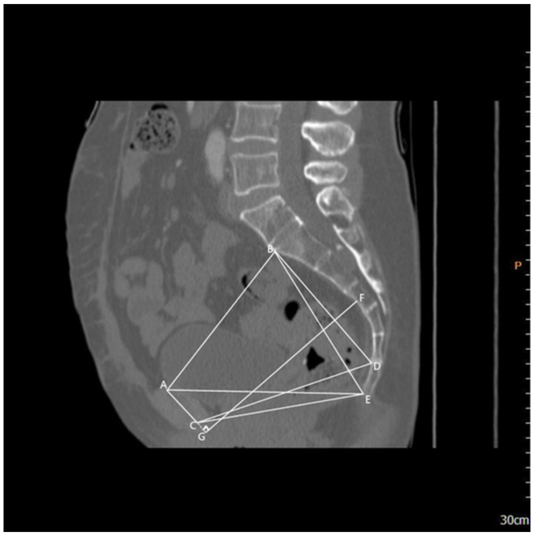

Figure 1. The mid-sagittal view of the pelvis showing pelvic dimensions.

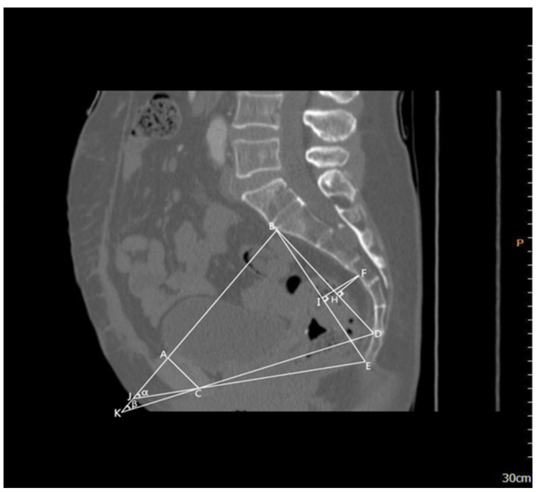

Figure 2. The mid-sagittal view of the pelvis showing the depth of the sacrococcygeal curvature, the depth of the sacral curvature and pelvic angles.

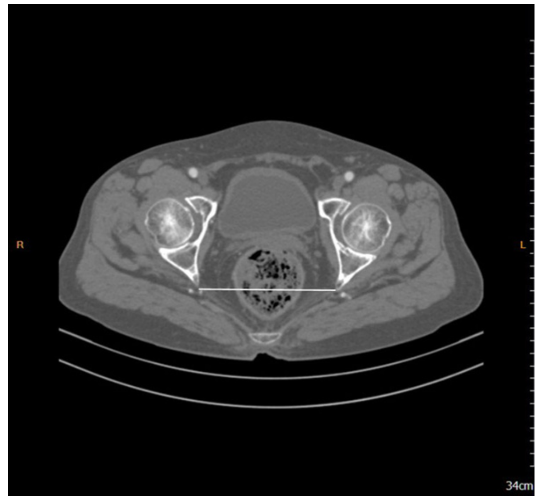

Figure 3. The axial section showing the interspinous diameter of the mid-pelvis.

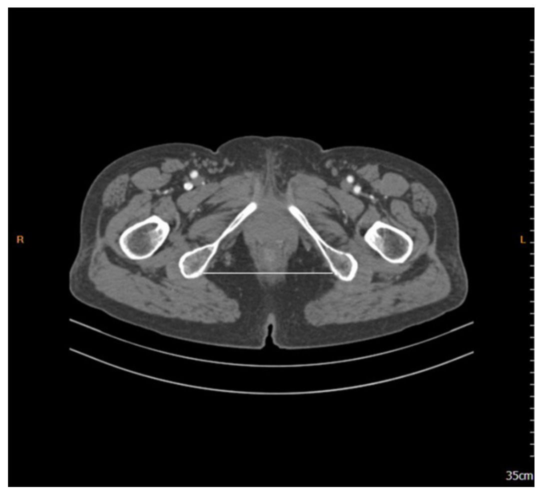

Figure 4. The axial section showing the intertuberous diameter of the pelvic outlet.

8. The sacral distance (BD): distance from the sacral promontory to the sacrococcygeal junction.

9. Sacrococcygeal-pubic angle (α): The angle between extension lines of anteroposterior diameter of the pelvic inlet and that of anteroposterior diameter of the pelvic outlet.

10. Sacro-pubic angle (β): The angle between extension lines of anteroposterior diameter of the pelvic inlet and that of anteroposterior diameter of the mid-pelvis.

11. The depth of the sacrococcygeal curvature (FI): a perpendicular line from the deepest portion of the sacrococcygeal hollow to the sacrococcygeal distance.

12. The depth of the sacral curvature (FH): a perpendicular line from the deepest portion of the sacral hollow to the sacral distance.

13. Diameter of upper pubis to coccyx (AE): a line from the superior, middle aspect of the pubic symphysis to the tip of the coccyx.

14. Sacro-pubic distance (FG): a perpendicular line from the deepest portion of the sacrococcygeal hollow to the height of pubic symphysis or its extension line.

Figures 1 and **2** outline the mid-sagittal view of the pelvis. **Figure 3** outlines the axial section

Table 1. Patients' clinical-pathological parameters (n=42)

	n
Gender (Male/Female)	27/15
Age (years) (range)	63.6±13.5* (29-85)
BMI (kg/m²) (range)	21.5±3.1* (16.9-30.8)
Distance of tumor from anal verge (cm) (range)	5.1±1.2* (3-7)
The maximum diameter of the tumor (cm) (range)	4☆ (3-7)
Surgical procedure	
Abdominoperineal resection (APR)	25
Low anterior resection (LAR)	17
Tumor invasive depth	
T1	2
T2	13
T3	22
T4	5
Lymph node metastasis	
N0	18
N1	18
N2	6
Tumor staging	
I	10
II	8
III	24

*: mean±standard deviation, ☆: median value.

showing the interspinous diameter of the mid-pelvis. **Figure 4** outlines the axial section showing the intertuberous diameter of the pelvic outlet. The above measurements are seen in **Figures 1-4**. Assessment of intraobserver error was carried out as detailed in the statistics section.

Statistical analysis

Statistical analyses were performed using SPSS version 17.0 (Statistical Package for Social Sciences™; SPSS, Inc., Chicago, IL, USA). Data were shown as means ± standard deviation or medians (minimum-maximum) when appropriate. We defined surgical procedures as dependent variables and clinical-pathological and pelvic anatomical parameters as independent variables. All statistically significant factors found by univariate analysis were then used in the multivariate analysis. Where appropriate, we used Independent-samples t test or Chi-square test of Fisher's exact test, to analyze relationships between clinical-pathological and pelvic anatomical parameters and surgical procedures. P<0.2 was considered statistically significant in univariate analysis to avoid missing potentially significant variables. Multivariate analysis was performed using logistic regression model with a backward stepwise method (Statistical significance was denoted by P<0.05).

To assess intraobserver variation, measurements of the pelvic dimensions and angles of 20 patients were repeated after an interval of 4 weeks, with the observer being blinded to the initial results. Paired-samples t test was applied. Intraobserver variation was calculated using Pearson's product-moment correlation coefficient. The lowest value obtained was 0.991. The two sets of measurements were highly correlated (P<0.001), indicating that the measurements were reproducible and accurate.

Results

Patients' clinical-pathological and pelvic anatomical parameters were respectively summarized in **Tables 1** and **2**. Univariate analysis showed that BMI (P=0.190), distance of tumor from anal verge (P=0.000), anteroposterior diameter of the pelvic inlet (P=0.114), anteroposterior diameter of the pelvic outlet (P=0.065), the interspinous diameter (P=0.128), the intertuberous diameter (P=0.128), the height of pubic symphysis (P=0.189), the depth of the sacrococcygeal curvature (P=0.133), diameter of upper pubis to coccyx (P=0.004), tumor invasive depth (P=0.115), and gender (P=0.056) were significantly associated with the surgical procedures if P<0.2 was considered statistically significant. However, there were no association between age, the maximum diameter of the tumor, lymph node metastasis, tumor staging and the other pelvimetry data and the surgical procedures (P>0.2) (**Table 3**). Out of the eleven significant factors found by univariate analysis, logistic regression with a backward stepwise method showed that BMI [relative risk (RR), 1.518; 95% CI, 1.050-2.139], distance of tumor from anal verge (RR, 5.639; 95% CI, 1.772-17.944) and diameter of upper pubis to coccyx (RR, 1.197;

Table 2. Patients' pelvic anatomical parameters (n=42)

	Total (n=42)	Female (n=15)	Male (n=27)	*p* values
Anteroposterior diameter of the pelvic inlet (mm)	112.26±12.55	122.29±12.08	106.70±8.91	**0.000**
Anteroposterior diameter of the mid-pelvis (mm)	112.08±8.50	117.45±8.95	109.10±6.71	**0.001**
Anteroposterior diameter of the pelvic outlet (mm)	88.62±7.66	94.22±7.93	85.52±5.52	**0.000**
The interspinous diameter (mm)	98.95±10.50	109.10±7.46	93.32±7.19	**0.000**
The intertuberous diameter (mm)	99.19±14.42	112.28±12.39	91.92±9.56	**0.000**
The height of pubic symphysis (mm)	36.23±3.65	35.02±3.30	36.91±3.72	0.109
The sacrococcygeal distance (mm)	123.10±13.41	122.55±10.52	123.41±14.96	0.844
The sacral distance (mm)	108.32±9.51	107.75±8.43	108.64±10.20	0.776
Sacrococcygeal-pubic angle (°)	51.56±8.88	47.42±6.00	53.87±9.46	**0.022**
Sacro-pubic angle (°)	37.51±6.17	35.68±4.35	38.53±6.85	0.154
The depth of the sacrococcygeal curvature (mm)	38.33±5.29	36.25±5.66	39.49±4.80	0.056
The depth of the sacral curvature (mm)	20.75±4.68	19.77±3.98	21.30±5.02	0.318
Diameter of upper pubis to coccyx (mm)	112.84±7.49	116.57±8.27	110.77±6.26	**0.014**
Sacro-pubic distance (mm)	123.62±10.61	128.60±14.29	120.85±6.73	**0.021**

All values are mean±standard deviation. Bold font in table means P<0.05. Comparison of pelvic anatomical parameters in male and female was performed using the Independent-samples t test.

Table 3. Univariate analyses between patients' clinical-pathological and pelvic anatomical parameters and surgical procedures

Variable	*p* Values
Age	0.574
BMI	**0.190**
Distance of tumor from anal verge	**0.000**
The maximum diameter of the tumor	0.304
Tumor invasive depth	**0.115★**
Gender	**0.056★**
Lymph node metastasis	0.477★
Tumor staging	0.519★
Anteroposterior diameter of the pelvic inlet	**0.114**
Anteroposterior diameter of the mid-pelvis	0.535
Anteroposterior diameter of the pelvic outlet	**0.065**
The interspinous diameter	**0.128**
The intertuberous diameter	**0.128**
The height of pubic symphysis	**0.189**
The sacrococcygeal distance	0.384
The sacral distance	0.885
Sacrococcygeal-pubic angle	0.818
Sacro-pubic angle	0.836
The depth of the sacrococcygeal curvature	**0.133**
The depth of the sacral curvature	0.566
Diameter of upper pubis to coccyx	**0.004**
Sacro-pubic distance	0.881

P<0.2 was considered statistically significant in univariate analysis to avoid missing potentially significant variables. Bold font in table means P<0.2. The above-mentioned univariate analyses were performed using the Independent-samples t test or Chi-square test of Fisher's exact test★ where appropriate.

95% CI, 1.024-1.400) were independent factors for determining SPP success or failure (P<0.05) (**Table 4**).

Discussion

Pelvimetry using conventional radiographs had ever been widely applied to predict cephalopelvic disproportion in pregnant women prior to labor [10]. But the x-ray measurement had poor sensitivity and specificity and a larger radiation dose, which limited its clinical application. Nowadays CT and magnetic resonance imaging (MRI) pelvimetry have been coming back into fashion for a lower or without radiation dose. CT and MR pelvimetry are also an accurate and reliable technique for obtaining pelvimetric measurements, which have been utilized for patients with rectal cancer [2, 4, 5, 11-13]. Costs of MRI pelvimetry are obviously greater than those of CT techniques. Finally, financial considerations limit the clinical usage of MRI in our centre. Therefore CT pelvimetry was widely used in patients with rectal cancer because of its relatively inexpensive costs and convenience.

In general, it is believed that female pelvises are wider and shallower than male pelvises. Colorectal surgeons are aware that the female pelvises are usually more accessible than the male pelvises when carrying out a SPP. Some authors have demonstrated significant differences in pelvic measurements between the sexes [5, 14]. But there is also considerable variation and overlap between the sexes [15]. In

Table 4. Multivariable analysis of patients' clinical-pathological and pelvic anatomical parameters

APR=0 LAR=1	β	SE	Wald	df	Sig	Exp (β)	95% CI	
							Lower	Upper
BMI	0.417	0.188	4.938	1	0.026	1.518	1.050	2.193
Distance of tumor from anal verge	1.730	0.591	8.577	1	0.003	5.639	1.772	17.944
Diameter of upper pubis to coccyx	0.180	0.080	5.064	1	0.024	1.197	1.024	1.400
Constant	-37.452	13.346	7.875	1	0.005	0.000		

APR=abdominoperineal resection; LAR=low anterior resection; β=coefficient; SE=standard error; Wald=Wald statistic; df=degrees of freedom; Sig=level of significance; Exp (β)=relative risk; CI=confidential interval. Logistic regression analysis of the factors indicated that anteroposterior diameter of the pelvic inlet, anteroposterior diameter of the pelvic outlet, the interspinous diameter, the intertuberous diameter, the height of pubic symphysis, the depth of the sacrococcygeal curvature, tumor invasive depth, and gender should be excluded, whereas BMI (P=0.026), distance of tumor from anal verge (P=0.003) and diameter of upper pubis to coccyx (P=0.024) were found to be significant for SPP completion (P<0.05). (Nagelkerke R Square=0.634).

our study, eight pelvic parameters that showed significant differences between the sexes were anteroposterior diameter of the pelvic inlet, anteroposterior diameter of the mid-pelvis, anteroposterior diameter of the pelvic outlet, the interspinous diameter, the intertuberous diameter, sacrococcygeal-pubic angle, diameter of upper pubis to coccyx and sacro-pubic distance. The above pelvic parameters except the sacrococcygeal-pubic angle represent the pelvis width, which were wider in female pelvis. On the contrary, the sacrococcygeal-pubic angle evaluate comprehensively sacrococcygeal length and bending degree, as well as the distance between pubis and the sacrum and coccyx, which was greater in male pelvis. While six pelvic parameters that showed no significant differences between the sexes were the height of pubic symphysis, the sacrococcygeal distance, the sacral distance, sacro-pubic angle, the depth of the sacrococcygeal curvature and the depth of the sacral curvature. The height of pubic symphysis, the sacrococcygeal distance and the sacral distance represent the pelvis depth, the depth of the sacrococcygeal curvature and the depth of the sacral curvature represent the degree of the pelvic curvature, and the sacro-pubic angle evaluate comprehensively sacral length and bending degree, as well as the distance between pubis and the sacrum, which were more overlap between the sexes, suggesting the measurements themselves may be a more useful predictor of difficulty than sex alone [16].

In this study, multivariate analysis showed that higher BMI, higher distance of tumor from anal verge, and larger diameter of upper pubis to coccyx were significantly associated with the success of SPP for mid-low rectal cancer. Furthermore, diameter of upper pubis to coccyx was the only one of the pelvic anatomical parameters significantly associated with the success of SPP, while other pelvic anatomical parameters had no correlations with the success of SPP. Larger diameter of upper pubis to coccyx reflects wider pelvis width, which could increase the pelvic working space and make a success of SPP completion. It is well known that the distance of tumor from anal verge is one of the most important factors influencing SPP completion. Higher distance of tumor from anal verge could lead to the success of SPP.

Besides larger diameter of upper pubis to coccyx and higher distance of tumor from anal verge, the present findings are valuable in suggesting that higher BMI could contribute most to the success of SPP, which is different from previous report [3]. Patients in the present study had an average BMI of 21.5±3.1 kg/m^2 (less than 25.0 kg/m^2), only five patients had BMI more than 25.0 kg/m^2. These BMI values were obviously lower than the general populations in western countries. This might be why BMI is not a risk factor of the success of SPP in our study. The possible explanation for these findings is the greater volume of peri-rectal fatty tissue in non-obese patients, which probably make the potential anatomical spaces of rectal surgery more likely to be found and mobilized. Our results have more or less similarities to Görög D et al [17]. They found that patient's obesity seemed to be a favorable factor for resectability of tumors located in the rectum when the surgical procedures were performed by surgeons with low case volume. Because the meso-rectum presents a considerable obstacle to the growth of cancers [18]. Their explanation is the probably smaller volume of peri-rectal fatty tissue in lean patients than in obese counterparts. Small volume of peri-rectal fatty tissue can contribute to the early tumor infiltration of the pelvic wall and/or adjacent organs, which decreased the rate of resectability of rectal cancer.

Conclusions

Our findings indicate that diameter of upper pubis to coccyx is the only one of the pelvic anatomical parameters significantly associated with the success of SPP, while other pelvic anatomical parameters had no correlations with the success of SPP. Besides larger diameter of upper pubis to coccyx and higher distance of tumor from anal verge, within the normal BMI range, higher BMI seemed to be a favorable factor for the success of SPP. Studies with larger sample sizes are needed to ascertain our results further.

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Disclosure of conflict of interest

None.

Abbreviations

DST, double stapling technique; CT, computed tomography; BMI, body mass index; SPP, sphincter preservation procedure; TME, total mesorectal excision; APR, abdominoperineal resection; LAR, low anterior resection; TNM, tumor node metastasis; MRI, magnetic resonance imaging.

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