CT-Determined Area of the Pelvis Occupied by an Upper Rectal Tumor as a Predictor of Surgical Difficulty in Patients Undergoing Laparoscopic Rectal Resection

Yoshitsugu Tsukamoto, Ryoji Makizumi, Takehito Otsubo, and Yuta Ogura

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Abstract
Objectives Laparoscopic surgery is widely used for treatment of colorectal cancer. However, due to the restricted operating space in patients with rectal cancer, the degree of surgical difficulty is greater than that in patients with colon cancer. For assistance in planning the surgery, we have calculated the pelvic volume, rectal volume, and tumor volume to derive occupancy of the rectum and tumor in the pelvic cavity. In the study described herein, we calculated the rectal tumor area and pelvic area by measuring the maximum diameter of the rectal tumor and the diameter of the pelvis on selected computed tomography (CT) slices and the analyzed these areas in relation to surgical outcomes.

Methods Sixty-two patients diagnosed with upper rectal cancer at St. Marianna University Hospital between October 2012 and December 2018 were included in the study. All were treated by laparoscopic surgery, having undergone computed tomography colonography (CTC) preoperatively. We calculated the rectal volume occupancy and rectal area occupancy and performed statistical analyses to determine whether a relation exists between these measurements and the surgical difficulty encountered or incidence of anastomotic leakage.

Results Significant positive correlation (r = 0.603, p < 0.01) was found between area occupancy and volume occupancy. Surgical difficulty, as evidenced by a relatively high blood loss volume, was significantly increased among patients with an area occupancy ≥ 52.54% (p = 0.0146). The incidence of anastomotic leakage was significantly high among patients with high area occupancy (p = 0.011) and particularly high in those with area occupancy ≥ 52.54%.

Conclusion The rectal area occupancy determined by means of CTC is a useful predictor of the frequency of complications and level of surgical difficulty in patients with upper rectal cancer treated laparoscopically.

Key words
Laparoscopic surgery, rectal cancer, computed tomography colonography, pelvic rectal occupancy

Introduction
Laparoscopic surgery is not only feasible for treatment of colorectal cancer but has become an attractive option because of its minimal invasiveness. It also allows for maintenance of bladder and sexual function because the magnified operative view helps surgeons identify and protect the pelvic nerves. Patients are expected to recover relatively quickly\(^1\)\(^{-}\)\(^4\). In addition, in terms of safety and degree of cure in cases of advanced colorectal cancer, outcomes similar to those achieved with open surgery are obtained\(^2\)\(^{-}\)\(^5\). Since laparoscopic surgery for colorectal cancer was first reported by Jacobs et al. in 1991\(^6\), the surgical indications have gradually increased, and the procedure has been widely adopted due to increased surgical skills and advances in medical devices\(^7\). Aware of its reliability, we have applied laparoscopic surgery for treatment of rectal cancer since early 2006. The indications for laparoscopic surgery...
in cases of rectal cancer have been gradually expanded at other hospitals also, although the effectiveness and safety of laparoscopic surgery for transverse colon cancer and rectal cancer have not been fully established. Factors such as local disease advancement, obesity, and extensive adhesions increase the degree of surgical difficulty, and decisions whether laparoscopic surgery is applicable are made at the various institutions on a case-by-case basis. Murakami et al. reported that obesity, a giant tumor, and a narrow pelvis are all risk factors for suture failure after laparoscopic abdominoperineal resection. These factors increase the difficulty of performing rectal surgery laparoscopically, especially in comparison to other surgical procedures performed for colorectal cancers, and the likelihood of complications is increased. A narrow pelvis usually narrows the field of vision, rendering both manipulation of forceps and anastomosis difficult. The intrapelvic space is usually smaller in men than in women; thus, the risk of anastomatic leakage after laparoscopic surgery is increased in men. In our department, we calculate the pelvic volume, rectal volume, and tumor volume, from which we derive the area occupied by rectum and tumor in the pelvic cavity. This occupancy, shown as a percentage, has been found to be a useful predictor of the degree of surgical difficulty and risk of complications when laparoscopic surgery is performed for treatment of upper rectal cancer. In the study described herein, we calculated the area of tumor occupancy simply by measuring the maximum diameter of the rectal tumor and the diameter of the pelvis on selected computed tomography (CT) slices. We then analyzed the surgical difficulty and incidence of postoperative anastomotic leakage.

**Patients and Methods**

**Patient selection**

Included in the study were 62 patients who were diagnosed with upper rectal cancer, i.e., cancer in the Ra portion, at St. Marianna University Hospital between October 2012 and December 2018 and treated subsequently by means of laparoscopic surgery. Not included in the study were patients who had previously undergone endoscopic submucosal dissection or endoscopic mucosal resection or in whom the tumor was not confined to the rectum. Computed tomography colonography (CTC) was performed preoperatively for all 62 patients.

**CTC**

In preparation for CTC, patients were placed on a low-residue, low-fat diet and given laxatives 1 day before the examination. CTC was performed by medical radiation technologists and radiologists under carbon dioxide insufflation in accordance with our hospital’s CTC protocol. An Aquilion/ONE VISION Edition CT system (Toshiba Medical Systems Co., Ltd., Tokyo, Japan) was used for the imaging in all cases. The beam width was set to 0.5 mm x 80 rows, slice thickness to 0.5 mm, reconstruction interval to 0.4 mm, and the pitch to 0.813. Nonionic contrast medium was used at a dose of 660 mgI/kg, and the entire volume was infused in 35 seconds. The bolus tracking was performed during the arteriovenous phase, with the region of interest being the abdominal aorta at the level of the third lumbar vertebra (L3). The threshold was set to 250 HU and the delay time to 20 seconds. The equilibrium phase started after contrast medium infusion and lasted 100 seconds. Carbon dioxide insufflation was performed with a PROTOCO2L system and catheter (6.7 mm, 20 Fr, 30 cc) (Sekisui Medical Co., Ltd., Tokyo, Japan).

**Measurement of the intrapelvic cavity, rectum, and tumor**

Each patient’s tumor was measured on axial cross-sectional CTC images obtained preoperatively at 5-mm slice thickness. The images were used to identify the site at which the diameter of the tumor was greatest. The longitudinal and transverse diameters of the rectum were then measured on a slice that passed through the center of the rectum. The longitudinal and transverse diameters of the pelvis were measured on the same slice. The calculations excluded the uterus or prostate and the bladder. Air in the rectum was also measured, and we calculated the pelvic diameter (PD) and rectal diameter (RD) on the basis of all measurements we obtained (Fig. 1).

We used the PD and RD to calculate occupancy of the rectum in relation to the pelvis as follows: The pelvic-rectal area occupancy (area occupancy) was defined as the percentage of the pelvic cavity occupied by the rectum at the site where the tumor diameter was greatest. The cut surface that includes the maximum tumor diameter can be imaged as an oval at this position. The oval area is $\pi AB$, where A is the radius of the vertical axis and B the radius of the horizontal axis. We performed the measurements based on these values, then calculated the area occupancy as follows:
Figure 1. Pelvic-rectal area occupancy
A: Pelvic longitudinal diameter (longitudinal PD)
a: Longitudinal rectal diameter (longitudinal RD)
B: Pelvic transverse diameter (transverse PD)
b: Transverse rectal tumor diameter (transverse RD)
Pelvic-rectal area occupancy (area occupancy), defined as the percentage of the pelvic cavity occupied by the rectum at the site where the tumor diameter is greatest, was calculated as follows:
\[
\frac{\pi \times \frac{1}{2} \text{ longitudinal RD} \times \frac{1}{2} \text{ transverse RD}}{\pi \times \frac{1}{2} \text{ longitudinal PD} \times \frac{1}{2} \text{ transverse PD}} \times 100 \quad \text{(and shown as a percentage)}
\]

We also evaluated volume occupancy. The volume was measured as described previously\(^1\). For each study patient, the volume was measured on a 3D reconstruction image that we created using ZioStation 2 (a 3D medical imaging processing workstation) and CT Colon Analysis software (Ziosoft Inc., Tokyo, Japan). The pelvic volume (PV) was defined as the rectal volume and tumor volume within the pelvic cavity and occupying the space between the superior margin of the pubic symphysis, the sacral promontory, and the anus. We devised an algorithm for extraction of the PV, allowing us to calculate the PV itself. We also devised an algorithm for extraction of the intrapelvic volume of the rectum (including the tumor), which yielded the RV. Furthermore, the calculations excluded the volumes of the uterus or prostate and the bladder (Fig. 2) Using the PV and RV values, we derived the occupancy of the rectum in relation to the pelvis according to the following formula:

Occupancy of the rectum in relation to the pelvis (volume occupancy) = RV/PV × 100 (and shown as a percentage)

Study variables
The following variables were examined: sex, age, disease stage, body mass index (BMI), time from the start of surgery to rectal transection, blood loss volume, number of staples used for the rectal stump, occurrence of anastomotic leakage, the tumor and rectal volume occupancy and tumor and rectal area occupancy in relation to the intrapelvic cavity. Anastomotic leakage was diagnosed on the basis of postoperative pyrexia, blood tests showing elevated leucocyte counts and C-reactive protein (CRP) levels, postoperative CT evidence of increased adipose tissue density, ascites, and/or free air.

Values are shown as mean ± SD. Sex, BMI, blood loss volume, time to rectal transection, and presence or absence of suture failure were analyzed in relation to area occupancy and volume occupancy by t-test or \(\chi^2\) test. Factors shown to be significant by such univariate analysis were subjected to multivariate logistic regression analysis. The relation between area occupancy and volume occupancy was assessed on the basis of Pearson’s correlation coefficient. JMP Pro Statistical Discovery 13.2 (SAS Institute Japan, Tokyo, Japan) was used for all statistical analyses, and p < 0.05 was considered statistically significant.
The study was approved by the St. Marianna University School of Medicine bioethics committee (approval number: 4404).

**Results**

The study group comprised 35 men and 27 women who ranged in age from 29 to 90 years (mean age: 67.7 years). The primary lesions were classified by disease stage as follows: stage 0 (2 patients [3.3%]), stage I (8 patients [12.9%]), stage II (19 patients [30.6%]), stage IIIa (18 patients [29.0%]), stage IIIb (10 patients [16.1%]), stage IIIc (2 patients [3.3%]) and stage IV (3 patients [4.8%]) (Table 1).

The overall area occupancy was 49.76 ± 10.74%, with a mean value of 50.50 ± 10.95% in men and 48.80 ± 10.58% in women (p = 0.533). The overall volume occupancy was 45.79 ± 9.59%, with a mean value of 48.65 ± 9.30% in men and 42.08 ± 8.81% in women (p = 0.005). In addition, significant positive correlation (r = 0.603, p < 0.001) was found between area occupancy and volume occupancy (Table 2).

The time to rectal transection was 190.5 ± 60.4 minutes, and the blood loss volume was 107.8 ± 180.5 mL. One, two, and three staples were used on the transected rectal stump in 24 patients (38.7%), 36 patients (58.1%), and 2 patients (3.2%), respectively. Anastomotic leakage occurred in a total of 14 patients (22.6%) (Table 3), 13 men (92.9%) and 1 woman (7.1%), with a significant difference between

| Variable | Data |
|----------|------|
| Total    | 62   |
| Age      | 67.7 ± 12.2 (29 - 90) |
| Sex      |      |
| Men      | 35 (56.5%) |
| Women    | 27 (43.5%) |
| Disease stage classification |      |
| 0        | 2 (3.3%) |
| I        | 8 (12.9%) |
| II       | 19 (30.6%) |
| IIIa     | 18 (29.0%) |
| IIIb     | 10 (16.1%) |
| IIIc     | 2 (3.3%) |
| IV       | 3 (4.8%) |
| Median BMI (range) |      |
| 25>      | 21.9 ± 3.37 (14.7 - 32.7) |
| 25 - 30  | 52 (83.9) |
| 30<      | 9 (14.5) |
|          | 1 (1.6) |

Mean ± SD (and range) values, number of patients, or number (and percentage) of patients are shown. BMI, body mass index.

**Table 1.** Characteristics of the Patients

| Variable |
|----------|
| Total patients (n = 62) |
| Male patients (n = 35) |
| Female patients (n = 27) |
| Rectal area occupancy | 49.76 ± 10.74 (26.15 - 78.46) |
|                      | 50.50 ± 10.95 (30.76 - 70.08) |
|                      | 48.80 ± 10.58 (26.15 - 78.46) |
| Pelvic-rectal volume occupancy | 45.79 ± 9.59 (21.21 - 67.64) |
|                      | 48.65 ± 9.30 (32.27 - 67.64) |
|                      | 42.08 ± 8.81 (21.21 - 62.21) |

Relation between rectal area occupancy and rectal volume occupancy:
Correlation coefficient: 0.603
95% CI: 0.416 – 0.741
p value: <0.001

*Men vs. women

**Table 2.** Rectal Area Occupancy and Rectal Volume Occupancy in the Total Patients and per Sex

| Factor                  | Data                     |
|-------------------------|--------------------------|
| Time to rectal transection (minutes) | 190.5 ± 60.4 (93 – 342) |
| Blood loss volume (mL)  | 107.8 ± 180.5 (5 – 972)  |
| Number of staples used  | 1.64 ± 1.65 (1 - 2)      |
|                        | 1 (38.7%)                |
|                        | 2 (58.1%)                |
|                        | 3 (3.2%)                 |
| Anastomotic leakage    | 14 (22.6%)               |
|                        | 48 (77.4%)               |
the sexes (p = 0.018). The leaks were managed by colostomy (4 patients [28.6%]), transanal drainage (7 patients [50%]), or antibiotic administration (3 patients [21.4%]). Thus, most of the leaks resolved after conservative treatment.

When we subjected the risk factors for anastomotic leakage to univariate analysis, we found a p value of 0.001 for area occupancy and a p value of 0.002 for volume occupancy (Table 4). When we entered these factors into multivariate analysis, we found a relation between anastomotic leakage and area occupancy (odds ratio [OR] 1.001, 95% confidence interval [CI], 1.000 to 1.001, p = 0.011), but no relation between anastomotic leakage and volume occupancy (OR 1.118, 95% CI 1.014 to 1.232, p = 0.002). Thus, the greater the rectal area occupancy, the greater the incidence of anastomotic leakage. Univariate analysis also showed male sex to be significant (p = 0.028) (Table 5).

We subjected the following factors to likelihood ratio testing for risk of complications: sex, area occupancy, volume occupancy (Table 6). The likelihood ratios were 7.375, 3.305, and 1.194, respectively.

We created a receiver operating characteristics (ROC) curve using the aforementioned results to investigate the cut-off value for area occupancy at which anastomotic leakage occurred. The cut-off value was 52.54, and the incidence of anastomotic leakage increased above this area occupancy value. Sensitivity and specificity were 85.7% and 72.9%, respectively (Fig. 3). Patients with area occupancies that met this criterion were referred to as the high-occupancy group.

We also compared surgical difficulty using the calculated cut-off values. Three factors were taken as indicators of surgical difficulty: time to rectal transection.

### Table 4. Leakage and No Leakage in Relation to Various Risk Factors

| Factor                        | Leakage | No leakage | p Value |
|-------------------------------|---------|------------|---------|
| Sex (male)                    | 13      | 22         | 0.002*  |
| BMI (kg/m²)                   | 22.83 ± 4.68 | 21.60 ± 2.89 | 0.230** |
| Rectal area occupancy (%)     | 57.60 ± 6.39 | 47.48 ± 10.70 | 0.011** |
| Pelvic-rectal volume occupancy (%) | 53.94 ± 8.91 | 43.40 ± 8.48 | 0.002** |
| Time to rectal resection (minutes) | 194.50 ± 57.4 | 189.33 ± 61.80 | 0.778** |
| Blood loss volume (mL)        | 87.43 ± 105.81 | 113.75 ± 197.61 | 0.610** |

BMI, body mass index.

*by χ² test  ** by t-test

### Table 5. Results of Univariate and Multivariate Analysis of Factors Associated with Anastomotic Leakage

| Factor                        | Univariate analysis | Multivariate analysis |
|-------------------------------|---------------------|-----------------------|
|                               | OR (95% CI)         | p Value               | OR (95% CI)         | p Value               |
| Sex (male)                    | 10.03 (1.397 – 71.98) | 0.002                 | 13.69 (1.327 – 141.21) | 0.028                 |
| BMI (kg/m²)                   | 1.114 (0.932 – 1.343) | 0.230                 |
| Rectal area occupancy (%)     | 1.001 (1.000 – 1.001) | 0.011                 | 1.001 (1.000 – 1.018) | 0.079                 |
| Rectal volume occupancy (%)   | 1.118 (1.014 – 1.232) | 0.002                 | 1.074 (0.965 – 1.193) | 0.191                 |
| Time until rectal transection (minutes) | 1.001 (0.988 – 1.014) | 0.778                 |
| Blood loss volume (mL)        | 0.995 (0.996 – 1.003) | 0.610                 |

OR, odds ratio; CI, Confidence interval; BMI, body mass index.

### Table 6. Results of Likelihood Ratio Testing for Risk of Complications

| Factor                        | Likelihood ratio (by chi-square test) | p Value |
|-------------------------------|--------------------------------------|---------|
| Sex                           | 7.375                                | 0.007   |
| Rectal area occupancy (%)     | 3.305                                | 0.069   |
| Rectal volume occupancy (%)   | 1.194                                | 0.178   |
Table 7. Degree of Surgical Difficulty in Cases of Rectal Area Occupancy < 52.54% and ≥ 52.54%

|                               | < 52.54% (n = 37 (59.7%)) | ≥ 52.54% (n = 25 (40.3%)) | p Value |
|-------------------------------|--------------------------|---------------------------|---------|
| Time to rectal transection (minutes) | 185.16 ± 59.89           | 198.40 ± 61.54            | 0.394   |
| Blood loss volume (mL)        | 64.54 ± 93.03            | 171.84 ± 250.42           | 0.015   |
| Number of staples used        | 1.62 ± 0.545             | 1.68 ± 0.558              | 0.347   |
| Anastomotic leakage           | 2 (5.4%)                 | 12 (48.0%)                | < 0.001 |
est affords the smallest working space and presents the highest level of difficulty when laparoscopic surgery is performed for rectal cancer. The area occupancy was selectively measured at the same site, and its effect may be greater than that of the volume occupancy because it translates to the space occupied by the tumor and bowel in relation to the entire intrapelvic space.

The intrapelvic space is smaller in men than in women, and this factor is a reported risk factor for the occurrence of suture failure after laparoscopic rectal surgery. We found, in the study described herein, that the risk of complications was greater in men than in women but that a significant difference did not exist between men and women in terms of area occupancy. This was evaluated at the site of maximum tumor diameter, and we believe that the pelvic diameter was smaller in the slice used for evaluation in men, although the difference in rectal diameter was probably due to the effects of the tumor rather than to the difference between men and women. For this reason, the numerator for the area occupancy value, which reflects the site of the maximum tumor diameter, will vary based on the tumor size, whereas the denominator will vary based on the difference between men and women. Variations will therefore occur due to individual factors, and we believe that this is why we found no statistical difference between men and women in terms of the area occupancy.

We investigated complications of laparoscopic surgery for rectal cancer and the associated risk factors using the occurrence of anastomotic leakage as the indicator. Rullier et al. investigated complications and risk factors related to rectal cancer surgery using anastomotic leakage in this way, and they found that anastomotic leakage was the most severe postoperative complication, with an associated mortality rate of 6% to 22%. The incidence of anastomotic leakage appears to be higher among cases of rectal cancer than among cases of other types of colorectal cancer, as documented by Fujiwara et al, who reported an incidence of 10% to 12% among patients with rectal cancer as opposed to an incidence of 2% to 5% among patients with other types of colorectal cancer. Diagnostic criteria for anastomotic leakage differ between hospitals. We consider postoperative pyrexia, an elevated leucocyte count, and blood C-reactive protein elevation to be suspicious for suture failure, and we perform CT when these changes arise. CT is performed for detection of increased adipose tissue density, ascites, and/or free air as evidence of anastomotic leakage. In calculating the incidence of anastomotic leakage among our study patients, we included those in whom suture failure was suspected, and this explains the relatively high incidence (22.6%) of anastomotic leakage noted.

Reported risk factors for suture failure following laparoscopic abdominoperineal resection are male sex, a narrow pelvis, a giant tumor, and obesity, among others. However, we did not observe any relation between anastomotic leakage and BMI, i.e., obesity, in our study. Of the patients in our study, 83.9% had a BMI < 25%, whereas 16.1% had a BMI ≥ 25%, which differs vastly from the obesity rate in the general Japanese population (according to the 2015 National Health and Nutrition Survey, obesity rates were 29.5% for men and 19.2% for women). The prevalence of obesity among patients included in our study was therefore lower than the national average, which probably explains why we found no relation between anastomotic leakage and obesity.

In addition to finding a significant relation between area occupancy and suture failure, we created an ROC curve to further investigate this relation, and we used a cut-off value of 52.54%. Patients with high area occupancy, i.e., with pelvic-rectal occupancy ≥ 52.54%, had an increased likelihood of developing anastomotic leakage. We also showed that the actual incidence of anastomotic leakage was higher among patients with high area occupancy. Thus, high area occupancy appears to be a convenient preoperative predictor of this complication.

We then performed a comparative investigation of surgical difficulty. Yamagishi et al. used the duration of surgery, blood loss volume, number of staples used for the rectal stump, and tumor location as indicators of the degree of surgical difficulty in cases of rectal cancer. We used the time to rectal transection, blood loss volume, and number of staples used for the rectal stump as indicators of surgical difficulty, and we compared high- and low-area occupancies in relation to these variables. We found no significant difference in the time to rectal transection or the number of staples used. However, we did find significant differences in blood loss volume and the occurrence of complications, with a higher incidence of anastomotic leakage among patients with high area occupancy, suggesting that surgery is relatively difficult in such patients. We believe that advanced surgical skills and advances in surgical devices have shortened operation times and reduced the number of staples needed. However, rectal resection was usually
difficult to perform in patients with high area occupancy due to difficulty in securing the surgical field. This may be the reason why the blood loss volume was significantly greater in this group of patients.

The more caudal, or lower, the lesion, the higher the risk of anastomotic leakage following laparoscopic surgery for rectal cancer, and we believe that placement of a covering stoma or transanal drain is necessary to reduce the frequency of complications and need for repeat surgery. The criteria used to determine whether a covering stoma or placement of a transanal drain is needed vary between hospitals. At our hospital, we create a stoma or insert a transanal drain in patients who undergo very low anterior resection, patients who have undergone radiotherapy, patients with recurrent disease, and patients in whom the degree of surgical difficulty is anticipated to be high. However, there are no definitive indications, and we make these decisions on a case-by-case basis. Although it is important to prevent complications, postoperative body fluid management is challenging after a stoma has been created, and the procedure causes patients to suffer psychologically, so we believe that definitive indications are needed for the procedure. Although we included only patients with a tumor located in the upper rectum in our study, we believe that it will be possible to obtain further data to establish indications for stoma creation or transanal drain placement in patients with high area occupancy by analyzing area occupancy in patients undergoing lower rectal laparoscopic surgery. Indications for laparoscopic surgery should also include surgeon-related factors, such as experience and techniques, tumor-related factors, such as tumor location and degree of progression, and patient-related factors, such as obesity and history of laparotomy.

To perform laparoscopic surgery safely, it is important for surgeons to understand the difficulties that can be encountered, the various preoperative factors predictive of such surgical difficulties, and countermeasures that can be used to prevent complications. Area occupancy may be a useful indicator in this regard. Surgery was relatively difficult for our patients with high area occupancy, so it would be desirable for such cases to be handled by expert surgeons. Patients with low area occupancy can be operated on safely by non-expert surgeons in the presence of instructor. Taking this approach would decrease surgeon-related risk factors and have an effect on tumor- and patient-related risk factors.

On the basis of our study results, we believe that the rectal area occupancy, calculated from measurements of pelvic and rectal diameter on CTC images, is useful for anticipating surgical difficulty and predicting complications of laparoscopic surgery performed for rectal cancer. Adding rectal area occupancy to established risk factors, such as male sex, a narrow pelvis, giant tumor, and obesity, provides for optimal preoperative assessment. It is possible to select cases that match a surgeon’s level of experience by predicting the degree of difficulty preoperatively, and we believe that area occupancy will be established as an important indicator and thus ensure safe surgery. In addition, area occupancy is easier to measure than volume occupancy and can be easily applied in clinical practice.

**Conclusion**

We conclude that the area of the pelvis occupied by an upper rectal tumor, calculated on CT images, can be used by laparoscopic surgeons to both anticipate the degree of surgical difficulty they will face and determine the risk of complications following rectal resection.

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**Conflicts of Interest**

The authors have nothing to disclose.

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