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MULTIMEDIA ARTICLE

Incidence and Clinical Outcomes of Gonadal Artery Injury during Colorectal Surgery in Male Patients

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Abstract

Background Gonadal artery is susceptible to accidental injury due to their anatomical proximity to the colon and rectum. There are few literature reviews focusing on this injury during colorectal surgery. We conduct a retrospective study to evaluate the incidence and the clinical significance of these injuries in terms of testicular size and testicular enhancement on the contrast CT scan.

Methods Patients' characteristic data included age, body mass index (BMI), diagnosis, operation type, cause of gonadal artery injury, side of injury, level of injury, method of vessel ligation, and follow-up period. We measured the testicular sizes before and after gonadal artery injury and measured the enhancement level by recording the mean attenuation value on the injury side and non-injury side of the testis on the CT scan.

Results The incidence of gonadal artery injury was 3.61% and 15 male patients with this injury were enrolled. There were 5 patients with iatrogenic injury and 10 patients with non-iatrogenic injury due to advanced tumor or inflammation. No patients had any complaints of testicular discomforts or atrophy after the surgery. The testicular sizes before and after the surgery showed no significant difference ($p = 0.877$). The mean attenuation values of the injury side and non-injury side of the testis also showed no significant difference ($p = 0.79$).

Conclusions Gonadal artery injury during colorectal surgery is not a rare complication. To prevent this injury, knowledge of the anatomy and staying in the proper plane of dissection are the key points. In patients with gonadal artery injury during colorectal surgery, sacrifice of the gonadal artery is safe without clinical significance in terms of testicular size and testicular enhancement on the contrast CT scan.

Keywords Gonadal artery · Colorectal · Male

Introduction

During colorectal surgery, genitourinary structures are susceptible to injury due to their anatomical proximity to the colon and rectum. The risk of injury increases with the complexity of the operation. Factors that increase the complexity of a colorectal operation are diverticulitis perforation, severe infection with pelvic abscesses, previous radiation, reoperative surgery, and locally advanced or recurrent cancer that distorts normal surgical planes.[1,2] The most commonly injured organ is the ureter, followed by the bladder and the urethra.[3] The incidence of gonadal arterial injury during microsurgical varicocelectomy has been estimated at 0.9–12%,[4,5] but the clinical consequence of testicular atrophy and spermatogenesis after gonadal artery injury was inconsistent.[4–8]

Up to date, there are few literature reviews focusing on the gonadal artery injury during colorectal surgery, although it is not a rare complication especially when advanced tumor or inflammation is over the dissection plane. Accidental gonadal artery injury during colorectal surgery may occur more commonly than expected, but the clinical significance of these

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arterial injuries is not known. In this study, we report the incidence of gonadal artery injury during colorectal surgery as determined by reviewing the chart, operative photo, and video. We also evaluate the clinical significance of these injuries in terms of testicular size and testicular enhancement on the contrast CT scan.

Materials and Methods

We conducted a retrospective study by reviewing the charts, operative photo, and video of the patients receiving colorectal surgery between October 2009 and September 2017 consecutively at Kaohsiung Veterans General Hospital, Taiwan. Patients' characteristic data included age, body mass index (BMI), diagnosis, operation type, cause of gonadal artery injury, side of injury, level of injury, method of vessel ligation, and follow-up period. We classified BMI into 3 groups: underweight (< 18.4), normal weight (18.5–24.9), and overweight (> 25) according to the WHO classification.[9] There were two main causes of gonadal artery injury: "non-iatrogenic" and "iatrogenic". "Non-iatrogenic" was defined as necessary injury of the gonadal artery due to advanced tumor or inflammation (Video, Fig. 1a,b) and "iatrogenic" as unintentional injury due to surgeon's manipulation (Video, Fig. 2a). The upper level injury was defined as the gonadal artery injury above the aortic bifurcation and lower level injury as below the aortic bifurcation.

The CT examinations were performed by at least eight multi-detector scanners (Toshiba, Aquilion, Nasu, Japan) with 3-mm slice thickness and 0.8-s gantry rotation time. Initially, unenhanced images were obtained. IV contrast (Iopamiro 300; Bracco, Milan, Italy) was given as 80–120 mL at a rate of 1–2 mL/s using an automatic pump injector (Angiomat 6000; Liebel-Flarsheim) via an antecubital vein. Scanning was initiated 100 s after the start of the injection.

The testicular size was measured by a single doctor (C-W Hsu). The images we chose for the preoperative testicular size measurement were the CT scan before the colorectal surgery; for the postoperative testicular size measurement were the CT scan after the colorectal surgery at least 1 year later (Fig. 1d and 2c). We measured the testicular size that was divided into the long-axis length and the short-axis width measurement. The long-axis length of the testis was measured between the upper border and lower border on the cross-sectional CT scan (Fig. 3a). The image showing the maximal cross-sectional area was chosen for the short-axis width (Fig. 3b). We measured the testicular enhancement level by placing a circular or ovoid region of interest[3] over the testis with gonadal artery injury but excluding the outer edges to avoid partial volume effects,[3] and the mean attenuation value was recorded in Hounsfield units[10] on the postoperative contrast-enhanced CT scan (Fig. 3c). Then, the other testis without gonadal artery injury was measured for comparison (Fig. 3d). Results were displayed as the median and range. Student's *t* test was used to analyze the association. All data were analyzed by using SPSS®, version 12.0 (SPSS Inc., Chicago, IL). $p < 0.05$ was accepted as statistically significant.

Results

There were 968 patients registered in this time period. Thirty-five patients had definite gonadal artery injury. We excluded

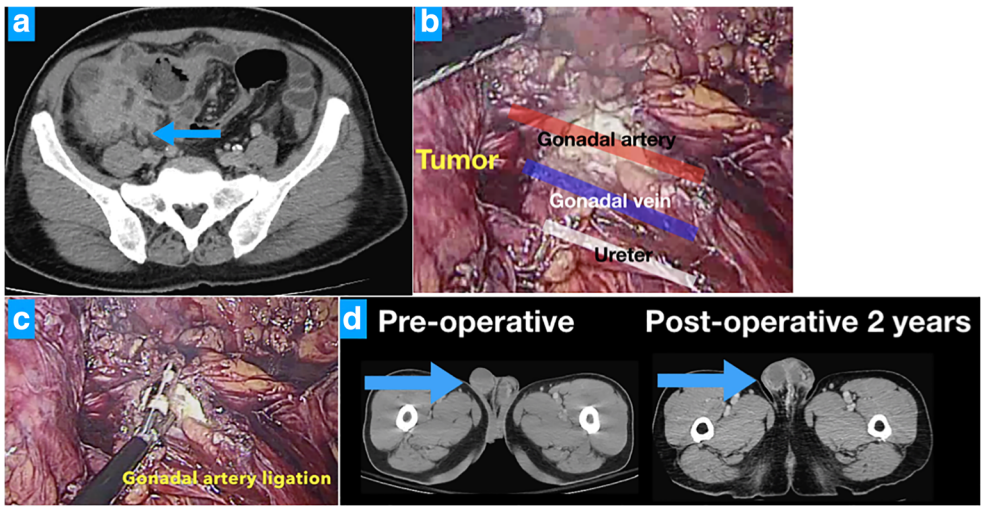

Fig. 1 **a** 63-year-old male (patient 6) had advanced ascending colon adenocarcinoma (cT4aN0M0, stage IIB) with retroperitoneal involvement. **b** During the medial to lateral dissection of the mesocolon in laparoscopic right hemicolectomy, the right ureter, gonadal artery, and vein were involved in the tumor. **c** We ligated the right gonadal artery at upper level by Ligasure® vessel sealing device. After the operation, the patient had no complaints of the scrotum or testis in the clinics. **d** The size and contour of the right testis had no significant difference on the contrast-enhanced CT scan 2 years later

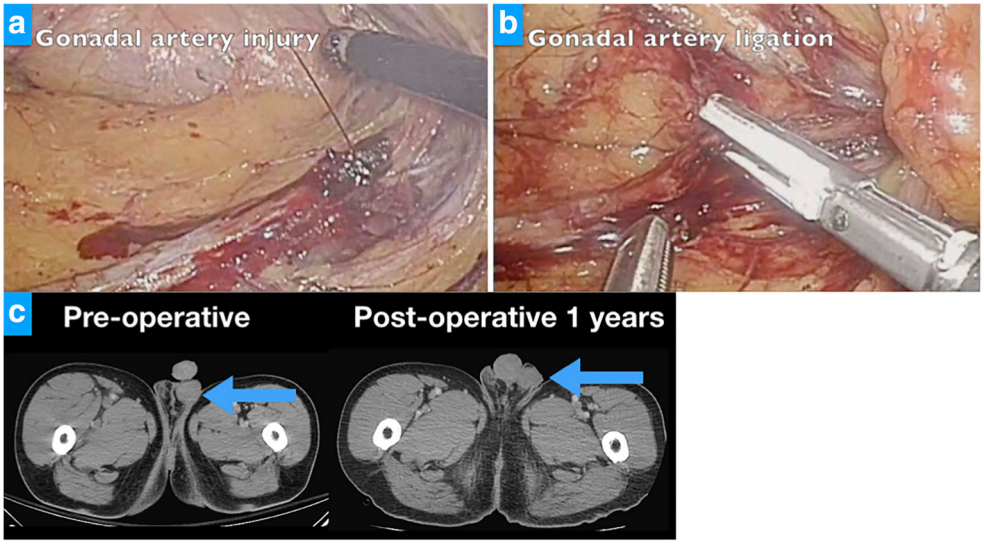

Fig. 2 **a** A 73-year-old male (patient 15) had sigmoid colon adenocarcinoma (cT1N0M0, stage I) During the medial to lateral dissection of the mesocolon in laparoscopic anterior resection, the left gonadal artery injury was noted. **b** We ligated the left gonadal artery at lower level by Ligasure® vessel sealing device. After the operation, the patient had no complaints of the scrotum or testis in the clinics. **c** The size and contour of the left testis had no significant difference on the contrast-enhanced CT scan 1 year later

female patients, patients with incomplete information, and patients with follow-up period less than 1 year. Ultimately, a total of 15 male patients with definite gonadal artery injury were enrolled in this study. The incidence of gonadal artery injury during colorectal surgery was 3.61% in this study. The clinical characteristics of 15 male patients with gonadal artery injury were showed in Table 1.

The mean age was 56 ± 13 (year, ranged from 38 to 73). There are 1 patient with underweight BMI, 9 with normal weight BMI, and 5 with overweight BMI. About the diagnosis, 13 patients had colorectal cancer and 2 patients had diverticulitis perforations. Of 13 patients with colorectal cancer, 2 had cancer perforation, 1 had neoadjuvant concurrent chemoradiotherapy (CCRT) for rectal cancer, and 3 had recurrent cancer. Open surgery was performed in 3 patients and laparoscopic surgery was performed in 12 patients with initial attempt but conversion to open in 4 patients. There were 5 patients with iatrogenic injury and 10 patients with non-iatrogenic injury due to advanced tumor or inflammation. Nine patients had left-side injury and 6 had right-side injury. Eight patients had lower-level injury and 7 had higher-level injury. Gonadal artery injury can be easily controlled by hand-tie ligation ($n = 4$), hemoclip ($n = 1$), or Ligasure® vessel sealing device (Fig. 1c and Fig. 2b, $n = 10$). The mean follow-up period was 39.6(months) ± 26.9 (ranged from 13 to 91).

Of 15 patients with gonadal artery injury, no patients had any complaints of scrotal or testicular discomforts after the

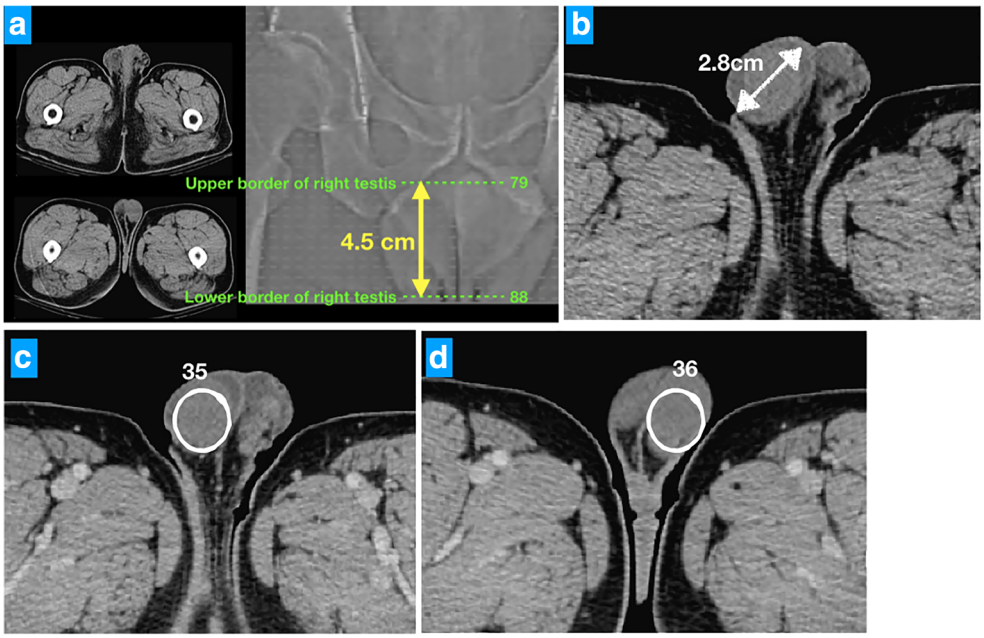

Fig. 3 **a** A 68 year-old male (patient 14) had right gonadal artery injury. The long-axis length of the testis was measured between the upper border and lower border on the cross-sectional CT scan. **b** The image showing the maximal cross-sectional area was chosen for the short-axis width. **c** A circular or ovoid region of interest was placed over the right testis and the mean attenuation value was measured in Hounsfield units on the postoperative contrast-enhanced CT scan. **d** Then, the left testis without gonadal artery injury was measured for comparison

Table 1 Clinical characteristics of 15 male patients with gonadal artery injury in colorectal surgery

Patient	Age	BMI	Diagnosis	Operation type	Cause of injury	Side	Level	Ligation method	Follow-up (months)
1	54	21	S-colon cancer, stage IIA	Lap. AR	Iatrogenic	Left	Lower	Hemoclip	87
2	38	25	Rectal cancer, stage I	Lap. LAR	Iatrogenic	Left	Lower	Ligasure	91
3	72	23	Cecal cancer, IIB	RH	Advanced tumor	Right	Upper	Ligasure	72
4	47	19	A-colon diverticulitis perforation	Lap. RH conversion to Open	Perforation with abscess	Right	Upper	Hand-tie	15
5	39	27	D-colon cancer with perforation, stage IVA	Lap. LH conversion to Open	Advanced tumor with abscess	Left	Upper	Hand-tie	48
6	63	30	Recurrent A-colon cancer, stage IIB	Lap. RH	Advanced tumor	Right	Upper	Ligasure	26
7	71	25	Recurrent S-colon cancer, stage IVB	AR	Advanced tumor	Left	Upper	Ligasure	36
8	38	19	Rectal cancer, stage IIC s/p CCRT	Lap. LAR conversion to Open	Advanced tumor	Left	Lower	Hand-tie	68
9	44	29	A-colon cancer with perforation, stage IIB	Lap. RH conversion to Open	Advanced tumor with abscess	Right	Lower	Hand-tie	55
10	63	31	T-colon cancer, stage IIIB	Lap. RH	Iatrogenic	Right	Upper	Ligasure	38
11	48	20	D-colon cancer, stage IIIC	Lap. LH	Advanced tumor	Left	Lower	Ligasure	29
12	51	28	S-colon diverticulitis perforation	AR	Perforation with abscess	Left	Lower	Ligasure	14
13	72	30	Recurrent S-colon cancer, stage IIIC	Lap.AR	Iatrogenic	Left	Lower	Ligasure	14
14	68	23	A-colon cancer, stage IIB	Lap. RH	Advanced tumor	Right	Upper	Ligasure	18
15	73	17	S-colon cancer, stage I	Lap.AR	Iatrogenic	Left	Lower	Ligasure	13

BMI body mass index, *S-colon* sigmoid colon, *A-colon* ascending colon, *D-colon* descending colon, *T-colon* transverse colon, *AR* anterior resection, *LAR* low anterior resection, *Lap* laparoscopic, *RH* right hemicolectomy, *LH* left hemicolectomy, *CCRT* concurrent chemoradiotherapy

surgery. No obvious scrotal tenderness or testicular atrophy on the physical examinations. The comparison of the testicular size on the CT scan was showed in Table 2. The median length and width of the testis before the injury were 4.3 cm (ranged from 3.7 to 4.9) and 2.4 cm (ranged from 2.1 to 2.6). The median length and width of the testis after the injury showed

Table 2 Comparison of the testicular size before and after gonadal artery injury on the CT scan

Patient	Before injury		After injury		
	Length (cm)	Width (cm)	Length (cm)	Width (cm)	*p* value
1	4	2.3	4	2.3	0.877
2	4.3	2.4	4	2.5	
3	3.7	2.2	4	2.3	
4	4.6	2.5	4.6	2.5	
5	3.7	2.1	4	2.1	
6	4	2.4	4	2.4	
7	4.3	2.3	4.3	2.3	
8	4.9	2.6	4.9	2.6	
9	4.6	2.2	4.9	2.1	
10	4	2.4	4.3	2.4	
11	3.7	2.5	3.7	2.5	
12	4.9	2.3	4.9	2.4	
13	4	2.4	4	2.4	
14	4.6	2.6	4.3	2.4	
15	4.3	2.3	4.6	2.3	
Median (range)	4.3(3.7–4.9)	2.4(2.1–2.6)	4.3(3.7–4.9)	2.4(2.1–2.6)	

no significant change ($p = 0.877$). The median attenuation values of the testis on the injury side and non-injury side on the postoperative contrast-enhanced CT scan were showed in the Table 3. The median attenuation value on testis with gonadal artery injury was 34 (31–37) and those without injury was 34(30–37), which showed no significant difference ($p = 0.79$).

Discussions

This is the first study reporting the incidence of gonadal artery injury during colorectal surgery and the clinical outcomes after the surgery. The incidence of gonadal artery injury during colorectal surgery was 3.61%, which was higher than the ureteral injury (0.28–0.44%) and bladder injury (< 1%).[11–13]

The risk of genitourinary injury can also depend on the surgeon's experience, especially with minimally invasive approaches.[10] Therefore, knowledge of the anatomy and meticulous dissection are the key points to avoid this injury. Staying in the holy plane of dissection will help in the prevention of the genitourinary injury. When mobilizing the colon along the white line of Toldt, maintaining the dissection plane just on the colonic side of the white line will ensure the lateralization of the retroperitoneal structures such as the ureter and the gonadal vessels. For the medial to lateral approach of laparoscopically mobilizing the mesentery of the retroperitoneum, one must first locate the sacral promontory, identify the pathway of the inferior mesenteric and superior hemorrhoidal artery, and initiate the plane of dissection just below the mesenteric vessels. This will help ensure access to the correct plane.[10]

But, sometimes, finding the appropriate planes can be difficult in patients with significant inflammation or repeat surgery. There were five risk factors associated with genitourinary injury during colorectal surgery including a severe diverticulitis or inflammatory bowel disease, a severe infection or abscesses, locally advanced or recurrent cancer that distorts normal dissection planes, previous radiation, and a reoperative field.[1,2]

Of the 15 patients with gonadal artery injury, 10 patients (66%) had these risk factors (10 with advanced cancer or inflammation, 3 with recurrent cancer, 1 with neoadjuvant CCRT, 2 with diverticulitis perforation). Actually, of these 10 patients, 3 had combined ureteral injury simultaneously. Of the 5 patients with iatrogenic gonadal artery injury, 4 patients (80%) had left-side injury at lower level during the laparoscopic medial-to-lateral dissection on the retroperitoneal plane (Fig. 2a). These injuries consisted of 3 lacerations and a thermal injury from Ligasure® vessel sealing device, which was similar to the iatrogenic ureteral injury, such as laceration, ligation, or thermal injury.[3] Underweight and overweight patients have a significantly increased risk of postsurgical complications compared with those with normal BMI in colorectal surgery.[14] Of these 5 patients with iatrogenic injuries, 3 had overweight BMI and 1 had underweight BMI. Obesity is another risk factor for genitourinary injuries, as the retroperitoneal organs in these patients are often displaced medially by large deposits of retroperitoneal fat, and are also encapsulated in fatty tissue.[10]

The clinical significance of gonadal artery injury in male patients was assessed using testicular size and enhancement measurements, as testicular atrophy is a potential and feared complication of arterial compromise.[4,5] Of 15 patients with gonadal artery injury after the colorectal surgery, no patients had any complaints of scrotal or testicular discomforts and no obvious testicular tenderness or atrophy on the physical examinations.

The method we used for measurement of the testicular size was based on the CT scan. Due to 3-mm slice thickness of the CT examination, there must be a ± 3 mm bias for the long-axis length of the testis. Also, there must be a bias on the enhancement level by placing a region of interest[3] over the testis on the contrast-enhanced CT scan. The ideal tool for the testicular size and enhancement level measurement is an orchidometer and sono-Doppler.[5] However, the patients who received colorectal surgery in our study did not receive the survey for the testis routinely before or after the surgery. Therefore, we measured the testicular size by the preoperative and postoperative CT scan and there was no significant difference (0.877). We also measured the median attenuation value of the testis to reflect the tissue perfusion.[15] The median attenuation values of the testis on the injury side and non-injury side on the

Table 3 The median attenuation values (HU) of the testis on the injury side and non-injury side on the postoperative contrast-enhanced CT scan

Patient	Injury side	Non-injury side	*p* value
1	36	35	0.79
2	33	33	
3	34	35	
4	37	38	
5	32	34	
6	35	35	
7	31	31	
8	33	34	
9	31	30	
10	36	33	
11	34	32	
12	37	37	
13	35	34	
14	35	36	
15	33	32	
Median (range)	34 (31–37)	34(30–37)	

postoperative contrast-enhanced CT scan were no significant difference ($p = 0.79$).

Why the testis does not have atrophy or ischemia even after the gonadal artery was ligated? There are three major arteries that supply the testicle: the testicular artery arising from the aorta; the cremasteric artery arising from the inferior epigastric artery; and the deferential artery arising from a branch of the superior vesical artery.[16] Anatomists state that there are numerous anastomoses between the testicular and deferential arteries in most males.[17] Therefore, at least in this small group study, it appears that the gonadal artery injuries do not represent a clinically significant complication.

There are at least three limitations in our study. First, this was a retrospective chart review study in nature and patient selection bias was inevitable. Second, the true incidence of gonadal artery injury could be underestimated because parts of the minor gonadal artery injuries could be neglected by the operative surgeon and not recorded in the operation note. Besides, before the laparoscopic era, some minor gonadal artery injury might be unnoticed without the magnification and the assistance of a laparoscopic camera. Third, the measurement of the testicular size was based on the CT scan and there must be a ± 3 mm bias due to the instrument limitation. Also, there must be a bias on the enhancement level measurement by placing a region of interest[3] over the testis on the contrast-enhanced CT scan.

Conclusion

Gonadal artery injury during colorectal surgery is not a rare complication. To prevent this injury, knowledge of the anatomy and staying in the proper plane of dissection are the key points. In patients with gonadal artery injury during colorectal surgery, sacrifice of the gonadal artery is safe without clinical significance in terms of testicular size and testicular enhancement on the contrast CT scan.

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Author Contribution Chao-Wen Hsu: study concept and design; acquisition of data; analysis and interpretation of data; drafting of the manuscript; statistical analysis. Min-Chi Chang, Chih-Chien Wu, Yu-Hsun Chen: acquisition of data. Jui-Ho Wang: critical revision of the manuscript for import ant intellectual content.

Compliance with Ethical Standards

Disclosures Chao-Wen Hsu MD, Min-Chi Chang MD, Jui-Ho Wang MD,

Chih-Chien Wu MD, Yu-Hsun Chen MD declare that they have no conflict of interest.

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