Surgery Today (2020) 50:703–710
https://doi.org/10.1007/s00595-019-01938-y

ORIGINAL ARTICLE

Early renal dysfunction after temporary ileostomy construction

Mizunori Yaegashi[1,2] · Koki Otsuka[1] · Toshimoto Kimura[1] · Teppei Matsuo[1] · Hitoshi Fujii[1] · Kei Sato[1] · Kiyoharu Takashimizu[1] · Tomoki Hatanaka[1] · Toru Yoshida[2] · Chihiro Tono[2] · Akira Sasaki[1]

Received: 23 May 2019 / Accepted: 29 November 2019 / Published online: 21 December 2019

Abstract

Purpose Loop ileostomy is often used to prevent complications after colorectal surgery, but it has been reported to cause renal impairment. This study aimed to evaluate the changes in the renal function after ileostomy and to compare these with the renal function after low anterior resection without ileostomy (low-ANT).

Methods The subjects included 58 patients who underwent ileostomy construction and closure for rectal cancer. The estimated glomerular filtration rate (eGFR) was calculated at specific time points after the index surgery. In addition, we conducted a case-matched study on 147 patients who underwent low-ANT.

Results The eGFR was significantly lower at 1 month after ileostomy than at the time of ileostomy construction (78.8 vs. 84.0, $p < 0.0001$) and did not improve after ileostomy closure. The only risk factor for a reduced eGFR was preoperative chemotherapy or chemoradiotherapy. In the case-matched study, 36 patients were allocated for each of the two groups. The number of ileostomy patients with a reduced eGFR was significantly increased 1 month after the index surgery ($p = 0.005$).

Conclusions The eGFR began to decrease at one month after ileostomy construction and did not improve after ileostomy closure.

Keywords Ileostomy · Glomerular filtration rate · Colorectal cancer · Renal impairment · Complication

Introduction

Anastomotic leakage remains a severe complication after colorectal surgery, with considerable effects on the quality of life and mortality [1, 2]. It has a high rate of occurrence, particularly in patients with risk factors, such as male sex, heart failure, and preoperative chemotherapy or chemoradiotherapy [3–5]. The formation of a defunctioning stoma, such as that seen with loop ileostomy or colostomy, had been thought to reduce the effects of anastomotic leakage and the rate of repeat intervention associated with leakage [6–8]. This stoma is often used in colorectal surgeries. One previous meta-analysis reported that ileostomy might be preferable over colostomy since this procedure is associated with fewer reoperations while also preventing anastomotic leakage after colorectal surgery.[9, 10]. The construction of an ileostomy reduces the risk of prolapse and sepsis, but a high stoma output can cause many complications, such as acute and chronic depletion of salt and water.

Dehydration due to a high stoma output is one of the most common reasons for readmission after ileostomy construction [11–13]. Indeed, recent studies have reported a decrease in the estimated glomerular filtration rate (eGFR) from ileostomy construction to closure [14, 15]. We need to design countermeasures for correcting the reduced eGFR. Measurement of the renal function is very important for determining when the renal function starts to decline after ileostomy construction and investigating whether or not the renal function improves after ileostomy closure. In addition, the changes in the renal function after ileostomy construction, compared with those after low anterior resection without ileostomy (low-ANT), remain unclear.

The present study evaluated the renal function from ileostomy construction to one year after ileostomy closure and compared the changes in the renal function between ileostomy and low-ANT.

✉ Mizunori Yaegashi
ymizunori@gmail.com

1 Department of Surgery, Iwate Medical University School of Medicine, 2-1-1 Idai-dori Yahaba, Shiwa, Iwate 028-3695, Japan

2 Department of Surgery, Iwate Prefectural Kuji Hospital, 10-1 Asahimati, Kuji, Iwate 028-0014, Japan

Methods

From January 2008 to December 2016, 717 patients with rectal cancer underwent operations at our hospital. This study included 68 patients who underwent loop ileostomy and subsequent ileostomy closure and 191 patients who underwent low-ANT.

First, we evaluated the renal function of patients who underwent loop ileostomy. Second, we conducted a case-matched study between cases of ileostomy and those of low anterior resection (Fig. 1). During this study, the patients were attended to at Iwate Medical University (IMU) in Japan. Patients with inflammatory bowel disease complications, such as ulcerative colitis and artificial dialysis, emergency surgery, and stage IV cancer were excluded from the study. The data were retrospectively collected from the patient records and included patient demographics, comorbidity, type of surgery, interval between ileostomy construction and closure, preoperative chemotherapy or chemoradiotherapy, adjuvant chemotherapy, and mortality. The amount of stoma output was recorded by medical staff during hospitalization. Any surgical complication associated with the construction or closure of the ileostomy was investigated. The protocol was approved by the institutional review board of IMU (H29-23).

This study defined a high stoma output as an output of > 2000 ml/24 h. At our institution, we administered an intravenous drip containing 500 ml of lactated Ringer's solution to patients with > 1000 ml of stoma output to correct dehydration associated with a high stoma output during hospitalization. We also used antidiarrheal drug as necessary to control the stoma output.

Stoma construction and closure

The loop ileostomy was constructed within approximately 20 cm from the ileocecal valve. The stoma was not rotated and was usually in its natural form. All ileostomies were everted and secured using intradermal sutures. At our institution, we performed stoma closure after confirming that none of the patients had recurrence based on computed tomography findings at 3 months after the index surgery. Furthermore, in patients who received adjuvant chemotherapy, stoma closure was subsequently performed. Under general anesthesia, stoma closure was performed with a peristomal skin incision, and intestinal anastomosis was performed using functional end-to-end anastomosis. Until June 2009, the peritoneum and muscles were closed in an ordinary fashion, and the skin was completely closed. After July 2009, a circumferential purse-string subcuticular suture was performed, leaving approximately 1 cm of defect at the center of the wound.

eGFR

The eGFR is often calculated using the equations from the Modification of Diet in Renal Disease study and the Chronic Kidney Disease Epidemiology of Collaboration [16, 17]. For this study, we used the Japanese Society of Nephrology formula, which was designed to more accurately estimate the eGFR in Japanese individuals [18], as follows:

$$\text{eGFR}\left(\text{mL/min/1.73 m}^2\right) = 194 \times \text{Serum creatinine}^{-1.094} \times \text{Age}^{-0.287}\ (\times 0.739 \text{ in females})$$

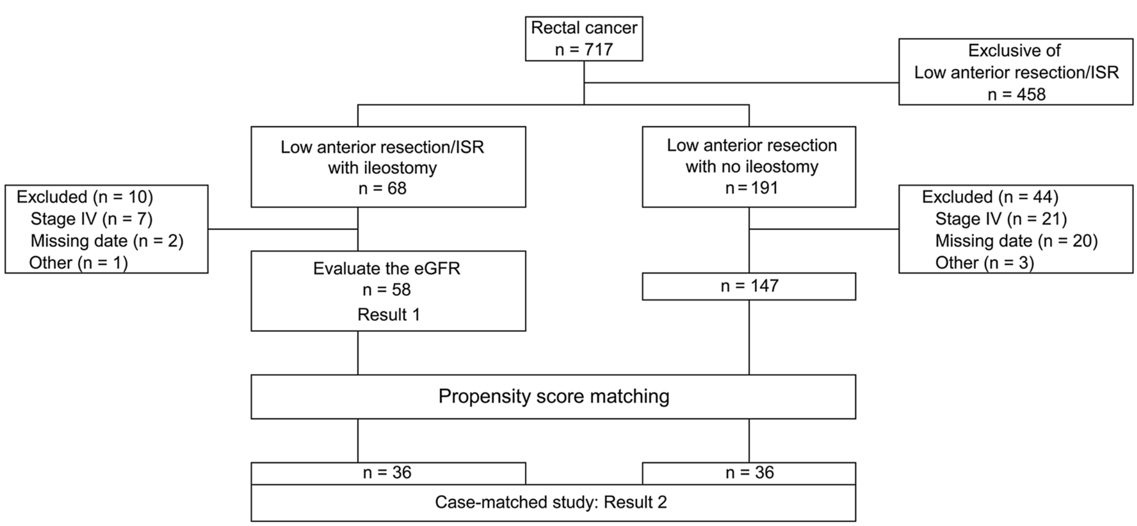

Fig. 1 Flow chart of the study inclusion. *ISR* intersphincteric resection

Definition of a decreased renal function

In this study, a decreased renal function was defined as a decrease in the eGFR of 5 mL/min/1.73 m^2 after the index surgery. That value was based on a previously reported annual eGFR decline rate of 0.75–1 mL/min/1.73 m^2 among individuals in the West, starting at 40 years old [19, 20]. In the general Japanese population, the average annual rate of eGFR decrease was reported to be 0.36 mL/min/1.73 [21]. The reduced eGFR of Japanese individuals was one-third of that of Western individuals. Recent reports have shown that the eGFR decrease ranges from approximately 4.5–6 mL/min/1.73 m^2 from ileostomy construction to ileostomy closure [15, 22]. Therefore, the eGFR in Japanese individuals decreased by more than 5 mL/min/1.73 m^2 within 1 year, thus indicating the occurrence of renal impairment.

Time points of the eGFR

To evaluate the eGFR of cases with loop ileostomy, the measurements were performed at the following time points: (A) at the time of the index surgery, (B) one month after the index surgery, (C) at the time of ileostomy closure, (D) six months after ileostomy closure, and (E) one year after ileostomy closure.

In the case-matched comparison of the changes in the eGFR, measurements of the eGFR for two groups were performed at the following time points: (i) at the time of the index surgery, (ii) 1 month after the index surgery, (iii) 6 months after the index surgery, (iv) 12 months after the index surgery, and (v) 18 months after the index surgery.

Statistical analyses

We hypothesized that the data were not normally distributed and performed nonparametric tests, such as Wilcoxon's signed-rank test, the Mann–Whitney *U* test, Chi-square test, and Fisher's exact test. The age, hypertension, and diabetes, which are reported as risk factors of renal impairment [15, 23], and risk factors evaluated using the univariate analysis in this study were selected for the multivariate analysis for determining the risk factors of a reduced eGFR. In the case-matched comparison, matching was done for the age, sex, preoperative chemotherapy/chemoradiotherapy, adjuvant chemotherapy, and anastomotic leakage. All statistical analyses were performed using the JMP software program, version 14.0 (SAS Institute, Inc., Cary, NC, USA). A p value of <0.05 was considered statistically significant.

Results

The eGFR after ileostomy

The renal function was evaluated in 58 of 68 patients who underwent loop ileostomy; of these, 10 patients were excluded because of stage IV cancer ($n=7$), multiple primary cancers ($n=1$), and missing data ($n=2$) (Fig. 1). The patient characteristics are summarized in Table 1. The participants included 41 males (71%) and 17 females (29%), with a median age of 60 years old (interquartile range [IQR] 50–66 years old). The median ileostomy duration was 193 days (IQR 151–265 days). Complications associated with ileostomy were found in 31 patients (53.4%). In addition, 26 patients (44.8%) had a high stoma output, and 10 (17.2%) had outlet obstruction. All cases of outlet obstruction emerged during hospitalization, and the abnormal stoma output with outlet obstruction was corrected. Three patients (5.5%) were readmitted because of dehydration, and two (3.6%) had peristomal skin problems. Three patients (5.2%) were readmitted because of dehydration with a high stoma output. Five patients (8.6%) had complications associated with ileostomy closure. Four patients (6.9%) experienced superficial surgical site

Table 1 Characteristics of patients

Variable	$n=58$
Age (years), median [IQR]	60 [50–66]
Gender (female), *n* [%]	17 [29.3]
Operation time (min), median [IQR]	261 [232–301]
Blood loss (mL), median [IQR]	27 [9.8–89.8]
pStage, *n* [%]	
0	0 [0.0]
I	16 [27.6]
II	19 [32.8]
IIIa	10 [17.2]
IIIb	13 [22.4]
Comorbidity	
Hypertension, *n* [%]	11 [19.0]
Diabetes, *n* [%]	8 [13.8]
Indications for surgery	
Low anterior resection, *n* [%]	49 [84.5]
Intersphincteric resection, *n* [%]	9 [15.5]
Other	
Period of ileostomy (day), median [IQR]	193 [151–265]
Preoperative chemotherapy or chemoradiotherapy, *n* [%]	19 [32.8]
Adjuvant chemotherapy, *n* [%]	33 [56.9]

IQR interquartile range

infection (SSI), and one patient (1.7%) experienced organ/space SSI. There was no operative mortality.

Measurement of the eGFR

The median (IQR) eGFR (mL/min/1.73 m^2) values at the different time points were (A) 84.0 (76.8–99.9), (B) 78.8 (71.7–90.0), (C) 78.1 (68.2–88.7), (D) 77.7 (65.2–87.8), and (E) 75.7 (64.7–85.5). The median eGFR values at time points B–E were significantly lower than at time point A ($p < 0.0001$) (Fig. 2). However, there was no marked difference in the median eGFR at any of the time points after time point B.

Risk factors for reduction in the eGFR

Of the 58 patients, 32 (55.1%) showed an eGFR reduction from the time of index surgery to ileostomy closure. In the univariate analysis, only preoperative chemotherapy or chemoradiotherapy ($p = 0.043$) was significantly associated with a reduced eGFR (Table 2). In the multivariate analysis, only preoperative chemotherapy or chemoradiotherapy was found to be significantly associated with a reduced eGFR (odds ratio [95% confidence interval] 4.0 [1.1–17.2], $p = 0.03$).

Case-matched comparison of the changes in eGFR

Of the 717 patients with rectal cancer, 58 patients underwent ileostomy, and 147 patients underwent low-ANT (Fig. 1); 36 ileostomy patients (62.1%) were case-matched with 36 low-ANT patients (24.5%) (Fig. 1). Table 3 presents the demographic characteristics of both groups.

The median (IQR) eGFR (mL/min/1.73 m^2) values at different time points after ileostomy were (i) 83.3 (73.1–93.0), (ii) 78.7 (69.1–89.9), (iii) 79.0 (68.1–90.0), (iv) 77.5 (63.9–86.4), and (v) 74.9 (64.5–82.6). The median (IQR) eGFR (mL/min/1.73 m^2) values at different time points after low-ANT were (i) 84.1 (72.3–97.5), (ii) 83.2 (70.2–95.9), (iii) 78.9 (68.1–93.0), (iv) 72.3 (67.7–89.6), and (v) 79.8 (66.0–89.9).

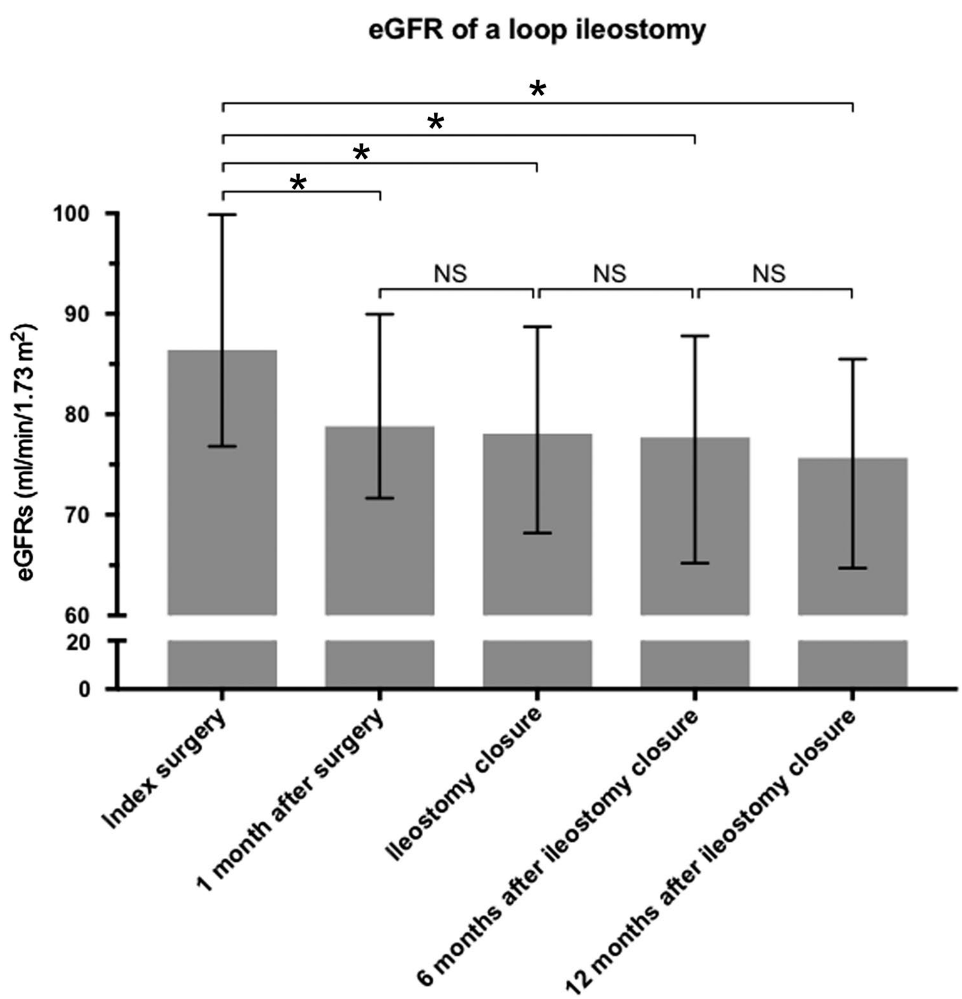

Fig. 2 Changes in the eGFR at each time point. The data are presented as the median and IQR. Comparisons were performed using Wilcoxon's signed-rank test. *$p < 0.0001$. *NS* not significant ($p > 0.20$), *eGFR* estimated glomerular filtration rate, *IQR* interquartile range

Table 2 Risk factors associated with a reduced eGFR from the time of index surgery to ileostomy closure

Variable	Classification	*n* (%)	*p* value
Age (years)	≥ 70	4/8 (50.0)	NS
	< 70	31/50 (62.0)	
Gender	Female	10/17 (58.8)	NS
	Male	22/41 (53.7)	
Hypertension	Yes	6/11 (54.6)	NS
	No	26/47 (55.3)	
Diabetes	Yes	4/8 (50.0)	NS
	No	28/50 (56.0)	
Period of ileostomy (days)	≥ 180	18/30 (60.0)	NS
	< 180	14/28 (50.0)	
High-volume output	Yes	16/26 (61.5)	NS
	No	16/32 (50.0)	
Outlet obstruction	Yes	7/10 (70.0)	NS
	No	28/48 (58.3)	
Preoperative chemotherapy or chemoradiotherapy	Yes	14/19 (73.7)	0.043
	No	18/39 (46.2)	
Adjuvant chemotherapy	Yes	20/32 (62.5)	NS
	No	12/26 (46.2)	

NS (not significant) = $p > 0.20$

eGFR estimated glomerular filtration rate

A comparison of the changes in the eGFR between the two groups

The changes in the eGFR at each time point after the index surgery were compared between ileostomy and low-ANT (ii–v). The changes in the eGFR were not significantly different between ileostomy and low-ANT at any time points after the index surgery. Figure 3 and Table 4 show the median (IQR) changes in the eGFR at each time point after ileostomy and low-ANT. The number of cases that showed an eGFR reduction at 1 month after the index surgery was significantly higher with ileostomy than with low-ANT (17 of 36 [47.2%] vs. 6 of 36 [16.7%]; $p = 0.005$). The number of cases that showed an eGFR reduction at the other time points was not markedly different between ileostomy and low-ANT (Table 5).

Discussion

In this study, the eGFR was significantly reduced after ileostomy construction. In other similar reports, the eGFR was shown to decrease from ileostomy construction to closure [14, 15]. Notably, in our study, the eGFR was already considerably reduced at one month after constructing the ileostomy and continued to decline thereafter. In addition,

Table 3 The comparison of the categorical variables between the two groups

Variable	Ileostomy (*n* = 36)	Low-ANT (*n* = 36)	*p* value
Gender (female), *n* [%]	11 [30.6]	11 [30.6]	1.0
Age (years) [IQR]	63 [56–68]	63 [58–69]	0.78
Operation time (min) [IQR]	253 [226–281]	212 [179–239]	0.0002
Blood loss (ml) [IQR]	23 [8–64]	12 [5–19]	0.0147
Diabetes, *n* [%]	5 [13.9]	8 [22.2]	0.36
Hypertension, *n* [%]	10 [27.8]	12 [33.3]	0.61
pStage, *n* [%]			0.27
0	0 [0.0]	0 [0.0]	
I	12 [33.3]	10 [27.8]	
II	10 [27.8]	8 [22.2]	
IIIa	5 [13.9]	12 [33.3]	
IIIb	9 [25.0]	6 [16.7]	
Adjuvant chemotherapy	17 [47.2]	17 [47.2]	1.0
Preoperative chemotherapy or chemoradiotherapy, *n* [%]	1 [2.8]	1 [2.8]	1.0
Indications for surgery, *n* [%]			0.011
Low-ANT	30 [83.3]	36 [100]	
Intersphincteric resection	6 [16.7]	0 [0.0]	
Wound infection, *n* [%]	1 [2.8]	0 [0.0]	0.31
Anastomotic leakage, *n* [%]	3 [8.3]	3 [8.3]	1.0
Mortality, *n* [%]	0 [0.0]	0 [0.0]	1.0
Period of ileostomy, day [IQR]	161 [141–278]		

Low-ANT low anterior resection without ileostomy, *IQR* interquartile range

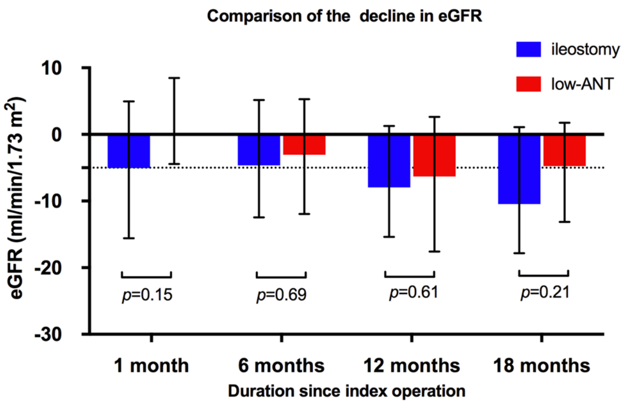

Fig. 3 The comparison of the decline in the eGFR. The data are presented as the median and IQR. Comparisons were performed using Wilcoxon's signed-rank test. *eGFR* estimated glomerular filtration rate, *IQR* interquartile range

the reduced eGFR did not improve after ileostomy closure (Fig. 2). Dehydration due to high-volume output of intestinal fluids from the ileostomy, as well as fluid malabsorption in the colon, may be associated with renal impairment [11–13]. Therefore, prevention of renal dysfunction after ileostomy construction can be achieved by performing early countermeasures, such as early ileostomy closure and correction of water and electrolytes. Early stoma closure was reported to be safe in select patients without anastomotic leakage [24–26]. Beck-Kaltenbach et al. [14] reported that patients with a decreased eGFR after ileostomy had significantly higher rates of severe surgical closure-related complications than cases with non-decreased eGFR after ileostomy; therefore, the timing of stoma closure is important. Migdanis et al. [27] reported that the supplementation of a special oral drink after discharge from hospital throughout the prescribed period was useful for preventing readmission due to fluid and electrolyte abnormalities. These previous studies underscore the importance of the early management of fluid and electrolytes after ileostomy construction. Gessler et al. [15] suggested that another stoma should be chosen, if possible, in patients at risk for renal impairment. Kim et al. [28] suggested that a fecal diversion device was a useful and safe alternative to a diverting stoma.

In our study, preoperative chemotherapy or chemoradiotherapy was found to be a risk factor for an eGFR reduction. A high stoma output or outlet obstruction was not evaluated as a risk factor because we performed correction for dehydration due to a high stoma output or outlet obstruction.

Other studies have reported that older and hypertensive patients had an increased risk of renal impairment and dehydration following loop ileostomy [13, 15, 23]. Scripcariu et al. [22] and Hayden et al. [29] reported that neoadjuvant chemotherapy was associated with readmission for dehydration. In the present case-matched study, the change in the eGFR tended to decline more after ileostomy than after low anterior resection, and the number of cases with a reduced eGFR at one month after the index surgery was significantly higher after ileostomy than after low anterior resection. These were unexpected results, as surgical stress was presumed to cause a reduced eGFR at one month after the index surgery, and we considered the finding of the number of cases with a reduced eGFR at other time points to not be significantly different between the two groups, thus indicating that a reduction of the eGFR after ileostomy construction occurs at an early stage after surgery. The renal function worsens with age, and a reduced eGFR gradually worsens with time [21]. We considered that the reason for the numbers of cases with a reduced eGFR at other time points was not significantly different between the ileostomy and low anterior resection groups is the eGFR in the two groups gradually decreased with time. Although no all cases of ileostomy showed a decline in the renal function, the ileostomy construction itself carried a

Table 5 Cases with a ≥ 5 mL/min/1.73 m^2 decline in the eGFR after index surgery

Duration after the index surgery	Ileostomy ($n=36$)	Low-ANT ($n=36$)	*p* value
1 month	17 (47.2%)	6 (16.7%)	0.005
6 months	20 (55.6%)	14 (38.9%)	0.16
12 months	21 (58.3%)	20 (55.6%)	0.81
18 months	23 (63.9%)	18 (50.0%)	0.23

eGFR estimated glomerular filtration rate, *Low-ANT* low anterior resection without ileostomy

Table 4 Amount of change in the eGFR (mL/min/1.73 m^2) after index surgery

Duration after the index surgery	Ileostomy ($n=36$)	Low-ANT ($n=36$)	*p* value
1 month, median [IQR]	− 5.1 [from − 15.6 to 5.0]	0.0 [from − 4.5 to 8.5]	0.15
6 months, median [IQR]	− 4.7 [from − 12.5 to 5.2]	− 3.1 [from − 12.0 to 5.3]	0.69
12 months, median [IQR]	− 8.0 [from − 15.4 to 1.3]	− 6.3 [from − 17.6 to 2.6]	0.61
18 months, median [IQR]	− 10.5 [from − 17.8 to 1.1]	− 4.8 [from − 13.1 to 1.8]	0.21

Low-ANT low anterior resection without ileostomy, *eGFR* estimated glomerular filtration rate, *IQR* interquartile range risk of decreasing the eGFR. In our study, the readmission rate due to dehydration from a high stoma output was 5%. Therefore, patients with risk factors for renal impairment should be considered for post-ileostomy management, as described above, or be managed with other operative methods.

A reduced renal function can occur with aging. In general, the eGFR gradually decreases after 40 years of age. In the general Japanese population, the average annual rate of decrease in the eGFR was reported to be 0.36 mL/min/1.73. This rate is significantly higher in individuals < 70 years old with an initial eGFR of < 50 mL/min/1.73 m^2 and in those 70–79 years old with an initial eGFR of < 40 mL/min/1.73 m^2 [21]. Imai et al. [21] reported that hypertension, proteinuria, and a lower eGFR were significant risk factors for a faster decline in the eGFR in a general Japanese population. In our study, the median decrease in the eGFR at 1 month after constructing the ileostomy was 5.2 mL/min/1.73 m^2, which was considerably higher and faster than the reported rate in the general Japanese population. The reduced eGFR associated with ileostomy may increase the risk of renal failure, considering that the eGFR did not improve after ileostomy closure. Renal impairment is a specific risk factor for cardiovascular events and increased mortality [30, 31]. In addition, chronic kidney disease and renal impairment can increase cancer-specific mortality [32–34]. Therefore, patients with ileostomy, particularly those with risk factors for renal dysfunction, should be followed up early.

Several limitations associated with the present study warrant mention. This was a retrospective study, and the data were collected from the patients' medical records. Furthermore, we did not include the operation time or blood loss among the factors used for matching (i.e., age, sex, preoperative chemotherapy/chemoradiotherapy, adjuvant chemotherapy, and anastomotic leakage). We concluded that significant differences in the operation time and blood loss between the two groups were inevitable because ileostomy construction increases the operative time and procedural time. However, we do not believe that the difference of 40 min in the operation time and 10 ml in blood loss had a significant effect on the eGFR. As mentioned above, we referred to a few reports [24–28] concerning countermeasures for renal dysfunction; however, we did not take such countermeasures in this study. It is challenging to develop countermeasures for the early reduction in the eGFR after ileostomy. In addition, we were unable to measure the ileostomy output per day and after hospital discharge and could not investigate the living conditions after discharge. We were also unable to research the long-term survival associated with renal impairment for ileostomy.

Conclusions

The eGFR was significantly reduced at one month after ileostomy construction and did not improve even after ileostomy closure. The number of patients with a reduced eGFR at one month after the index surgery was higher with ileostomy than with low-ANT. We observed an early reduction in the eGFR after ileostomy construction.

Acknowledgements The authors would like to thank all of the members of the IMU School of Medicine for their excellent assistance and Enago (www.enago.jp) for the English language review.

Funding No funding was received for this study.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This retrospective study was approved by the institutional review board of Iwate Medical University (IMU).

Research involving human and animal participants This study was an observational study with no intervention.

Informed consent All patients provided their informed consent before the surgery. According to the institutional review board of IMU and based on the retrospective design of this study, we informed the public regarding the research program.

References

1. Mirnezami A, Mirnezami R, Chandrakumaran K, Sasapu K, Sagar P, Finan P. Increased local recurrence and reduced survival from colorectal cancer following anastomotic leak: systematic review and meta-analysis. Ann Surg. 2011;253:890–9.
2. Ashburn JH, Stocchi L, Kiran RP, Dietz DW, Remzi FH. Consequences of anastomotic leak after restorative proctectomy for cancer: effect on long-term function and quality of life. Dis Colon Rectum. 2013;56:275–80.
3. Shinji S, Ueda Y, Yamada T, Koizumi M, Yokoyama Y, Takahashi G, et al. Male sex and history of ischemic heart disease are major risk factors for anastomotic leakage after laparoscopic anterior resection in patients with rectal cancer. BMC Gastroenterol. 2018;18:117.
4. Vasiliu EC, Zarnescu NO, Costea R, Neagu S. Review of risk factors for anastomotic leakage in colorectal surgery. Chirurgia (Bucur). 2015;110:319–26.
5. Yoshioka Y, Uehara K, Ebata T, Yokoyama Y, Mitsuma A, Ando Y, et al. Postoperative complications following neoadjuvant bevacizumab treatment for advanced colorectal cancer. Surg Today. 2014;44:1300–6.
6. Marusch F, Koch A, Schmidt U, Geibetaler S, Dralle H, Saeger HD, et al. Value of a protective stoma in low anterior resections for rectal cancer. Dis Colon Rectum. 2002;45:1164–71.
7. Gastinger I, Marusch F, Steinert R, Wolff S, Koeckerling F, Lippert H, et al. Protective defunctioning stoma in low anterior resection for rectal carcinoma. Br J Surg. 2005;92:1137–42.

8. Yao H, An Y, Zhang Z. The application of defunctioning stomas after low anterior resection of rectal cancer. Surg Today. 2019;49:451–9.
9. Rondelli F, Reboldi P, Rulli A, Barberini F, Guerrisi A, Izzo L, et al. Loop ileostomy versus loop colostomy for fecal diversion after colorectal or coloanal anastomosis: a meta-analysis. Int J Colorectal Dis. 2009;24:479–88.
10. Tilney HS, Sains PS, Lovegrove RE, Reese GE, Heriot AG, Tekkis PP. Comparison of outcomes following ileostomy versus colostomy for defunctioning colorectal anastomoses. World J Surg. 2007;31:1142–51.
11. Shabbir J, Britton DC. Stoma complications: a literature overview. Colorectal Dis. 2010;12:958–64.
12. Messaris E, Sehgal R, Deiling S, Koltun WA, Stewart D, McKenna K, et al. Dehydration is the most common indication for readmission after diverting ileostomy creation. Dis Colon Rectum. 2012;55:175–80.
13. Paquette IM, Solan P, Rafferty JF, Ferguson MA, Davis BR. Readmission for dehydration or renal failure after ileostomy creation. Dis Colon Rectum. 2013;56:974–9.
14. Beck-Kaltenbach N, Voigt K, Rumstadt B. Renal impairment caused by temporary loop ileostomy. Int J Colorectal Dis. 2011;26:623–6.
15. Gessler B, Haglind E, Angenete E. A temporary loop ileostomy affects renal function. Int J Colorectal Dis. 2014;29:1131–5.
16. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. Ann Intern Med. 1999;130:461–70.
17. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF 3rd, Feldman HI, et al. A new equation to estimate glomerular filtration rate. Ann Intern Med. 2009;150:604–12.
18. Matsuo S, Imai E, Horio M, Yasuda Y, Tomita K, Nitta K, et al. Revised equations for estimated GFR from serum creatinine in Japan. Am J Kidney Dis. 2009;53:982–92.
19. Eriksen BO, Ingebretsen OC. The progression of chronic kidney disease: a 10–year population-based study of the effects of gender and age. Kidney Int. 2006;69:375–82.
20. Lindeman RD, Tobin J, Shock NW. Longitudinal studies on the rate of decline in renal function with age. J Am Geriatr Soc. 1985;33:278–85.
21. Imai E, Horio M, Yamagata K, Iseki K, Hara S, Ura N, et al. Slower decline of glomerular filtration rate in the Japanese general population: a longitudinal 10–year follow-up study. Hypertens Res. 2008;31:433–41.
22. Scripcariu DV, Siriopol D, Moscalu M, Scripcariu V. Variations of the renal function parameters in rectal cancer patients with a defunctioning loop ileostomy. Int Urol Nephrol. 2018;50:1489–95.
23. Takeda M, Takahashi H, Haraguchi N, Miyoshi N, Hata T, Yamamoto H, et al. Factors predictive of high-output ileostomy: a retrospective single-center comparative study. Surg Today. 2019;49:482–7.
24. Danielsen AK, Park J, Jansen JE, Bock D, Skullman S, Wedin A, et al. Early closure of a temporary ileostomy in patients with rectal cancer: a multicenter randomized controlled trial. Ann Surg. 2017;265:284–90.
25. Farag S, Rehman S, Sains P, Baig MK, Sajid MS. Early vs. delayed closure of loop defunctioning ileostomy in patients undergoing distal colorectal resections: an integrated systematic review and meta-analysis of published randomized controlled trials. Colorectal Dis. 2017;19:1050–7.
26. Alves A, Panis Y, Lelong B, Dousset B, Benoist S, Vicaut E. Randomized clinical trial of early versus delayed temporary stoma closure after proctectomy. Br J Surg. 2008;95:693–8.
27. Migdanis A, Koukoulis G, Mamaloudis I, Baloyiannis I, Migdanis I, Kanaki M, et al. Administration of an oral hydration solution prevents electrolyte and fluid disturbances and reduces readmissions in patients with a diverting ileostomy after colorectal surgery: a prospective, randomized, controlled trial. Dis Colon Rectum. 2018;61:840–6.
28. Kim S, Jung SH, Kim JH. Ileostomy versus fecal diversion device to protect anastomosis after rectal surgery: a randomized clinical trial. Int J Colorectal Dis. 2019;34:811–9.
29. Hayden DM, Pinzon MC, Francescatti AB, Edquist SC, Malczewski MR, Jolley JM, et al. Hospital readmission for fluid and electrolyte abnormalities following ileostomy construction: preventable or unpredictable? J Gastrointest Surg. 2013;17:298–303.
30. Go AS, Chertow GM, Fan D, McCulloch CE, Hsu CY. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. N Engl J Med. 2004;351:1296–305.
31. Sarnak MJ, Levey AS, Schoolwerth AC, Coresh J, Culleton B, Hamm LL, et al. Kidney disease as a risk factor for development of cardiovascular disease: a statement from the American Heart Association Councils on Kidney in Cardiovascular Disease, High Blood Pressure Research, Clinical Cardiology, and Epidemiology and Prevention. Hypertension. 2003;42:1050–65.
32. Chen DP, Davis BR, Simpson LM, Cushman WC, Cutler JA, Dobre M, et al. Association between chronic kidney disease and cancer mortality: a report from the ALLHAT. Clin Nephrol. 2017;87:11–20.
33. Na SY, Sung JY, Chang JH, Kim S, Lee HH, Park YH, et al. Chronic kidney disease in cancer patients: an independent predictor of cancer-specific mortality. Am J Nephrol. 2011;33:121–30.
34. Weng PH, Hung KY, Huang HL, Chen JH, Sung PK, Huang KC. Cancer-specific mortality in chronic kidney disease: longitudinal follow-up of a large cohort. Clin J Am Soc Nephrol. 2011;6:1121–8.