Colorectal surgery navigation using fluorescence, artificial intelligence, and mixed reality

Shunjin Ryu, MD, Ph, D; Takahiro Kitagawa, MD; Keisuke Goto, MD; Atsushi Nagashima, MD; Takehiro Kobayashi, MD; Junichi Shimada, MD;
Ryusuke Ito, MD, Ph, D; Yukio Nakabayashi, MD, Ph, D
Department of Digestive Surgery, Kawaguchi Municipal Medical Center

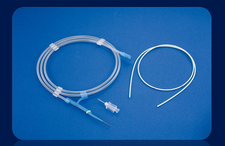
Introduction

- With the spread of minimally invasive surgery (MIS) nationwide, society demands MIS that guarantees safety and curability.
- In our hospital, for the safe performance of MIS and educational purpose, we have been actively introducing surgical navigation.
- We investigated fluorescence ureteral navigation (FUN), holographic navigation (HN) using mixed reality technique, and artificial intelligence navigation (AIN) by deep learning.

The values are presented as the median [Interquartile range] or n (%).



VISERA ELITEII
Olympus

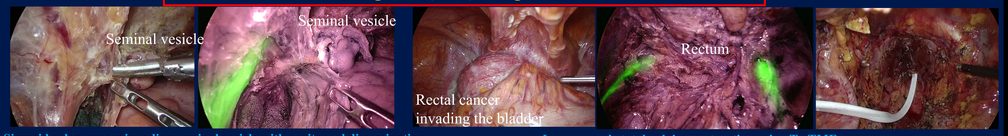


Fluorescent ureteral catheter (FUC)



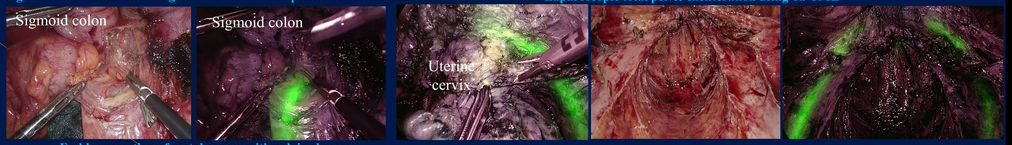


Fluorescence ureteral navigation (FUN) using fluorescent ureteral catheter



Sigmoid colon cancer invading seminal vesicle with peritoneal dissemination

Laparoscopic total pelvic exenteration using Ta-TME



En bloc resection of rectal cancer with pelvic abscess covered by the pelvic wall and right adnexa

Hartmann procedure with combined resection of the uterus and ovary

Purpose and Method

Patients with stage T4 colorectal cancer (n=208)
From January 2017 to November 2022
Kawaguchi Municipal Medical Center

After February 2020
patients who were preoperatively considered
to carry a high risk of ureteral damage.

FUN＋Group (n=37) | **FUN－Group (n=171)**

- In the FUN＋ group, fluorescence ureter navigation was performed with FUN and the VISERA ELITE2 system.
- FUN insertion was performed before surgery.
- The two groups were compared in terms of surgical outcomes and patient characteristics retrospectively.

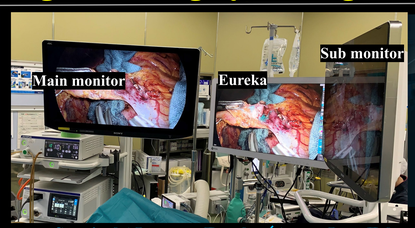
Result

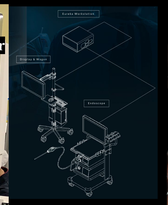
	T4FUN＋	T4FUN－	P-value
Operative duration (minutes) [a]	427 [365–621]	316 [262–398]	<0.001
Blood loss (ml)	10 [5–80]	20 [5–100]	0.398
Postoperative hospital stay (days)	12 [9-19]	11 [9-15]	0.112
Postoperative complications (CD grade III or over)	5 (14%)	18 (11%)	0.570
Ureteral injury	0	2 (1.6%)	1.000
Surgical procedure			<0.001
Open	0	43 (35%)	
laparoscopic	37 (100%)	128(75%)	
Conversion to open surgery	0/37	9/43 (21%)	0.003

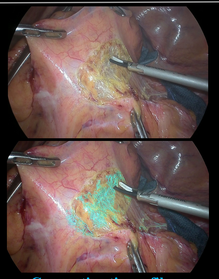
FUN can help to safely increase the laparoscopic surgery rate while safely visualizing the ureter.

Table. Features of surgical navigations

Artificial intelligence	Surface anatomy	Real time information	Not invasive
Fluorescence	See through anatomy (5-10mm)	Real time information	Invasive (ICG, catheter)
Hologram	Deep anatomy	Preoperative information	Not invasive







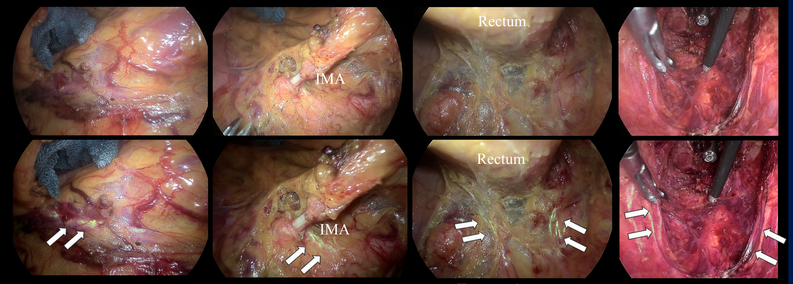
Connective tissue fibers

Surgical AI system Eureka（Anaut Inc., Tokyo, Japan）

This AI model is connected to the laparoscopic system and is able to highlight anatomical structures such as connective tissues appearing in the dissected layer, nerves, and ureters in the surgical field in real time.

Kumazu Y, Kobayashi N, et al. Sci Rep. 2021 Oct 27;11(1):21198.

Artificial intelligence navigation -Highlight of anatomical structure-



Ureter | Lumbar splanchnic nerves | Hypogastric nerves | Pelvic visceral nerve (S3, S4)

Purpose

Evaluation of the surgeons' subjective satisfaction scores with Artificial intelligence navigation (AIN) with Eureka

Method

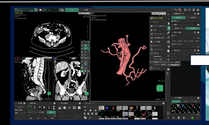
In the left colorectal surgery (n=10, from November 2022 to December 2022), surgeons who participated in the surgery rated their subjective satisfaction scores (SSSs) with the visibility provided by AIN for each anatomical structure.

SSSs were obtained based on a visual analog scale ranging from 0 to 10, representing bad to good.

Result

Anatomical structure	Surgeons' subjective satisfaction scores
Right hypogastric nerve during the median approach	4.5[3–6.]
Lumbar splanchnic nerves during dissection of the dorsal IMA	7[6–7]
Ureter during sigmoid mesocolon mobilization after IMA ligation	3[2–6]
Bilateral hypogastric nerves at the dorsal rectum	4[3–5]
Pelvic visceral nerves (S3, S4)	3[2–5.25]
Connective tissue in the dissection layer	9[8-10]

Although the navigation effects of the AIN may varies by anatomical structure, AIN can potentially assist anatomical recognition.



Pre operative CT image



Holoeyes system
(Holoeyes, Inc., Tokyo, Japan)



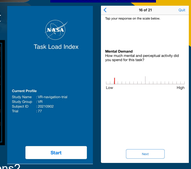
Hololens2/Microsoft



Subjective evaluation of mental workload
The NASA-TLX



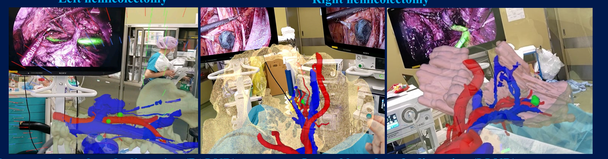
A 3D hologram of the arteries, veins and tumor was downloaded to HoloLens2 with the Holoeyes MD system.
Lymph node dissection and central vascular dissection was performed while viewing the holograms with HoloLens2.



Holographic navigation (HN) using mixed reality technique



Left hemicolectomy | Right hemicolectomy



Para aorta lymph node dissection (PALND) | Lateral lymph node dissection (LLND)

Purpose

This study aimed to investigate the feasibility of HN using mixed reality technique and subjective evaluation of mental workload for surgeons in colorectal surgery (n=41, from August 2021 to December 2022).

Method

Surgical outcome and TLX score of each surgery and evaluated.

Result

Age (years)	72 [64-78]
Male/Female	33 / 8
BMI (kg/m^2)	23.5 [22.0-27.2]
Ileocecal resection	2 (5%)
Partial resection of descending colon	3 (7%)
Partial resection of transverse colon	4 (10%)
Right hemicolectomy	15 (37%)
Left hemicolectomy	6 (15%)
Sigmoidectomy	1 (2%)
LLND	10 (2%)
PALND	3 (7%)

Open / laparoscopic	0/41
Conversion to open surgery	0
Operative duration (minutes)	368 [291-454]
Blood loss (ml)	10 [3-15]
Postoperative hospital stay (days)	10 [8-16]
Postoperative complications (CD grade III or over)	5 (12%)

TLX score	
Own performance	20 [8–30]
Mental demand	30 [20–50]
Physical demand	55 [45–63]
Temporal demand	50 [40–60]
Effort	55 [40–63]
Frustration	60 [50–65]
Weighted Rating	36 [30-45]

HN is a highly novel surgical concept that can potentially reduce the mental demand on surgeons.

Conclusion

The invasive insertion of FUC allows visualization of the ureter covered with fat. AIN can only show anatomy when it is exposed, but it is noninvasive and should improve with learning.
HN is not real-time, but it can help you understand deep anatomy obtained from preoperative images.
The combination of these navigation methods is expected to result in more accurate and easy anatomical recognition.
It may help to improve the rate of minimally invasive surgery, surgical difficulty reduction, and surgical education.