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Evaluation of a new motorized endoscope versus conventional endoscopy: a single-center, single-blind, randomized controlled trial

Seoyeon Lee[1,4], Gihong Park[2,4], Mi Jin Oh[1], Ji Kon Ryu[1,2] & Hyunsoo Chung[1,2,3]✉

Despite advances in gastrointestinal endoscopy, the core mechanical principle remains unchanged. This single-center, single-blind, randomized controlled non-inferiority trial compared a novel motorized endoscope (ME) with a conventional endoscope (CE) in 178 adults undergoing screening esophagogastroduodenoscopy. Participants were randomized 1:1 and blinded by pre-procedure sedation. 78 patients received ME and 84 received CE procedures. ME was non-inferior to CE in the primary outcome of total operability score (no biopsy: 95% CI − 1.77 to 0.59, margin − 3; biopsy: − 2.65 to 1.39, margin − 4) and significantly reduced physical fatigue (1.35 ± 0.48 vs. 1.63 ± 0.62; $p = 0.002$) and improved lens cleanliness (1.83 ± 0.59 vs. 2.17 ± 0.87; $p = 0.004$) in individual operability items, while lowering physical demand (1.39 ± 0.49 vs. 1.67 ± 0.63; $p = 0.002$) in NASA-TLX score. CE achieved superior image quality in overall assessment, view, and resolution (all $p < 0.05$). Patient satisfaction and safety were comparable. ME provided ergonomic benefits without compromising safety or patient experience, achieving non-inferior operability.

***Trial registration*. Clinical Research Information Service (CRIS), TRN: KCT0010918, Registration date: 19/08/2025.**

Flexible gastrointestinal endoscopy system is an essential medical device for the diagnosis and treatment of gastrointestinal diseases. It allows early diagnosis and treatment, improving patient outcomes and reducing morbidity[1,2]. It also provides real-time visualization for targeted interventions such as lesion removal, hemostasis, and stricture dilation, thereby enhancing clinical decision-making and disease management[3–5].

Although endoscopy systems have evolved over time, several mechanical limitations persist. While accessory instruments and imaging technologies like image-enhanced endoscopy have advanced rapidly, improvements in the mechanical design—particularly in physical control and maneuverability—remain limited[6–9]. In contrast, laparoscopic and robotic surgical systems have shown continuous and substantial progress in both hardware and ergonomics, broadening their application across general surgery, obstetrics and gynecology, urology, and thoracic surgery[10–13]. Since the introduction of the first electronic video endoscope in 1983, the basic operating principles of flexible endoscopy remain largely unchanged. The manual control knobs, actuated via mechanical strings and a chain-sprocket structure, still requires considerable thumb force to control the bending section. Additionally, the air, water, and suction functions are controlled by mechanical valves, relying entirely on finger force. Prolonged use may cause strain, leading to fatigue and musculoskeletal disorders[14,15].

To overcome these limitations, a new high-resolution motorized flexible endoscope (ME) has been developed. Designed with a focus on reducing operator strain, the ME incorporates motor-driven articulation and electronic air-water-suction controls to improve procedural comfort. This study aimed to evaluate the clinical usability of the newly developed ME system (ME-400, MGS-400; MedInTech Inc., Seoul, South Korea) and to assess whether it is non-inferior to a conventional endoscope (CE) (CLV-290, CV-290, GIF-HQ290; Olympus Corp., Tokyo, Japan) in diagnostic esophagogastroduodenoscopy (EGD). As the first clinical application of the novel ME in patients, this trial primarily focused on endoscopist-reported operability as the main outcome, reflecting the

[1]Department of Internal Medicine, Seoul National University Hospital, 101, Daehak-ro, Jongno-gu, Seoul, Republic of Korea. [2]Department of Internal Medicine and Liver Research Institute, Seoul National University College of Medicine, 101, Daehak-ro, Jongno-gu, Seoul, Republic of Korea. [3]Department of Medical Device Development, Seoul National University College of Medicine, 101, Daehak-ro, Jongno-gu, Seoul, Republic of Korea. [4]These authors contributed equally: Seoyeon Lee and Gihong Park. ✉email: h.chung@snu.ac.kr

importance of operator handling in a device with a fundamentally different mechanical and ergonomic design, while also considering image quality, patient satisfaction, and safety.

Methods

New motorized endoscopy system

Unlike conventional endoscopes that rely on mechanical control knobs to manipulate the bending section via tensioned strings and a chain-sprocket structure, ME utilizes motors installed within the light source unit. These motors receive electrical signals from the control interface to control scope articulation (Fig. 1B). Shifting the power transmission mechanism from the control interface to the light source unit reduces internal components in the control interface, lowering its total weight by approximately 41.7% compared to a conventional endoscope, to 350 g. In addition, replacing the manual knob, which operates under the tension of a mechanical string, with an electronic encoder wheel reduced the physical effort required for operation (Fig. 1A and B). To preserve the familiar tactile feedback and maneuvering sensation comparable to conventional endoscopes and to minimize user unfamiliarity, the angulation control torque was adjusted and optimized. This resulted in a reduction of approximately 76.5–90.6%, with torque in the up, down, left, and right directions reduced to ≤ 0.1 Nm, compared to the CE system (Supplementary Video S1). Moreover, to mimic the maneuvering sensation of CE, the new system implemented reactive force similar to that of CE.

Furthermore, while maintaining a familiar grip design and operational feel to ensure ease of adoption and user familiarity, ergonomic improvements were made by repositioning the encoder wheels and buttons using the space gained from component reduction, further reducing finger fatigue (**Figure S1**). The reduction in wheel radii—from 34 mm (up/down) and 26.5 mm (left/right) to 22 mm and 21 mm for the encoder wheels—resulted in approximately 35.3% and 20.8% decreases, respectively, thereby lowering finger strain and enhancing accessibility. As shown in Fig. 1C and D, the air-water-suction functionality was converted from mechanical valves to electrical switches, reducing the finger load required for operation by 49.6–90.9% for water, suction, and other buttons except for the air button, which requires less than or equal to 1 N in both systems. To increase familiarity with the air/water function, a single electrical switch with two pushing steps were used to mimic the original mechanical valve's operating sensation. The first step requires less than or equal to 1 N for the air function, and the second step requires at least 6.2 N for the water function, which remains quantitatively lower than the force required by manual valves in the CE system. This transition to electrical switches not only reduces finger fatigue, but also eliminates failures caused by valve detachment or O-ring degradation. It further enhances usability by allowing users to map any desired function to their selected buttons. Additionally, various software can be integrated to enhance procedural control, allowing users to customize operational settings. For example, the system can be programmed to sustain air or suction activation beyond button release, triggered either by a prolonged press or a double-click gesture.

The CE system uses a high-definition (HD) monochrome charge-coupled device (CCD) sensor with a resolution of 1280 × 720 pixels, combined with a rotating red, green, and blue (RGB) filter-applied disk for color rendering. This can cause a color breakup phenomenon in the images, potentially interfering with diagnosis[16]. In ME, adopting full high-definition (FHD) color complementary metal oxide semiconductors (CMOS) sensor with a resolution of 1920 × 1080 pixels eliminates color breakup phenomena while providing twice the image resolution compared to CE (**Figure S2**). Other specifications, including field of view, insertion tube diameter, working length, total length, instrument channel diameter, and angulation, were developed to remain identical. A detailed comparison between the ME and CE is presented in Table 1.

Study design

This single-center, single-blind, randomized controlled non-inferiority trial was conducted at Seoul National University Hospital between July and December 2024. Participants who volunteered for screening EGD were enrolled via the Korea National Enterprise for Clinical Trials if eligible. The inclusion criteria were adults aged 19–70 years who were healthy, voluntarily undergoing screening EGD, and provided written informed consent. Key exclusion criteria included contraindications to EGD, recent gastrointestinal bleeding, history of gastric surgery or endoscopic submucosal dissection, severe cardiopulmonary or psychiatric illness, coagulation disorders, pregnancy, or sedative hypersensitivity. Further details of the inclusion and exclusion criteria are provided in the Supplementary material.

Prior to this trial, a pilot study was conducted. Three core items of operability (air button functionality, easy handling, and physical fatigue) were assessed. The mean total score from these items was 7.81 ± 2.23 for ME and 5.25 ± 1.77 for CE, with a mean difference of approximately 2.6 points (score range 5–15, with lower scores indicating better operability). Based on these findings, a non-inferiority margin of 10% was extrapolated for the present study. Considering the result of the pilot study, non-inferiority margin was set conservatively to ensure clinical relevance while maintaining statistical feasibility.

Using PASS 2022 (NCSS Statistical Software, USA), the required sample size for a mean non-inferiority test was calculated. Based on a one-sided significance level of 0.025, 80% power, and a non-inferiority margin of 10% for the primary outcome score, 76 participants per group (total of 152) were required. Accounting for a 15% dropout rate, the final sample size was set at 180 participants (90 per group). Randomization was performed using a block randomization method with mixed block sizes to ensure a 1:1 balanced allocation between the two groups. The randomization table was generated using SAS 9.4 for reproducibility. Table generation and web-based randomization were managed by the Medical Research Collaborating Center, Seoul National University Hospital. All endoscopic procedures were performed under sedation. Participants were blinded to group assignment (single blind), as the sedative was administered before the procedure began.

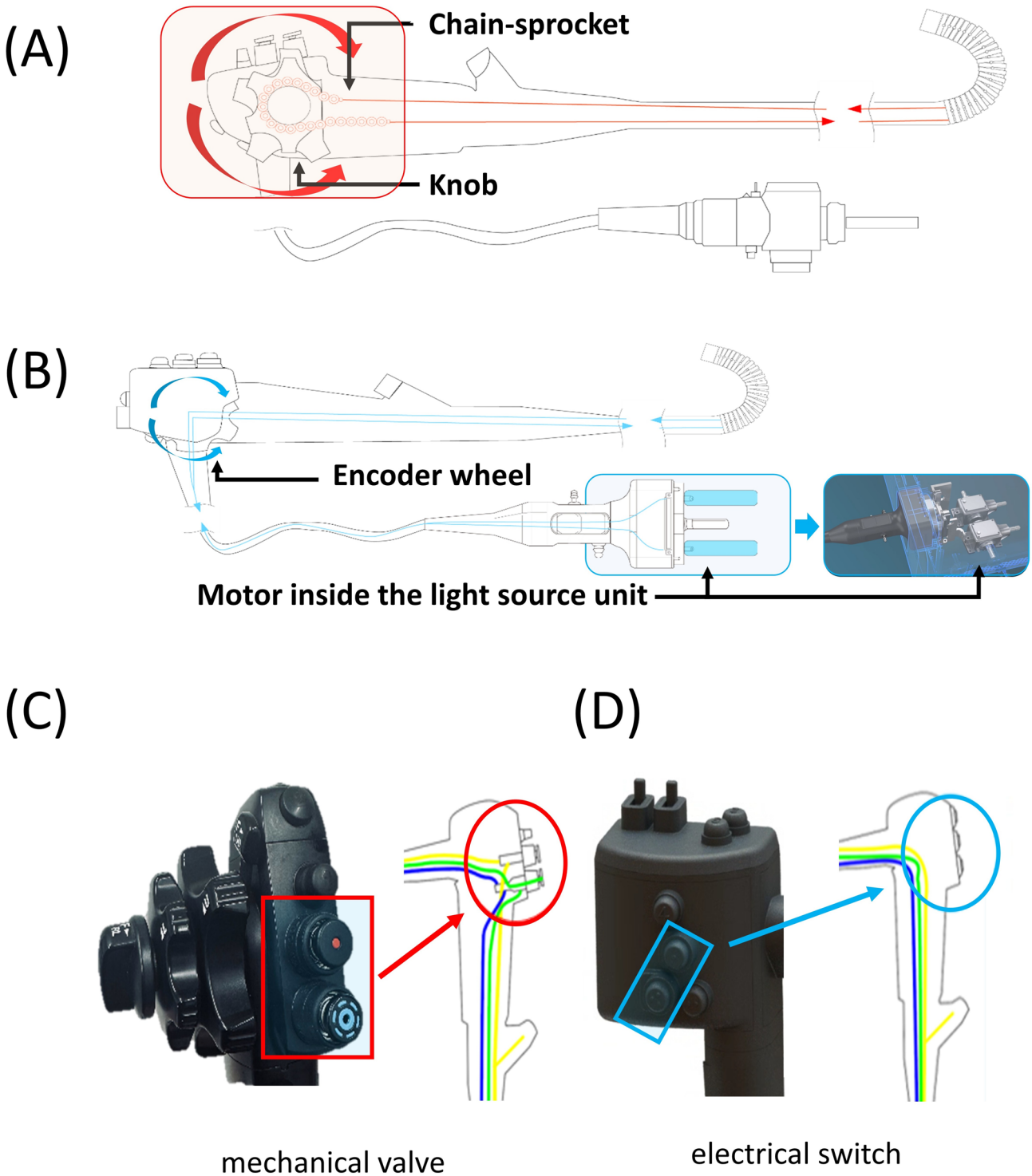

Fig. 1. Structural Differences Between Conventional and Motorized Endoscope. **A** Conventional endoscope system employing a mechanical chain-sprocket structure connected to a manual knob for bending control. **B** Motorized endoscope system utilizing an encoder wheel and an internal motor embedded within the light source unit, enabling bending control via electrical signals. **C** Conventional endoscope with mechanical valves for air, water, and suction functions. **D** Motorized endoscope incorporating low-resistance electrical switches replacing mechanical valves to reduce operator fatigue.

Ethics statement

This clinical trial followed the principles of the Declaration of Helsinki and was approved by the Institutional Review Board of Seoul National University Hospital (IRB number: 2312-010-1489). The study was registered in the Clinical Research Information Service (CRIS, KCT0010918) on 19/08/2025.

		Conventional Endoscope	Motorized Endoscope
Depth of field		Normal: 7–100 mm, Near focus: 3–7 mm	5–100 mm
Distal end outer diameter		10.2 mm	10.0 mm
Control interface weight		≥ 600 g	350 g
Angulation control torque	Up	≤ 1.28 Nm	≤ 0.12 Nm
	Down	≤ 0.92 Nm	≤ 0.14 Nm
	Left	≤ 0.51 Nm	≤ 0.12 Nm
	Right	≤ 0.47 Nm	≤ 0.11 Nm
Function button operating force	Air	≤ 1 N	≤ 1 N
	Water	≥ 12.30 N	≥ 6.2 N
	Suction	≥ 10.98 N	≤ 1 N
	Other	≥ 8.20 N	≤ 1 N
Knob/wheel radius	Up, Down	34 mm	22 mm
	Left, Right	26.5 mm	21 mm
Motor-actuated control		X	O
Flexible software installation		X	O
Sensor type		Monochrome CCD	Color CMOS
Image resolution		HD (1280 × 720 pixels)	FHD (1920 × 1080 pixels)
Field of view		140°	
Insertion tube diameter		9.9 mm	
Working length		1,030 mm	
Total length		1,350 mm	
Instrument channel diameter		2.8 mm	
Angulation	Up	210°	
	Down	90°	
	Left	100°	
	Right	100°	

Table 1. Specifications of conventional and motorized endoscopes. CCD, charge-coupled device; CMOS, complementary metal oxide semiconductors; HD, high definition; FHD, full high definition.

Endoscopic procedure and data collection

All procedures were performed under sedation by two expert endoscopists who have over 20 years of experience (H.C and J.K.R). The procedure followed a standardized sequence (esophagus → stomach → duodenum → stomach [retroflexion] → esophagus) to ensure thorough observation without blind spots. Additionally, at least eight images were captured in accordance with the European Society of Gastrointestinal Endoscopy guidelines.

Outcomes

The primary endpoint was the total operability score, assessed using a standardized 9-item questionnaire completed by endoscopists immediately after each procedure. The questionnaire was administered in person and evaluated procedural convenience, including general ease of use, maneuverability of the motor-based system (ME only), physical fatigue, visual fatigue, air insufflation, suction quality, lens irrigation, tool insertion into the working channel, and biopsy performance.

Secondary endpoints included the individual operability items and patient-reported outcomes on discomfort, satisfaction, and willingness to repeat the procedure. Patient surveys were distributed via a secure mobile messaging app approximately four hours post-procedure and repeated on day seven. Additional secondary endpoints included the NASA Task Load Index (NASA-TLX) assessing endoscopist mental workload and image quality ratings, both assessed immediately following the procedure. Lower scores indicated better performance across all items. Details of the surveys and questionnaires used for assessments are provided in the Supplementary material.

Statistical analysis

Survey scores are presented as mean ± standard deviation. Categorical variables are expressed as frequency and percentage. Continuous variables were compared using the t-test, and categorical variables using the chi-square test. A p-value < 0.05 was considered statistically significant. Regarding missing data, there were three cases where surveys were not completed (two from endoscopists and one from a patient). These cases were treated as missing values in the intention-to-treat analysis and excluded from the per-protocol analysis. All statistical analyses were performed using R software (version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria).

Results

Patient enrollment

A total of 250 individuals were recruited. Of these, 72 were excluded due to not meeting the inclusion criteria or meeting the exclusion criteria. The remaining 178 individuals were randomized, with 88 allocated to the ME group and 90 to the CE group. Ten participants in the ME group and six in the CE group did not undergo endoscopic examination, resulting in 78 and 84 participants undergoing the procedure, respectively. In the ME group, one endoscopist survey could not be evaluated. In the CE group, one endoscopist survey could not be evaluated, and one patient did not complete the patient survey. A summary of patient enrollment is shown in Fig. 2.

Baseline characteristics, patient survey results and safety

In both the ITT and PP populations, no significant differences in sex or age were observed between groups. Similarly, no significant differences were observed in any items of the first (4 h post-endoscopy) or second (7 days post-endoscopy) patient surveys, including sedation, pain scale, satisfaction, and willingness to undergo repeat endoscopy.

No severe adverse events occurred in either group. In the first patient survey, 15% (ME) and 11% (CE) reported pain; in the second survey, 7.6% and 7.2%, respectively. There were no significant differences between groups. All reported pain was mild (1 on a 5-point scale), localized to the throat or upper abdomen, and resolved spontaneously without intervention. Except for pain, no adverse events related to the procedure or sedation were reported. Details are summarized in Table 1 and Table S1.

Primary outcome (operability)

For the primary outcome (total operability score; maximum 30 without biopsy, 40 with biopsy), the 95% confidence intervals (CIs) were within the predefined non-inferiority margin of 10%, supporting the non-inferiority of ME to CE (no biopsy: 95% CI [−1.77 to 0.59; margin −3], biopsy: [−2.65 to 1.39; margin −4]). However, as the 95% CIs included 0, superiority of ME over CE was not demonstrated, indicating that no significant difference was observed between the groups (Fig. 3). For individual items, ME showed significantly better scores than CE for physical fatigue (1.35 ± 0.48 vs. 1.63 ± 0.62; $p = 0.002$) and lens cleaning (1.83 ± 0.59 vs. 2.17 ± 0.87; $p = 0.004$), in both ITT and PP analyses. Other items showed no significant differences between the groups (Table 2; Fig. 4).

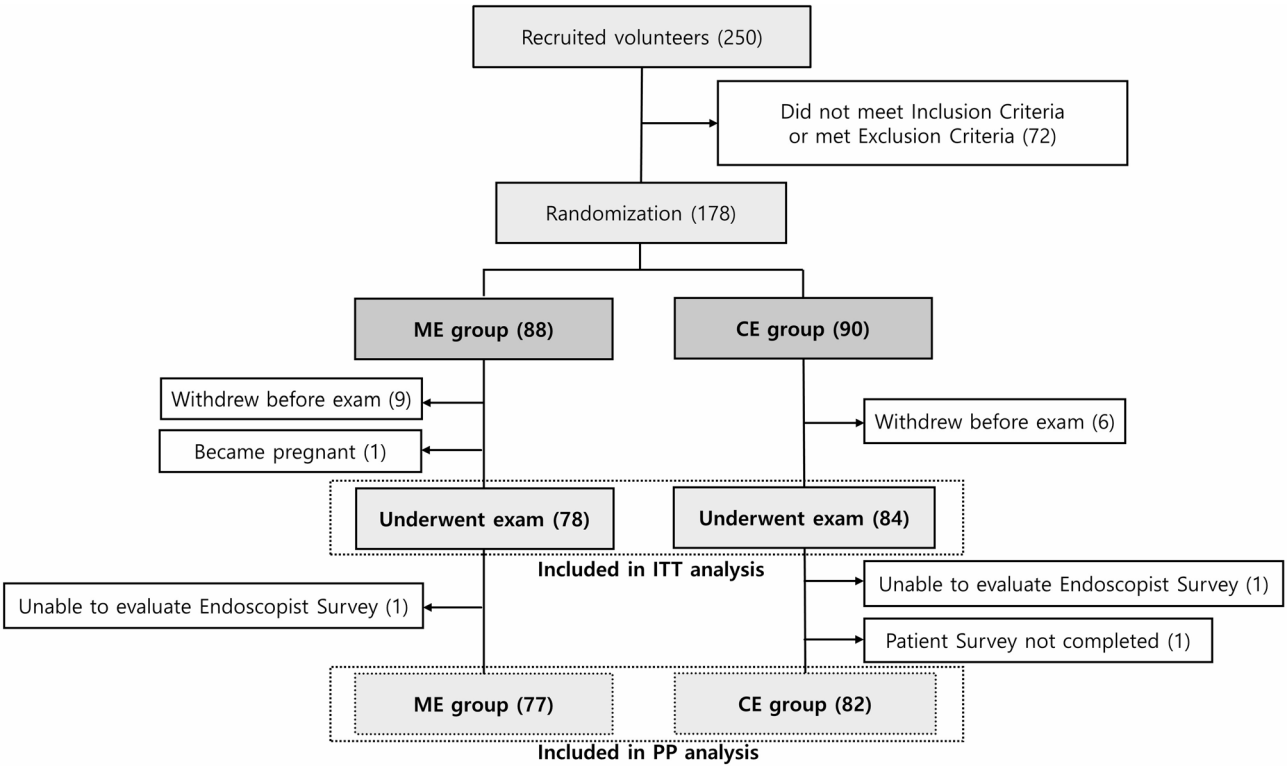

Fig. 2. Flowchart of Patient Enrollment, Randomization, and Analysis Populations. *ME* motorized endoscope, *CE* conventional endoscope, *ITT* intention-to-treat, *PP* per-protocol.

		Intention-To-Treat			
		Overall (*N* = 162)	ME (*N* = 79)	CE (*N* = 83)	p-value
	Sex				0.061
	Female	104 (64%)	45 (57%)	59 (71%)	
	Male	58 (36%)	34 (43%)	24 (29%)	
	Age	41 ± 11	40 ± 11	41 ± 11	0.8
Patient survey #1	Sedation	1.31 ± 0.84	1.41 ± 0.95	1.22 ± 0.72	0.2
	Pain	21 (13%)	12 (15%)	9 (11%)	0.4
	Pain location				> 0.9
	Throat	17 (85%)	9 (82%)	8 (89%)	
	Upper abdomen	3 (15%)	2 (18%)	1 (11%)	
	Lower abdomen	0 (0%)	0 (0%)	0 (0%)	
	Others	0 (0%)	0 (0%)	0 (0%)	
	Pain scale	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	> 0.9
	Satisfaction	1.25 ± 0.59	1.27 ± 0.61	1.24 ± 0.58	0.8
	Want to repeat	155 (96%)	75 (95%)	80 (98%)	0.4
Patient survey #2	Pain	12 (7.4%)	6 (7.6%)	6 (7.2%)	> 0.9
	Pain location				> 0.9
	Throat	8 (73%)	4 (80%)	4 (67%)	
	Upper abdomen	3 (27%)	1 (20%)	2 (33%)	
	Lower abdomen	0 (0%)	0 (0%)	0 (0%)	
	Others	0 (0%)	0 (0%)	0 (0%)	
	Pain scale	1.50 ± 1.00	1.50 ± 1.22	1.50 ± 0.84	> 0.9
	Satisfaction	1.33 ± 0.67	1.37 ± 0.68	1.29 ± 0.65	0.5
	Want to repeat	156 (96%)	74 (94%)	82 (99%)	0.11

Table 2. Patient demographics and patient survey results (Intention-To-Treat analysis). Continuous variables are presented as mean ± standard deviation, and categorical variables as number (%). The t-test was used to compare continuous variables, and the chi-square test was used for categorical variables. Patient Survey #1 was conducted 4 h post-endoscopy, and Patient Survey #2 was conducted 7 days post-endoscopy. Lower scores indicate better outcomes in the patient survey. *ME* motorized endoscope, *CE* conventional endoscope.

NASA-TLX and image quality

In the NASA-TLX score, ME showed a significantly better scores than CE for physical demand (1.39 ± 0.49 vs. 1.67 ± 0.63; $p = 0.002$) in both ITT and PP analyses. Other items showed no significant differences between the groups. (Table 3; Fig. 4)

In the image quality score, CE showed significantly better scores than ME for quality (1.61 ± 0.51 vs. 1.82 ± 0.48; $p = 0.010$), view (1.58 ± 0.50 vs. 1.75 ± 0.52; $p = 0.031$), and resolution (1.46 ± 0.50 vs. 1.68 ± 0.57; $p = 0.012$) in both ITT and PP analyses. Other items showed no significant differences (Table 3; Fig. 4).

Discussion

This single-center, single-blind randomized controlled trial evaluated a novel ME across multiple domains—including operability, image quality, safety, and patient satisfaction—compared to CE. The results demonstrated that ME was non-inferior to CE in terms of total operability score and showed superiority in specific domains such as physical fatigue and lens cleaning. ME also showed better performance than CE in the physical demand item of the NASA-TLX score, suggesting ergonomic benefits. However, CE demonstrated better performance in image-related parameters, including image quality, view, and resolution. Safety outcomes were similar between groups, with no severe adverse events reported and only minor, self-limiting discomforts observed.

The improved ergonomic performance of ME is likely attributable to its underlying mechanical design. Unlike CE, which operates through a mechanical string and chain-sprocket system requiring greater finger force, ME integrates motor-driven controls that operate via electrical signal transmission. In addition, by significantly reducing internal components within the control interface, ME decreased the total weight significantly. These factors collectively contributed to the lower physical fatigue and physical demand scores observed with ME. The same mechanism also explains the better ME score in lens cleaning. In CE, activation of the water function requires continuous finger pressure on a mechanical valve. In contrast, ME employs electronic switches, reducing finger load by up to 90.9% compared with CE, particularly during lens cleaning. CE's mechanical design also allows simultaneous spraying of air and water, which can impair visibility, whereas ME electronically separates these functions, preventing unintended water spraying when only air is desired. Furthermore, in CE, complete valve occlusion is necessary to maximize air pressure, and water flow varies with finger pressure, leading to inconsistent performance. By contrast, ME ensures full air pressure and stable water output through electronic control, thereby providing consistent cleaning quality. Thus, ME demonstrates superior lens cleaning

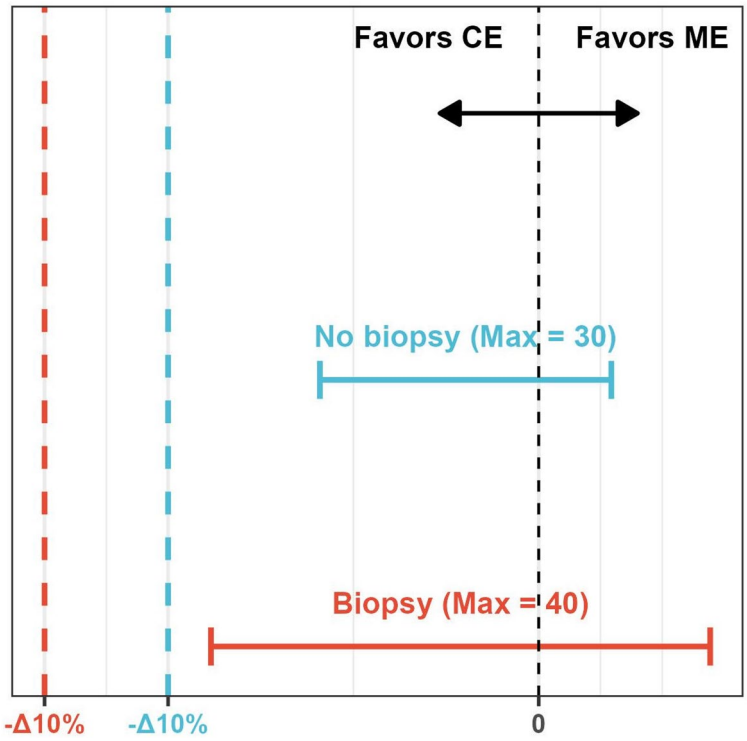

Fig. 3. Non-Inferiority Test for Primary Outcome: Operability Score. Mean difference and 95% confidence intervals between motorized endoscope and conventional endoscope groups, stratified by biopsy status. Dashed lines indicate the predefined 10% non-inferiority margins (red: biopsy, max = 40; blue: no biopsy, max = 30).

	Intention-To-Treat				Per-Protocol			
	Overall (*N* = 162)	ME (*N* = 79)	CE (*N* = 83)	*p*-value	Overall (*N* = 159)	ME (*N* = 77)	CE (*N* = 82)	*p*-value
Easy handling	1.71 ± 0.49	1.78 ± 0.45	1.65 ± 0.53	0.10	1.71 ± 0.49	1.78 ± 0.45	1.65 ± 0.53	0.089
Easy handling (Motor only)	1.51 ± 0.53	1.51 ± 0.53			1.51 ± 0.53	1.51 ± 0.53		
Physical fatigue	1.49 ± 0.57	1.35 ± 0.48	1.63 ± 0.62	**0.002**	1.49 ± 0.57	1.35 ± 0.48	1.62 ± 0.62	**0.002**
Psychological fatigue	1.56 ± 0.57	1.51 ± 0.55	1.60 ± 0.58	0.3	1.55 ± 0.57	1.51 ± 0.55	1.60 ± 0.58	0.3
Air	1.71 ± 0.68	1.62 ± 0.63	1.78 ± 0.72	0.14	1.70 ± 0.68	1.62 ± 0.63	1.78 ± 0.72	0.14
Suction	1.73 ± 0.67	1.78 ± 0.75	1.67 ± 0.59	0.3	1.72 ± 0.67	1.78 ± 0.75	1.66 ± 0.57	0.3
Lens cleaning	2.01 ± 0.76	1.83 ± 0.59	2.17 ± 0.87	**0.004**	2.00 ± 0.76	1.83 ± 0.59	2.16 ± 0.87	**0.006**
Working channel	1.86 ± 0.55	2.06 ± 0.64	1.73 ± 0.45	0.074	1.86 ± 0.55	2.06 ± 0.64	1.73 ± 0.45	0.074
Biopsy	1.75 ± 0.58	1.78 ± 0.73	1.73 ± 0.45	0.8	1.75 ± 0.58	1.78 ± 0.73	1.73 ± 0.45	0.8

Table 2. Operability Scores. Continuous variables are presented as mean ± standard deviation. The t-test was used to compare continuous variables. Bolded values indicate statistical significance ($p < 0.05$). The "Easy handling (Motor only)" item was assessed only in the motorized endoscopy group. Lower scores indicate better outcomes in the operability score. *ME* motorized endoscope, *CE* conventional endoscope.

performance, primarily attributable to the stability and reliability achieved through electronic separation and control of air and water functions (Supplementary Video S2). Notably, ME preserved operability characteristics familiar to endoscopists by incorporating reactive force mechanisms, which may explain the lack of significant differences in other operability or workload domains.

Despite incorporating a high-resolution CMOS sensor, ME received lower scores than CE in image quality assessments. This discrepancy likely reflects differences in post-processing strategies. CE applies filters such as edge enhancement and spatial denoising to artificially increase clarity beyond the native signal. In contrast, ME employs post-processing mainly to enhance image quality without exaggeration, thereby preserving native resolution and maintaining stable color balance. While this approach may give ME images a "different" impression to endoscopists accustomed to CE, it does not distort mucosal or lesional features. Representative comparisons

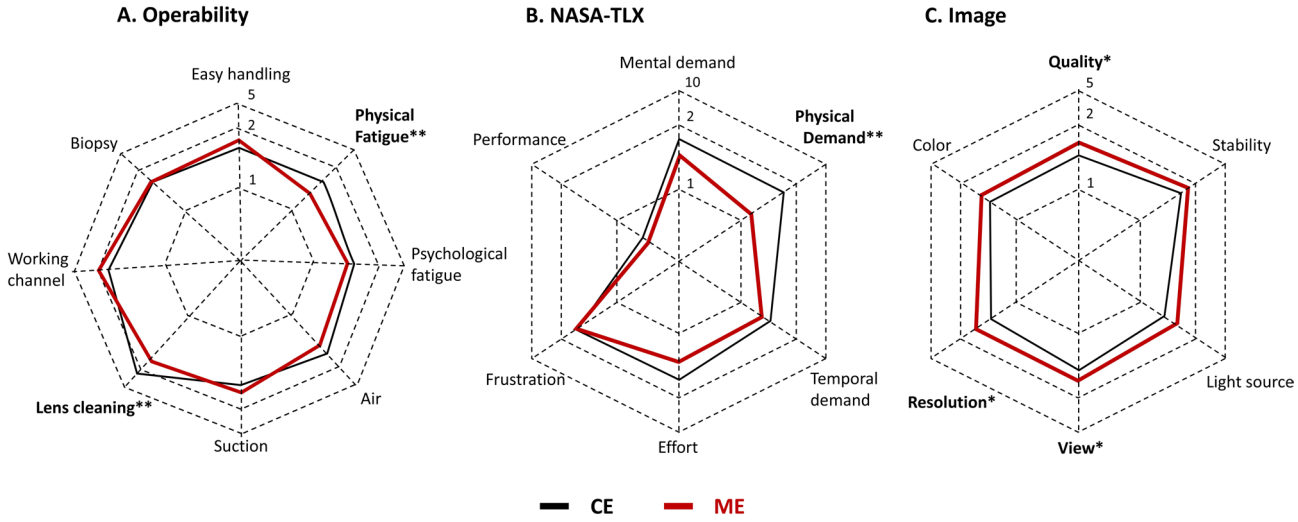

Fig. 4. Comparison of Operability, NASA-TLX, and Image Quality Scores. **A** Operability score, **B** NASA-Task Load Index (NASA-TLX), and **C** image quality score shown as radar plots for motorized endoscope (ME) and conventional endoscope (CE). Lower scores indicate better performance. Bolded items represent statistically significant differences. $^{*}P<0.05$, $^{**}P<0.01$.

		Intention-To-Treat				Per-Protocol			
		Overall (*N* = 162)	ME (*N* = 79)	CE (*N* = 83)	p-value	Overall (*N* = 159)	ME (*N* = 77)	CE (*N* = 82)	p-value
NASA-TLX	Mental demand	1.59 ± 0.69	1.51 ± 0.60	1.66 ± 0.75	0.15	1.58 ± 0.69	1.51 ± 0.60	1.66 ± 0.76	0.2
	Physical demand	1.54 ± 0.58	1.39 ± 0.49	1.67 ± 0.63	**0.002**	1.53 ± 0.58	1.39 ± 0.49	1.67 ± 0.63	**0.002**
	Temporal demand	1.47 ± 0.50	1.40 ± 0.49	1.53 ± 0.50	0.11	1.47 ± 0.50	1.40 ± 0.49	1.52 ± 0.50	0.13
	Effort	1.56 ± 0.62	1.48 ± 0.53	1.64 ± 0.69	0.10	1.56 ± 0.62	1.48 ± 0.53	1.63 ± 0.69	0.12
	Frustration	1.47 ± 0.55	1.49 ± 0.60	1.45 ± 0.50	0.6	1.47 ± 0.55	1.49 ± 0.60	1.44 ± 0.50	0.5
	Performance	0.67 ± 0.57	0.69 ± 0.52	0.65 ± 0.61	0.7	0.67 ± 0.57	0.69 ± 0.52	0.65 ± 0.62	0.6
Image	Quality	1.71 ± 0.51	1.82 ± 0.48	1.61 ± 0.51	**0.010**	1.71 ± 0.51	1.82 ± 0.48	1.61 ± 0.52	**0.009**
	Stability	1.78 ± 0.60	1.86 ± 0.56	1.70 ± 0.64	0.10	1.78 ± 0.60	1.86 ± 0.56	1.71 ± 0.64	0.12
	Light source	1.62 ± 0.61	1.70 ± 0.71	1.54 ± 0.50	0.11	1.62 ± 0.61	1.70 ± 0.71	1.55 ± 0.50	0.12
	View	1.66 ± 0.51	1.75 ± 0.52	1.58 ± 0.50	**0.031**	1.67 ± 0.51	1.75 ± 0.52	1.59 ± 0.50	**0.038**
	Resolution	1.56 ± 0.55	1.68 ± 0.57	1.46 ± 0.50	**0.012**	1.57 ± 0.55	1.68 ± 0.57	1.46 ± 0.50	**0.014**
	Color	1.58 ± 0.53	1.65 ± 0.56	1.52 ± 0.50	0.12	1.58 ± 0.53	1.65 ± 0.56	1.51 ± 0.50	0.11

Table 3. NASA-TLX and image quality Scores. Continuous variables are presented as mean ± standard deviation. The t-test was used to compare continuous variables. Bolded values indicate statistical significance ($p<0.05$). Lower scores indicate better performance. *NASA-TLX* National Aeronautics and Space Administration Task Load Index, *ME* motorized endoscope, *CE* conventional endoscope.

are provided in Supplementary Figure S3, and typical ME videos are demonstrated in Supplementary Videos S3. This unfamiliarity is expected to diminish as endoscopists gain more experience with the ME system.

Motorized endoscopy has been applied to both enteroscopes and colonoscopes since the introduction of motorized enteroscopy in 2015[17]. However, conventional motorized systems differ fundamentally in both mechanism and purpose from the novel endoscope evaluated in this study. Traditional motorized endoscopy—particularly motorized spiral enteroscopy—utilizes a spiral overtube driven by an external motor over the scope to facilitate advancement, propulsion, and right-hand torque during procedures[18–22]. In contrast, the novel system described here employs an internally integrated motor, activated by electrical signals, to control the endoscope's wheels and buttons, enabling fully motorized operation.

A key strength of this study lies in its prospective, randomized design, which allowed for a comprehensive comparison of ME and CE under real-world conditions. The findings suggest that ME may offer ergonomic advantages while maintaining safety and user familiarity. The observed reduction in endoscopist fatigue is especially noteworthy. Although assessed in the short term, this benefit may carry important long-term implications, as concerns regarding musculoskeletal burden among endoscopists have long been recognized

and have become increasingly relevant with the growing complexity and duration of endoscopic procedures. This issue is also highly pertinent for physicians who perform large volumes of routine diagnostic examinations on a daily basis. By mitigating physical strain during procedures, ME has the potential to reduce cumulative occupational burden and contribute to the prevention of chronic musculoskeletal injuries. These ergonomic advantages may ultimately improve the sustainability of endoscopic practice and enhance the long-term well-being of endoscopists.

However, several limitations should be acknowledged. It was conducted at a single tertiary center, and all procedures were performed by highly experienced endoscopists (>20 years of experience), which may limit the generalizability to other settings or to less experienced endoscopists. Only two endoscopists performed all procedures, which made it unfeasible to conduct sensitivity analyses stratified by operator characteristics such as age, sex, or ergonomic history. Potential bias caused by endoscopists' long-term familiarity with CE should also be taken into consideration. In addition, the study focused exclusively on diagnostic procedures; therapeutic performance remains to be evaluated. Nevertheless, a multicenter randomized controlled trial involving endoscopists with varying levels of experience is currently underway, which will allow more comprehensive analyses, including sensitivity analyses adjusted for operator-related factors, and further studies are planned to assess the system's performance in therapeutic endoscopy.

Additionally, the ME platform offers opportunities for future integration with proprietary software modules, including lesion size estimation, auto-navigation, and fine motor calibration for therapeutic interventions[23]. These advancements may further enhance the utility of the system, potentially improving procedural efficiency and reducing occupational strain among endoscopists.

Conclusion

The novel motorized endoscopy system demonstrated non-inferiority to conventional mechanical endoscopy in terms of procedural operability. It provided ergonomic benefits, including reduced physical demand and fatigue. These advantages were achieved without compromising safety or patient satisfaction, supporting the feasibility of ME as a user-friendly alternative. Nevertheless, optimization of image quality is still required. Ongoing investigations, including a multicenter randomized controlled trial and a pilot study of therapeutic procedures, are expected to further validate its performance and enhance generalizability.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to patient privacy and institutional data protection policies but are available from the corresponding author on reasonable request.

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Author contributions

S.L. and G.P. contributed equally to drafting the initial manuscript, preparing visual materials, and performing statistical analyses. M.J.O., J.K.R., and H.C. coordinated the research and edited the manuscript. J.K.R. and H.C. supervised and guided the overall study. All authors reviewed and approved the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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Correspondence and requests for materials should be addressed to H.C.

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