

A Novel Endoluminal Robotic Platform for Endoscopic Submucosal Dissection

System Architecture and Preclinical Feasibility Study



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BACKGROUND

Endoscopic submucosal dissection (ESD) enables en-bloc resection of early gastrointestinal neoplasia but remains **technically demanding** because of limited traction, lack of triangulation, and high operator workload, contributing to a steep learning curve

OBJECTIVE

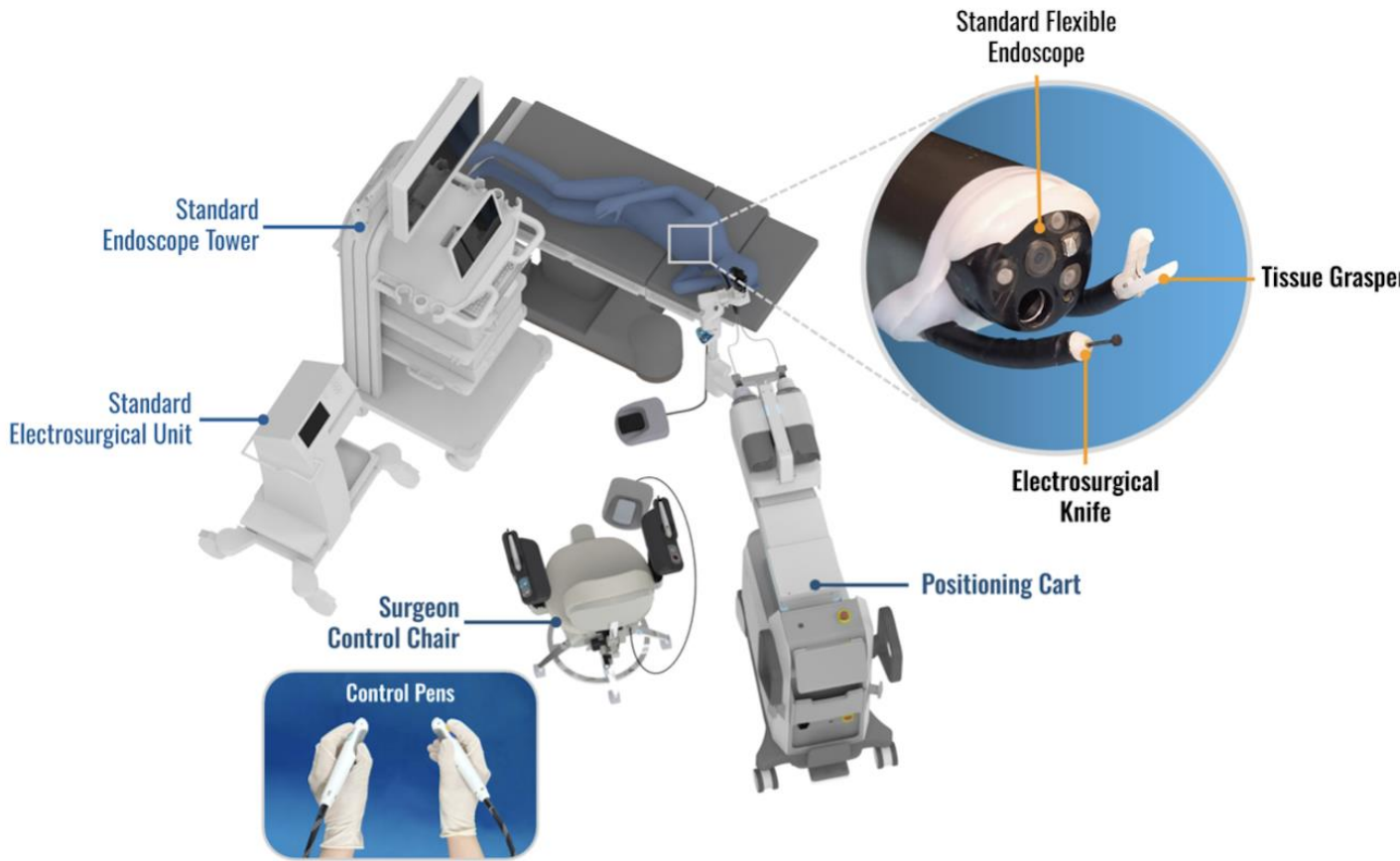
We evaluated a **novel endoluminal robotic platform** designed to provide surgical-like bimanual triangulation, stable traction/counter-traction, and improved ergonomics while preserving compatibility with standard gastroscopes.

METHODS

- The **robotic system** (Intilume System, Agilis Robotics, Hong Kong, SAR) uses an external positioning cart to drive two 3.5-mm flexible robotic instruments mounted onto a native gastroscope via a cap-and-sheath interface and controlled by compact pen-style motion-tracking.
- Two fellows without prior ESD experience and two interventional endoscopy fellows with early experience performed four ESDs
- Outcomes: en-bloc resection, procedure time, specimen surface area, dissection speed, tissue injury, and operator workload assessed using NASA-TLX, OSATS and GEARS evaluations.

Table 1. Comparative ESD performance outcomes: Robotic vs. Conventional.

	Robotic (n=8)	Conventional (n=8)	P
En-bloc resection	8 (100%)	6 (75.0%)	0.47
Procedure time in minutes	14.1 (4.3)	21.6 (7.6)	0.028
Muscular injury	0 (0%)	5 (62.5%)	0.20
Full thickness injury	0 (0%)	0 (0%)	-
Specimen surface area, mm ²	491.5.(240.9)	288.2 (150.1)	0.07
Specimen area (% relative to ideal target surface area)	69.5 (34.1)	40.8 (21.2)	0.08
Dissection speed mm ² /min	36.5 (23.4)	16.3 (10.1)	0.05
NASA-TLX score	34.7 (24.1)	75.0 (15.4)	0.002



- All procedures were completed (8 robotic, 8 conventional). **Robotic ESD achieved 100% en-bloc resection versus 75%** with conventional ESD ($p=0.47$), was **significantly faster** (14.1 ± 4.3 vs 21.6 ± 7.6 minutes; $p=0.028$), and demonstrated **higher dissection speed** (36.5 ± 23.4 vs 16.3 ± 10.1 mm²/min; $p=0.05$).
- No muscular injuries occurred** with robotic ESD compared with 5/8 conventional cases; no full-thickness injuries occurred.
- Operator workload was markedly lower with robotic ESD** (NASA-TLX 34.7 ± 24.1 vs 75.0 ± 15.4 ; $p=0.002$).

RESULTS

Table 2. Summary of subjective ergonomic assessment between the robotic versus conventional endoscopic submucosal dissection: National Aeronautics and Space Administration Task Load Index (NASA-TLX), Objective Structured Assessment of Technical Skills (OSATS), and Global Evaluative Assessment of Robotic Skills (GEARS)

	Robotic (n=8)	Conventional (n=8)	P
NASA-TLX score			
Mental Demand	46.3 (29.5)	78.1 (12.5)	0.024
*Physical Demand	26.9 (22.8)	76.3 (9.5)	0.0007
*Temporal Demand	35.6 (25.7)	71.9 (17.1)	0.011
Performance	23.8 (23.9)	67.4 (26.5)	0.009
*Effort	43.1 (25.8)	81.3 (10.9)	0.008
Frustration	31.3 (29.9)	75.0 (23.9)	0.004

OSATS score			
Respect for Tissue	3.7 (0.7)	3.6 (0.7)	0.60
*Time and motion	3.3 (1.0)	3.3 (1.0)	0.82
*Instrument handling	3.6 (0.9)	3.8 (0.9)	0.35
*Flow of operation	3.4 (0.8)	3.0 (1.2)	0.2
Knowledge of instrument	3.8 (0.7)	3.8 (1.4)	1
*Use of assistants	3.0 (0.5)	3.5 (0.5)	0.001
Overall performance	3.4 (0.9)	3.4 (1.1)	1

	1st Robotic (n=4)	2nd Robotic (n=4)	P
GEARS score			
Depth perception	3.5 (0.8)	3.4 (0.9)	0.60
*Bimanual dexterity	3.5 (0.5)	3.6 (0.7)	0.60
*Efficiency	3.1 (1.2)	3.6 (1.1)	0.28
Force sensitivity	3.4 (0.7)	3.6 (0.9)	0.35
*Robotic control/autonomy	3.5 (0.8)	3.9 (1.1)	0.20

*Ergonomic domains; Continuous variables (mean, SD)

CONCLUSION

In a randomized ex-vivo crossover model, a **bimanual endoluminal robotic platform compatible with standard endoscopes improved ESD efficiency, tissue control, and operator ergonomics** compared with conventional ESD. These findings support further development and progression to first-in-human feasibility evaluation, with potential to lower the ESD learning curve.