Supplementary Table 1 Active flexible endoscopy platforms

Device name (Manufacturer)	Actuation	Technical features	Clinical features	Studies	Acceptability	Clinical Outcomes	TRL
Aer-O-Scope *GI View Ltd., Ramat Gan, Israel*[1-3]	Electropneumatic	Two balloons create a seal and CO2 inflation between the balloons pneumatically progresses the proximal balloon forward. Operated by a handheld controller.	Two cameras allow 200 degree viewing angle. Single use.	**Pfeffer 06:** Porcine study, 20 pigs. **Vucelic 06:** Human study, 12 healthy adults. **Gluck 16:** Human study, 58 CRC screening patients.	Vucelic 06 human study started unsedated and only 2/12 requested sedation. No other patient experience measures reported. No PREMs in 2016 study. Endoscopist	98.2% caecal intubation rate, mean caecal intubation time of 11 minutes. 87.5% of polyps detected by Aer-O-Scope compared to CC. CE marked and FDA approved.	8

					s in 2016 study reported ease of use.		
ColonoSight *Stryker GI Ltd., Haifa, Israel*[4]	Electropneumatic	A multilumen sheath is inflated with air to progress the scope through the lumen. Can we controlled similarly to standard colonoscopy and simultaniously with the IntraPull technology.	Multiple infection prevention and control mechanism employed. Similar controls to standard colonoscopy with the added IntraPull option to progress the device. Single use sheath/components so no need for reprocessing.	**Shike 08**: animal study on 12 pigs and 7 sheep, human study on 178 participants.	No reported PREMs. Physicians reported it helped progress the colonoscope.	90% caecal intubation rate at a mean time of 11.2 minutes. Polypectomy, biopsy and APC have been demonstrated using the device. FDA approved.	8

Consis medical *Beer'Sheva, Israel*[5]	Electrohydraulic	A reusable capsule with a light source, camera, water/air port and working channel, mounted on an inverted sheath that is propelled by pressurised water.	Working channel. Semi-disposable.	None available	No information available	No trial available.	3
Endoculus *Department of Mechanical Engineering & Division of Gastroenterology, University*	Electronic	Locomotion is via two motor drives with micro-pillared treads, offering skid steering. A fixed tether	Working channel, suction, insufflation & irrigation.	**Sliker 12:** porcine in-vivo study showing mobility of the device within an	No information available	Unable to traverse the sigmoid colon of a pig in-vivo. Manoeuverability demonstrated	4

of Colorado, USA[6-9]	contains channels for insufflation and irrigation, and a 1.98mm working channel. CMOS camera and an adjustable LED. Capsule size 6.0cm x 3.0cm x 2.3cm. Contains an inertial measurement unit, magnetometer, motor encoders, and motor current		isolated section of caecum. **Prendergast 18:** autonomous navigation of a curved phantom model. **Formosa 20:** Porcine study, in-vivo then ex-vivo on one pig. **Zhang 21**: autonomous biopsy in benchtop	in ex-vivo pig colon with speeds of up to 40 mm/s.

		sensors to aid in future autonomy strategies. Dual joystick controller.		testing.			
Endoo robotic colonoscope *Endoo Project, Pisa, Italy*[10]	Magnetic Tethered capsule	Magnetic capsule with a multi-lumen soft tether pulled through the colon via attraction to a larger external magnet mounted on a robotic arm. Nylon cables in the shaft offer variable	Working channel, suction & irrigation. Narrow band imaging capablities. Variable stiffness control of the shaft. Closed loop control.	**Verra 20:** ex-vivo porcine colon human simulator study involving 10 expert endoscopist and 5 trainees.	No information available	No trial available.	4

		stiffness. 2 x CMOS 1080p cameras for stereoscopic vision. 4 x LEDs for white light imaging and also 4 x UV-LEDs for narrow band imaging.					
Endotics *ERA Endoscopy SRL, Peccioli, Italy*[11-14]	Electropneumatic, inchworm	Extension and retraction between a proximal and distal clamping system allow progression in an inchworm motion.	Working channel, suction & irrigation channels. 180 degree angulation. Single use.	**Consentino 09:** ex vivo and in vivo animal studies showing device safety, pilot in-human	Pain and discomfort scores significantly lower for Endotics compared to CC in Consentino	Pilot study CIR only 27.5%. CIR improved to 81.6% with a sensitivity of 93.3% for polyp detection and a mean CIT of 45 minutes.	8

	Handheld controller. CMOS camera & LED light source.		study on 40 adults. **Tumino 10:** human trial on 71 participants. **Tumino 17:** retrospective analysis of 102 Endotics procedures following incomplete CC. **Trecca 20:** learning curve study of 57	09 study. Less sedation use for Endotics compared to CC in Tumino 10 study. Most patients report mild or no discomfort and had a high willingness to repeat the procedure in Trecco 20 study.	CIR in incomplete CC was 93.1% with a CIT of 51 minutes. CIR and CIT improved to 100% and 22 minutes allowing a learning block. CE marked.

				participants .			
Invendoscope *Invendo Medical GmbH, Weinheim, Germany (acquired by Ambu A/S, Copenhagen, Denmark in 2017)*[15-17]	Electromechanical, inverted sleeve (SC40 Model)	SC40 model used an inverted sleeve with 8 wheels to propel through the colon. SC200 and SC210 models no longer used the inverted sleeve but retain the robotically controlled tip	Working channel, suction & irrigation channels. 114 degree viewing angle. 180 degree tip angulation. Single use.	**Rosch 08:** in vivo porcine study on 5 pigs showing device safety, clinical trial on SC40 model at 2 working lengths. **Groth 11:**	SC40 mean acceptance rating of 1.96/6. SC20 pain and discomfort scores of 1.6/6 and 2.3/6. SC210 study 35/40 patients propofol	SC40: CIR 79-90% with CIT 20-26 minutes. SC20: CIR 98.4% with CIT 15 minutes. SC210: CIR 95% with CIT 14.2 minutes. SC210 FDA approved and CE marked.	8

		angulation. 14mm at the tip with a taper to 20mm at the proximal shaft. Controlled via a handheld joystick.		clinical trial on 61 participants using the SC20 model. **Straulino 18:** clinical trial on 40 participants using the SC210 model.	sedated.	
Magnetic Flexible Endoscope *STORM lab, Leeds, UK & Nashville, TN, United*	Magnetic Tethered capsule	Magnetic capsule with a multi-lumen soft tether pulled through the colon via attraction to a	Working channel, suction & irrigation. Single use. Capable of autonomous manoeuvres such as retroflexion and autonomous navigation.	**Martin 20:** extensive ex-vivo testing and in-vivo porcine study.	None available	Clinical trial 5 due 2022.

States[18]		larger external magnet mounted on a robotic arm. Controlled by a handheld controller. Closed loop control and levitation.	Closed loop control.				
Neoguide *NeoGuide Endoscopy System, Los Gatos, CA, USA (acquired by Intuitive Surgical Inc., Sunnyvale, CA, USA in*	Electromechanical, snake-like	16 independent articulated segments with 2 DOF allow a snake like movement. Sensors allow position trakcing to render a 3D	3.2mm working channel, suction & irrigation channels similar to a CC.	**Eickhoff 07:** initial clinical trial with 11 participants recruited and 10 procedures carried out.	Two patients reported mild self limiting abdominal pain post-procedure. Of the 2 who had a	CIR 100%. Median CIT 20.5 minutes. FDA approved in 2006 but not longer on the market.	8

2009)[19]	mapping of the colon and maintain the natural shape when progressing to avoid looping and lateral forces. CCD for visualisation. Tip control via a wheel system similar to CC.		previous colonoscopy, both reported the NeoGuide was no more uncomfortable than CC. All 10 reported a willingness to undergo another NeoGuide colonoscopy in the future. Physician satisfaction rates with the

					NeoGuide are reported as 100%.	
Robotic capsule colonoscope *VECTOR project*[20-21]	Magnetic capsule	Magnetic capsule with a 2mm tethering cable is pulled around the colon using an external permanent magnet mounted on a robotic arm.	Channels for washing, irrigation or insufflation and a working channel available in the 2nd prototype.	**Arezzo 13:** benchtop testing on ex vivo porcine colon using 22 endoscopists. **Valdastri 12:** benchtop testing on ex vivo	None available	Technology used to develop the Endoo and MFE devices. 3/4

				porcine colon using 12 endoscopists and in-vivo porcine study.			
NIS Inspire-C System[22]	Electropneumatic	Robotically controlled tendon wire-driven servomechanism with an omnidirectional 90mm bending section at the tip capable of 160 degree	Single use. 2mm working channel and washing/irrigation/suction channels. The balloons also depress folds to improve visibility.	**Foo 21:** clinical trial of 19 participants undergoing NISInspire-C system colonoscopy then CC.	Behavioural pain scale - non-intubated was the same for NISInspire-C System and CC.	CIR was 89.5% (17/19) and CIT was 26.3 minutes (SD: 17.9 mins). No reported complications.	6

		angulation. Two balloons with a suction port act to anchor and shorten the colon to reduce loops. HD CMOS image sensor 2 megapixel camera. Joystick control of the bending tip.					
Magnetic Assisted Colonoscopy System *Department of*	Magnetic Tethered capsule	External permanent magnet and load cells mounted on a	Working channel.	**Huang 21:** Benchtop model study showing	None available	None available	3

Electrical Engineering, National Taiwan University, Taipei, Taiwan (R.O.C.)[23]	robotic frame attract and pull an internal permanent magnet. CMOS image sensor and LED light.		tracking accuracy and 83% completion rate using an autonomous navigation algorithm.			
Soft Robotic Pneumatic Sleeve[24]	Single use add-on device which attachs to a normal endoscope to provide feedback on the pressures exerted using imbedded sensors and	Add-on device to standard endoscope with diameters 9.5-13.8mm.	**McCandless 21:** In-vitro testing show a reduction in the pressure on a single sensor from 4.7N to 1.9N by means of	None available	None available	3

		then redistribute the pressure by inflating balloons. Attachment length is 118mm and when attached, increases the outer diameter of the endoscope to 19.5mm.		redistributing the pressure on inflation of the balloon.			
Shape-lockable self-propelling robot *Key Laboratory of Mechanism*	Pneumatic	Consists of a propulsion module, sensing module, and a shape-locking	Not yet advanced enough to comment on clinical features.	**Liu 21**: propulsion demonstrated in benchtop testing,	None available	None available	3

Theory and Equipment Design of Ministry of Education, Tianjin University, Tianjin, People's Republic of China[25]	module integrated through a multi-sectional back bone. Tethered by an electrical cable. 6 expanding actuating balloons around the backbone propel the device. 195mm in length and 22mm in diameter. CCD camera.	including wet environment, around a curve and on a vertical gradient.

Paddling/reel robot with Multimodal Robotic Colonoscope Interface (MRCI) *School of Aerospace and Mechanical Engineering, Korea Aerospace University, Goyang-si, Republic of Korea Center for Micro-BioRobotics,*	Electronic	The device is made up of 3 parts: the paddles section, the steering tip and the feeding mechanism. Paddling actuation is achieved using 6 coated steel legs controlled by an external actuator, a Bowden cable and a spring. Beyond the paddles is a steering tip	Not yet advanced enough to comment on clinical features.	**Kang 21:** In-vitro pig colon studies show proof of concept and safety. Able to traverse straight, curved and up to 60^0 gradient sections of pig colon.	None available	None available	4

Istituto Italiano di Tecnologia (IIT), Pontedera, Italy The BioRobotics Institute, Scuola Superiore Sant'Anna, Pontedera, Italy[26]	with 2 DoF and 180^0 bending angle made from an Olympus colonoscope parts (Olympus, PCF-Q180AL, Japan). 180^0 torque is capable using a servomotor. The feeding mechanism made up of a motor with a roller system to progress or retract the

		endoscope. The MRCI integrate the information from the various systems. Maximum diameter with the paddles extended at their limit of 50^0 is 33mm. No camera yet installed.					
Magnetically-Guided Capsule Endoscope *Intelligent Robotics*	Magnetic Tethered capsule	External permanent magnet mounted on a robotic arm controls an	Nozzle for irrigation and insufflation, as well as a working channel for washing or use of therapeutic equipment.	**Zhang 21:** Ex-vivo pig colon study proves proof of concept of	None available	None available	4

Institute, School of Mechatronical Engineering, Beijing Institute of Technology, Beijing, China[27]	internal permanent magnetic within a tethered capsule head. The capsule contains 8 pressure sensitive pads to monitor contact pressure with the mucosa can be used to guide the motion of the capsule. Camera and LED light	using pressure sensors to maintain magnetic coupling, and potentially reduce patient discomfort.

		source. Capsule length 30mm and diameter 19mm.					
Highly integrated dual hemisphere capsule robot (DHCR) *Key Laboratory for Precision and Non-Traditional Machining Technology, Ministry of Education, Dalian*	Magnetic Capsule	Magnetic assisted capsule endoscope capable to retrograde movement up the GI tract from the rectum to the caecum as well as antegrade movement via the oral route. The DHCR	Capable of rotation and movement to optimise visualisation.	**Zhang 22:** Ex-vivo pig colon study showing proof of actuation in a straight line and around a curve. Proof of ability to rotate to scan an area.	None available	None available	4

University of Technology, Dalian, China[28]	utilises active and passive hemispheres to actuate via a spatial universal rotating magnetic field. Contains an LED light source and a CMOS image sensor, as well as radiotransmitting unit and battery capable of 30 minutes operation time. An operator		

	uses a joystick to control a tri-axis Helmholtz coil generated magnetic field.	

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