

Table S1. Comparison of different kinds of endovascular surgical robots.

Country	Company	Product name	Compatible endovascular devices			Endovascular device delivery system	Actuation parts	Operations performed	Level of automation	Telecontrol
			Guide wires	Catheters	Stent grafts					
China	Aopeng	ALLVAS	all kinds of commercially available guide wires	all kinds of commercially available catheters	stent delivery; can release	RX devices and OTW devices	grippers	EVAR; TEVAR; PCI; PVI; NVI; VCFI	Level 3	○ ^a
U.S.	Hansen Medical	Sensei X Series	0.014in,0.018in,0.035in	Artisan Extend Control Catheter	— ^b	— ^b	tendon-driven guide catheter	PCI; CA; EVAR	Level 1	○ ^a
		Magellan	0.014in,0.018in,0.035in	6F or 9F or 10F Magellan robotic catheter	— ^b	— ^b	tendon-driven guide catheter	PCI; CA; EVAR; TEVAR	Level 1	○ ^a
U.S.	Catheter Precision	Amigo	— ^b	part of commercially available catheters	— ^b	— ^b	friction wheels	CA	Level 1	○ ^a
U.S.	Stereotaxis	Genesis RMN	— ^b	magnetic drive catheter	— ^b	— ^b	Vdrive and magnetic control	CA	Level 1	○ ^a
U.S.	Corindus	CorPath 200	0.014in	5-7F commercially available catheters	stent delivery; can't release	RX devices	friction wheels	PVI; PCI	Level 1	○ ^a

Country	Company	Product name	Compatible endovascular devices			Endovascular device delivery system	Actuation parts	Operations performed	Level of automation	Telecontrol
			Guide wires	Catheters	Stent grafts					
France	Robocath	CorPath GRX	0.014in	5-7F commercially available catheters	stent delivery; can't release	RX devices	friction wheels	NVI; PVI; PCI	Leve 1	○ ^a (long geographic distance)
		R-One	commercially available guidewires	commercially available catheters	stent delivery; can release	RX devices	friction wheels	PCI	Level 1	○ ^a (long geographic distance)
		RobEnt	commercially available guidewires(0.035in)	commercially available catheters	not reported	— ^b	gripping and rotational units	NVI	Level 1	○ ^a (long geographic distance)

CA stands for catheter ablation; EVAR stands for endovascular aortic repair; NVI stands for neurovascular intervention; OTW devices stands for over-the-wire devices; PCI stands for percutaneous coronary intervention; PVI stands for Peripheral vascular intervention; RX devices stands for rapid exchange devices; TEVAR stands for thoracic endovascular aortic repair; VCFI stands for vena cava filter implantation. ^a available; ^b unavailable.

Table S2. Endovascular device database.

Database name	Brand	Product name	Product code	Outer diameter	Length	Diameter of delivery system	Stent release distance	Proximal bare stent release methods	Distance between mark points			
									G1G2	G2G3	G3G4	G4G5
Stent database	Medtronic	Valiant™ Thoracic Stent Graft	VAMF3636C200TU	24 French	-	40mm	210mm	rotate 90° and retract 20mm	100mm	110mm	383mm	100mm
	Medtronic	Endurant II AAA Stent Graft System-BIFURCATIONS	ETBF2516C166E	18 French	-	40mm	170mm	rotate 360°*15	100mm	106mm	205mm	100mm
	Medtronic	Endurant II AAA Stent Graft System-LIMBS	ETLW1616C124 E	14 French	-	40mm	125mm	-	100mm	106mm	205mm	100mm
Guidewire database	Terumo	Radifocus™ Guide Wire M Standard Type	RF*GA35263M	0.035in	2600mm	-	-	-	-	-	-	-
	Cook Medical	Lunderquist Extra-Stiff Wire Guide	TSMG-35-260-LES	0.035in	2600mm	-	-	-	-	-	-	-
	Boston Scientific	Amplatz Super Stiff™	M001465021	0.035in	2600mm	-	-	-	-	-	-	-
Catheter database	Optimed	AltaFlow Measuring Catheter	1080-4100	5 French	1100mm	-	-	-	-	-	-	-

The database is consisted of the stent database, the guidewire database, and the catheter database, which are commonly used in TEVAR and EVAR. Devices for other kinds of surgeries are not listed. The stent database includes the stent release distance, proximal bare stent release methods, and distance between mark points which contribute to automated deployment of stents. Mark points were illustrated in Additional File 2. The guidewire database and the catheter database are built for precise control of clamping force, especially according to the item of outer diameters.

Table S3. Surgical list module of TEVAR.

No. of the procedure	Procedure	Device	Movement distance (mm)	Relative distance (mm)	Push speed (mm/s)	Push Length (mm)	Rotation angle of M3 (°)	Rotation Speed (°/s)	Robotic arm involvement	M1	M2	M3	M4
1	Guidewire reaches right 0 point Push guidewire to P1	Guidewire							N				
2	Catheter reaches right 0 point Push catheter to P2	Pigtail catheter							N				
3	Retract guidewire to right 0 pint	Guidewire							N				
4	Preoperative angiography	-	-	-	-	-	-	-	N	-	-	-	-
5	Extra-stiff wire reaches right 0 point Push extra-stiff wire to P1	Extra-stiff wire							N				
6	Retract pigtail catheter to right 0 point	Pigtail catheter							A2				
7	Stent-graft reaches right 0 point Stent-graft delivery	Stent-graft							N				
8	Stent-graft positioning	Stent-graft							N				

9 ^a	Stent-graft deployment Bare stent release	Stent-graft	A2	   									
10	Delivery system withdrawal	Stent-graft	A1	   									
11 ^b	Retract delivery system to right 0 point	Stent-graft	A2	   									
12	Pigtail catheter reaches right 0 point Push pigtail catheter to P2	Pigtail catheter	N	   									
13	Retract extra-stiff wire to right 0 point	Extra-stiff wire	N	   									
14	Postoperative angiography	-	-	-	-	-	-	-	N	-	-	-	-

In column of movement distance, the value means the movement distance of endovascular devices. A plus sign means forward distance and a minus sign means backward distance. In column of relative distance, the value means the distance from the tip of the device to the 0 point at the end of the step. In column of push speed, the value means the speed of each action unit. In column of push length, the value means the distance of each action unit. In column of rotation angle of M3, a plus sign means clockwise and a minus sign means counterclockwise. Green circle means “loosen”. Yellow circle means “hold”. Red circle means “clamp”. In some steps, robotic arms also involved. N stands for No. A stands for Arm that involves in the step. ^a The delivery system remained stationary, and the movement distance represents the retraction distance of the slider or the tip capture release handle. ^b Retraction of delivery system was divided into two parts. The upper line represented rapid retraction and the lower line represented slow retraction.

Table S4. Surgical list module of EVAR.

No. of the procedure	Procedure	Device	Movement distance (mm)	Relative distance (mm)	Push speed (mm/s)	Push Length (mm)	Rotation angle of M3 (°)	Rotation Speed (°/s)	Robotic arm involvement	M1	M2	M3	M4
1	Guidewire reaches right 0 point Push guidewire to P1	Guidewire							N				
2	Catheter reaches right 0 point Push catheter to P2	Pigtail catheter							N				
3	Retract guidewire to right 0 pint	Guidewire							N				
4	Preoperative angiography	-	-	-	-	-	-	-	N	-	-	-	-
5	Extra-stiff wire reaches right 0 point Push extra-stiff wire to P1	Extra-stiff wire							N				
6	Retract pigtail catheter to right 0 point	Pigtail catheter							A2				
7	Stent-graft reaches right 0 point Stent-graft delivery	Stent-graft							N				
8	Stent-graft positioning	Stent-graft							N				
9 ^a	Stent-graft deployment Bare stent release	Stent-graft							A2				

10	Delivery system withdrawal	Stent-graft	A1				
11 ^b	Retract delivery system to right 0 point	Stent-graft	A2				
Establishment of extra-stiff wire channel							
12	Aortic iliac stent reaches left 0 point Aortic iliac stent delivery	Aortic iliac stent	N				
13	Aortic iliac stent positioning	Aortic iliac stent	N				
14 ^a	Aortic iliac stent deployment	Aortic iliac stent	A2				
15	Delivery system withdrawal	Aortic iliac stent	A1				
16 ^b	Retract delivery system to left 0 point	Aortic iliac stent	A2				
17	Pigtail catheter reaches left 0 point Push pigtail catheter to P2	Pigtail catheter	N				
18	Retract extra-stiff wire to left 0 point	Extra-stiff wire	N				
19	Postoperative angiography	-	N	-	-	-	-

In column of movement distance, the value means the movement distance of endovascular devices. A plus sign means forward distance and a minus sign means backward distance. In column of relative distance, the value means the distance from the tip of the device to the 0 point at the end of the step. In column of push speed, the value means the speed of each action unit. In column of push length, the value means the distance of each action unit. In column of rotation angle of M3, a plus sign means clockwise and a minus sign means counterclockwise. Green circle means “loosen”. Yellow circle means “hold”. Red circle means “clamp”. In some steps, robotic arms also involved. N stands for No. A stands for Arm that involves in the step. ^a The delivery system remained stationary, and the movement distance represents the retraction distance of the slider. ^b Retraction of delivery system was divided into two parts. The upper line represented rapid retraction and the lower line represented slow retraction.

Table S5. Patient characteristics.

Items	Age (years)	Sex (n)	Aneurysm location	Hypertension (n)	Diabetes mellitus (n)	Hyperlipidemia (n)	COPD (n)	Prior myocardial infarction (n)	Prior stroke or TIA (n)	Peripheral vascular disease (n)	Aneurysm morphology	Maximal diameter of aorta (mm)	Hostile neck of aneurysm (n)	Neck length (mm)	Neck diameter (mm)	Neck angulation (°)
Patient 1	73	Male	Thoracic aorta	Y	Y	N	N	N	N	N	Fusiform	56.2	N	45.3	32.5	0
Patient 2	68	Male	Abdominal aorta	Y	N	N	N	N	Y	N	Fusiform	58.4	N	19.2	26.7	27.2

COPD stands for chronic obstructive pulmonary disease; N stands for no; TIA stands for transient ischemic attack; Y: yes.

Table S6. Surgical list of TEVAR.

No. of the procedure	Procedure	Device	Movement distance (mm)	Relative distance (mm)	Push speed (mm/s)	Push Length (mm)	Rotation angle of M3 (°)	Rotation Speed (°/s)	Robotic arm involvement	M1	M2	M3	M4
1	Guidewire reaches right 0 point Push guidewire to P1	Guidewire	+860	860	10	20	-	-	N				
2	Catheter reaches right 0 point Push catheter to P2	Pigtail catheter	+840	840	10	20	-	-	N				
3	Retract guidewire to right 0 point	Guidewire	-860	0	10	20	-	-	N				
4	Preoperative angiography	-	-	-	-	-	-	-	N	-	-	-	-
5	Extra-stiff wire reaches right 0 point Push extra-stiff wire to P1	Extra-stiff wire	+860	860	10	20	-	-	N				
6	Retract pigtail catheter to right 0 point	Pigtail catheter	-840	0	10	20	-	-	A2				
7	Stent-graft reaches right 0 point Stent-graft delivery	Stent-graft	+680	680	10	20	-	-	N				
8	Stent-graft positioning	Stent-graft	+4	684	1	1	-	-	N				

9 ^a	Stent-graft deployment		-210	684	30	210	-	-	A2				
	Bare stent release	Stent-graft	-20	684	30	20	-90	90					
10	Delivery system withdrawal	Stent-graft	-210	474	10	210	-	-	A1				
11 ^b	Retract delivery system to right 0 point	Stent-graft	-460	14	10	20	-	-	A2				
			-14	0	1	1							
12	Pigtail catheter reaches right 0 point	Pigtail catheter	+840	840	10	20	-	-	N				
	Push pigtail catheter to P2												
13	Retract extra-stiff wire to right 0 point	Extra-stiff wire	-860	0	10	20	-	-	N				
14	Postoperative angiography	-	-	-	-	-	-	-	N	-	-	-	-

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Table S7. Surgical list of EVAR.

No. of the procedure	Procedure	Device	Movement distance (mm)	Relative distance (mm)	Push speed (mm/s)	Push Length (mm)	Rotation angle of M3 (°)	Rotation Speed (°/s)	Robotic arm involvement	M1	M2	M3	M4
1	Guidewire reaches right 0 point Push guidewire to P1	Guidewire	+700	+700	10	20	-	-	N				
2	Catheter reaches right 0 point Push catheter to P2	Pigtail catheter	+680	+680	10	20	-	-	N				
3	Retract guidewire to right 0 pint	Guidewire	-700	0	10	20	-	-	N				
4	Preoperative angiography	-	-	-	-	-	-	-	N	-	-	-	-
5	Extra-stiff wire reaches right 0 point Push extra-stiff wire to P1	Extra-stiff wire	+700	700	10	20	-	-	N				
6	Retract pigtail catheter to right 0 point	Pigtail catheter	-680	0	10	20	-	-	A2				
7	Stent-graft reaches right 0 point Stent-graft delivery	Stent-graft	+360	360	10	20	-	-	N				
8	Stent-graft positioning	Stent-graft	+4	364	1	1	-	-	N				
9 ^a	Stent-graft deployment Bare stent release	Stent-graft	-170 -	364 364	30 -	170 -	- -5400	- 90	A2				

10	Delivery system withdrawal	Stent-graft	-170	194	10	170	-	-	A1				
11 ^b	Retract delivery system to right 0 point	Stent-graft	-180	14	10	20	-	-	A2				
			-14	0	1	1							
Establishment of extra-stiff wire channel													
12	Aortic iliac stent reaches left 0 point Aortic iliac stent delivery	Aortic iliac stent	+220	220	10	20	-	-	N				
13	Aortic iliac stent positioning	Aortic iliac stent	+6	226	1	1	-	-	N				
14 ^a	Aortic iliac stent deployment	Aortic iliac stent	-125	226	30	125	-	-	A2				
15	Delivery system withdrawal	Aortic iliac stent	-125	101	10	125	-	-	A1				
16 ^b	Retract delivery system to left 0 point	Aortic iliac stent	-100	1	10	20	-	-	A2				
			-1	0	1	1							
17	Pigtail catheter reaches left 0 point Push pigtail catheter to P2	Pigtail catheter	+680	680	10	20	-	-	N				
18	Retract extra-stiff wire to left 0 point	Extra-stiff wire	-700	0	10	20	-	-	N				
19	Postoperative angiography	-	-	-	-	-	-	-	N	-	-	-	-

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Table S8. Detailed information regarding the procedure and outcomes.

Items	Anesthesia	Stents	Operation time (min)	Blood loss (ml)	Total contrast volume used (ml)	Fluoroscopy time (min)	Procedural radiation exposure			Technical success	In-hospital death	In-hospital MACEs	MACEs in six months
							Procedure table (μGy)	Operator (μGy)	Patient (mGy)				
Patient 1	General	Valiant	80	80	80	15	40	2	800	Y	-	-	-
Patient 2	General	Endurant	104	50	130	21	110	4	1435	Y	-	-	-

MACE stands for major adverse cardiac event; Y stands for yes.