

ORIGINAL ARTICLE



Senhance surgical system in benign hysterectomy: A real-world comparative assessment of case times and instrument costs versus da Vinci robotics and laparoscopic-assisted vaginal hysterectomy procedures

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Asensus Surgical

Abstract**Objectives:** Comparison of retrospective, learning curve benign hysterectomy cost and case time data from Senhance total laparoscopic hysterectomy (TLH) cases with similar da Vinci robot cases and laparoscopic-assisted vaginal hysterectomy (LAVH) cases.**Methods:** Instrument costs, console time, and case time analysis from six surgeons at four U.S. and European hospitals compared with retrospective, sequential da Vinci TLH and standard laparoscopic LAVH cases extracted from the CAVAlytics database.**Results:** Senhance Gyn surgeons in their learning curve when compared to da Vinci learning curve Gyn surgeons achieved lower median instrument costs (\$559 vs. \$1393, respectively, $p < 0.001$) with comparable console times (91.5 vs. 96 min, $p = 0.898$); Senhance and LAVH case costs were comparable (\$559 vs. \$498, $p = 0.336$).**Conclusion:** In benign hysterectomy, the Senhance system may present a lower-cost approach with equivalent case times compared with similar da Vinci robotic cases.**KEYWORDS**

benign hysterectomy, da Vinci, laparoscopy, robotics, Senhance

1 | INTRODUCTION

Over the last two decades, the da Vinci[®] robot (Intuitive Surgical, Inc.) has emerged as a prevalent minimally invasive approach to hysterectomy.¹ As its use has increased, there has also been a concomitant reduction in the number of abdominal hysterectomies for benign indications: both overall and relative to other approaches to hysterectomy. Together with total laparoscopic hysterectomy (TLH), laparoscopic-assisted vaginal hysterectomy (LAVH), vaginal hysterectomy and laparoscopic supracervical hysterectomy, the increase in robotic hysterectomy has resulted in the decrease of abdominal hysterectomy to approximately 28%.² Since its approval

by the FDA for benign gynaecology in 2005, scores of studies and publications have assessed the clinical and economic strengths and weaknesses of the Intuitive Surgical da Vinci robot's use in benign hysterectomy, with the vast majority of studies underscoring robotic surgery as generally equivalent clinically to laparoscopy together with some reports of reduced pain, less blood loss, and shorter length of stay albeit with generally higher cost and longer operative times, though this variable may also be dependent on patient characteristics and comorbidities.^{3–5}

Today, surgical costs and operative times are increasingly critical given the need to improve contribution margins in surgical procedures as a key driver in hospital profitability. Moreover, with the

growing understanding of best practices in robotic surgery and related robotic program optimisation,^{6,7} newer studies and publications are demonstrating that, in specific robotic surgery case types, including benign hysterectomy, cases can be performed for comparable or even lower cost when compared to laparoscopy, with equivalent clinical outcomes.^{6–10}

1.1 | Senhance surgical system

In 2018, the introduction of the Senhance[®] Surgical System (Asensus Surgical US, Inc.) in the United States and Europe presented robotic and laparoscopic surgeons with an alternative to the Intuitive Surgical da Vinci robot. Comprised of an open-platform, modular architecture with three mobile arms that allow for use of existing laparoscopic vision systems, trocars and OR tables (Figure 1), the Senhance system's instruments are reusable. The system incorporates eye-tracking camera control, haptic sensing, and 3DHD visualisation. Case set-up for Senhance procedures generally includes raising the patient so the camera port is aligned with the front of the arms' collar; setting the patient in Trendelenburg; setting the scope to 0° to provide clearance for anaesthesiology; and using the xyphoid process as the point for arm placement. Both arms use instruments that are 310 mm in length (Figure 2).

For Gyn cases specifically, cameras in Senhance cases should be placed proximal to the umbilicus, but can also be located distally, subject to patient anatomy. Instrument port placement is suggested to be set a minimum of 8 cm from the camera port (Figure 3). Surgical instrument set-up, docking and undocking can be performed by a surgical assistant and surgeon. Docking and undocking take place on a robotic arm using a clamp and lock system, which does not require attachment of the robotic arm directly to a trocar. Standard laparoscopes, cameras, insufflators, trocars, and reusable instruments reduce surgical expense. Use of other instruments like ultrasonic energy are compatible with the system which can use both 3 and 5 mm trocars and instruments for minimally invasive surgery advantages.

For reference, an overview of the key specifications of the da Vinci Si and Xi robot models, as well as the LAVH surgical procedure and associated technology, has been covered previously in the literature in great depth.^{11–15}

2 | MATERIALS AND METHODS

Given the objective of assessing the comparative costs and case times between the Senhance robot, the da Vinci robot and the LAVH cases, retrospective instrument cost, console times (Senhance and da Vinci), and operative time data were evaluated based on 28 sequential Senhance total laparoscopic hysterectomies (with and without adnexa removal) performed by six gynaecologic surgeons in their robotic learning curve from four hospitals in the United States and Europe between June 2019 and January 2020 (Tables 1 and 2).

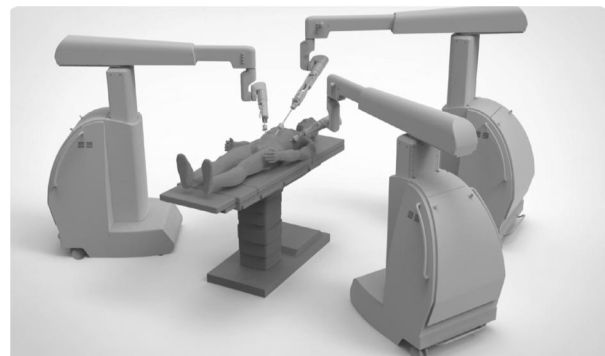


FIGURE 1 Basic Senhance surgical system components

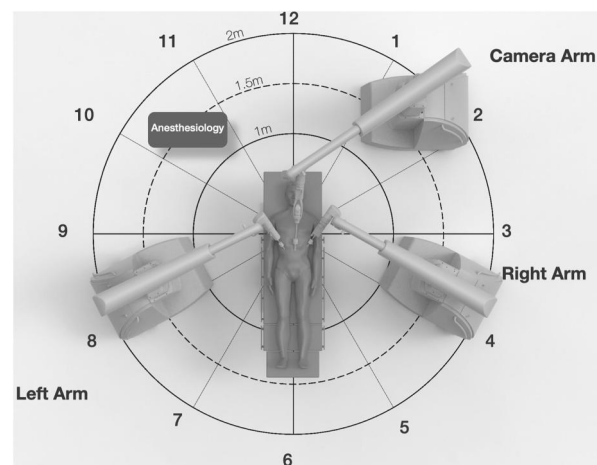


FIGURE 2 Initial Senhance room set-U

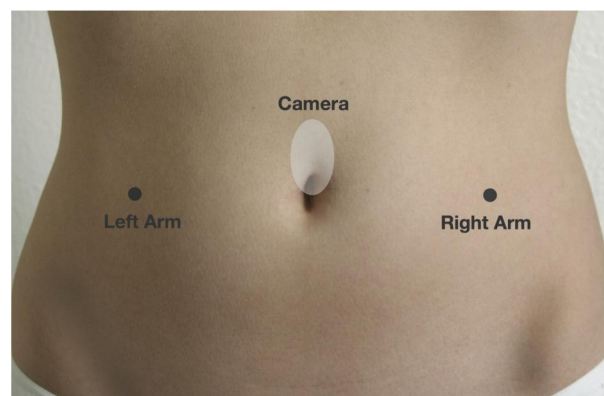


FIGURE 3 Recommended Senhance Gyn Port Placement

TABLE 1 Senhance hospitals and case volumes

Location	No. of Senhance cases
Site 1	7
Site 2	10
Site 3	9
Site 4	2
Total	28



TABLE 2 Asensus Surgical Senhance data summary

Date	Location	Surgeon	Procedure	Cockpit time (min)	Surgery elapsed time (min)	Instrument costs
15/08/2019	Site 3	A	Total hysterectomy	208	286	\$662
05/09/2019	Site 3	A	Total hysterectomy	153	198	\$162
20/06/2019	Site 3	A	Total hysterectomy	192	241	\$162
05/09/2019	Site 2	B	Total hysterectomy	125	172	\$666
12/09/2019	Site 2	B	Total hysterectomy	100	163	\$624
29/08/2019	Site 2	B	Total hysterectomy	69	120	\$624
26/09/2019	Site 2	B	Total hysterectomy	47	124	\$624
05/09/2019	Site 2	B	Total hysterectomy	123	175	\$582
22/08/2019	Site 2	B	Total hysterectomy	110	148	\$582
22/08/2019	Site 2	B	Total hysterectomy	89	131	\$582
26/09/2019	Site 2	B	Total hysterectomy	101	130	\$124
24/06/2019	Site 3	C	Total hysterectomy	118	173	\$204
28/10/2019	Site 3	C	Total hysterectomy	89	128	\$162
28/02/2020	Site 3	C	Total hysterectomy	91	149	\$162
12/07/2019	Site 3	C	Total hysterectomy	95	135	\$124
10/01/2020	Site 3	C	Total hysterectomy	95	151	\$120
06/12/2019	Site 3	C	Total hysterectomy	92	155	\$120
03/10/2019	Site 2	D	Total hysterectomy	80	136	\$162
03/10/2019	Site 2	D	Total hysterectomy	90	141	\$162
28/01/2020	Site 1	E	Total hysterectomy	51	87	\$624
08/10/2019	Site 1	E	Total hysterectomy	58	88	\$624
25/02/2020	Site 1	E	Total hysterectomy	48	93	\$578
07/01/2020	Site 1	E	Total hysterectomy	22	84	\$540
15/10/2019	Site 1	E	Total hysterectomy	83	118	\$540
01/10/2019	Site 1	E	Total hysterectomy	67	115	\$624
28/01/2020	Site 1	E	Total hysterectomy	65	103	\$580
23/01/2020	Site 4	F	Total hysterectomy	93	237	\$580
23/01/2020	Site 4	F	Total hysterectomy	172	209	\$162
Average				97.36	149.64	\$409.36
Range				22–208 min	84–286 min	\$120–666

All surgery was performed by attending gynaecological surgeons who were experienced laparoscopists prior to learning the Senhance technology. All surgeons using the Asensus Surgical Senhance robotic had previously used an Intuitive Surgical da Vinci robot.

Two retrospective cohorts of 56 da Vinci TLH cases (Table 3) and 34 standard laparoscopic LAVH cases, respectively (Table 4), were extracted from the CAVaLytics™ database (CAVA Robotics International, LLC). The CAVaLytics database aggregates operational, clinical and financial robotic surgery data in connection with hospital robotic programs including other comparative minimally invasive

laparoscopic data across service lines. The database is used to track efficiency and to guide and measure change management and program improvement at the surgeon, service line and system-wide levels.

The da Vinci cohort included 10 surgeons and the LAVH cohort included 12 surgeons. Surgeons were selected based on their initial independent cases for both da Vinci and LAVH. All had completed residency training, were board certified and had laparoscopic privileges. The range of private practice experience was 3–30 years. Each surgeon was adding da Vinci TLH or LAVH as a new procedure thereby presenting two comparative cohorts, each with



TABLE 3 Intuitive Surgical da Vinci data summary

Date	Surgeon	Procedure	Console time (min)	Surgery elapsed time (min)	Room time (min)	Instrument costs
26/07/ 2018	G	Robotic laparoscopic assisted hysterectomy vaginal with salpingectomy	91	102	141	\$1393
23/10/ 2017	G	Robotic laparoscopic total hysterectomy salpingectomies	98	115	134	\$1393
11/12/ 2017	G	Robotic laparoscopic total hysterectomy salpingectomies	80	96	129	\$1393
07/06/ 2018	G	Robotic laparoscopic total hysterectomy salpingectomies	99	113	154	\$1393
03/08/ 2018	G	Robotic laparoscopic total hysterectomy salpingectomies	117	129	155	\$1393
18/10/ 2018	G	Robotic laparoscopic total hysterectomy salpingectomies	81	97	134	\$1393
19/10/ 2018	G	Robotic laparoscopic total hysterectomy salpingectomies	113	121	153	\$1393
20/12/ 2018	G	Robotic laparoscopic total hysterectomy salpingectomies	75	94	122	\$1393
12/04/ 2019	H	Robotic laparoscopic hysterectomy total uterus greater than 250G w/salpingectomy	100	108	144	\$1393
19/07/ 2019	H	Robotic laparoscopic total hysterectomy	38	56	100	\$1125
01/11/ 2019	H	Robotic laparoscopic total hysterectomy	46	61	88	\$1125
08/11/ 2019	H	Robotic laparoscopic total hysterectomy	50	68	88	\$1393
03/05/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	63	71	111	\$1393
10/05/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	50	63	101	\$1393
21/06/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	79	96	138	\$1393
12/07/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	55	73	103	\$1125
06/09/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	74	93	124	\$1125
11/10/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	76	93	121	\$1125



TABLE 3 (Continued)

Date	Surgeon	Procedure	Console time (min)	Surgery elapsed time (min)	Room time (min)	Instrument costs
18/10/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	61	71	104	\$1125
08/11/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	62	71	92	\$1125
22/11/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	67	83	114	\$1125
27/12/ 2019	H	Robotic laparoscopic total hysterectomy salpingectomies	58	70	97	\$1125
29/04/ 2019	H	Robotic laparoscopic total hysterectomy salpingoophorectomy	65	80	118	\$1393
03/05/ 2019	H	Robotic laparoscopic total hysterectomy salpingoophorectomy	88	106	140	\$1393
22/11/ 2019	H	Robotic laparoscopic total hysterectomy salpingoophorectomy	65	83	118	\$1125
10/11/ 2017	I	Robotic laparoscopic total hysterectomy salpingoophorectomy	106	116	153	\$1393
01/12/ 2017	I	Robotic laparoscopic total hysterectomy salpingoophorectomy	185	195	232	\$1393
02/08/ 2018	I	Robotic laparoscopic total hysterectomy salpingoophorectomy	125	135	183	\$1393
19/12/ 2019	I	Robotic laparoscopic total hysterectomy salpingoophorectomy	101	109	134	\$1125
04/01/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	103	113	161	\$1393
26/01/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	100	112	147	\$1393
16/03/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	155	163	203	\$1393
12/04/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	90	104	135	\$1393
11/05/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	120	140	166	\$1393
29/06/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	110	125	156	\$1393

(Continues)



TABLE 3 (Continued)

Date	Surgeon	Procedure	Console time (min)	Surgery elapsed time (min)	Room time (min)	Instrument costs
06/07/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	79	99	139	\$1393
27/07/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	103	112	145	\$1393
29/08/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	139	147	195	\$1393
26/09/ 2018	I	Robotic laparoscopic total hysterectomy salpingectomies	105	125	167	\$1393
10/07/ 2020	J	robotic assisted hysterectomy, bilateral salpingectomy, cystoscopy	107	118	142	\$1408
17/01/ 2020	J	Robotic assisted hysterectomy, bilateral salpingectomy, observational cystoscopy	66	81	109	\$1168
12/06/ 2020	J	Robotic assisted hysterectomy, bilateral salpingectomy, observational cystoscopy	79	96	123	\$1168
21/02/ 2020	J	Robotic assisted total laparoscopic hysterectomy, bilateral salpingoophorectomy, observational cystoscopy	72	93	124	\$1168
13/07/ 2020	K	Robotic assisted laparoscopic hysterectomy bilateral salpingoophorectomy anterior repair cystoscopy	94	116	154	\$1150
28/07/ 2020	K	Robotic assisted total laparoscopic hysterectomy bilateral salpingoophorectomy cystoscopy	108	123	153	\$1270
12/02/ 2020	K	Robotic assisted total laparoscopic hysterectomy bilateral salpingectomy cystoscopy	111	126	154	\$1150
28/07/ 2020	K	Robotic assisted total laparoscopic hysterectomy bilateral salpingoophorectomy cystoscopy	88	100	134	\$1150
13/07/ 2020	K	Robotic assisted total laparoscopic hysterectomy left salpingoophorectomy right salpingectomy cystoscopy	125	137	169	\$1150
03/03/ 2020	K	Robotic total laparoscopic hysterectomy, bilateral salpingoophorectomy, cystoscopy	124	142	166	\$1150
23/07/ 2020	L	Robotic assisted total laparoscopic hysterectomy, bilateral salpingectomy, observational cystoscopy	56	76	116	\$1172
12/06/ 2020	M	Robotic assisted total laparoscopic hysterectomy, bilateral salpinectomy, observational cystoscopy, removal of skin tags on left thigh and right abdominal fold	138	148	176	\$1408
10/03/ 2020	N	Robotic total laparoscopic assisted hysterectomy bilateral salpingo oophorectomy	129	142	225	\$1360



TABLE 3 (Continued)

Date	Surgeon	Procedure	Console time (min)	Surgery elapsed time (min)	Room time (min)	Instrument costs
08/07/ 2020	O	Robotic assisted total laparoscopic hysterectomy, bilateral salpingectomy	108	130	156	\$1168
07/02/ 2020	P	Robotic assisted laparoscopic hysterectomy, bilateral salpingoophorectomy, cystoscopy	120	132	156	\$1238
07/02/ 2020	P	Robotic assisted laparoscopic hysterectomy, bilateral salpingoophorectomy, cystoscopy	122	132	156	\$1238
31/01/ 2020	P	Robotic assisted total laparoscopic hysterectomy, exam under anaesthesia, bilateral salpingoophorectomy, cystoscopy, uterine stents	221	236	259	\$1173
Average			95	110	143	\$1287
Range			38–221 min	56–236 min	88–259 min	\$1125–\$1408

similar surgeon experience versus the Senhance initial case data. All cases reflect the surgeons' learning curves in independent practice.

When comparing the operation, which includes cuff closure at the console for a Senhance TLH and da Vinci TLH, the operative time (i.e., cut to close) for LAVH was selected as the best comparison because it includes the cuff closure and is a more accurate representation of the complete operation. Instrument costs include the life-limited adaptors and instruments such as graspers and energy devices (monopolar, bipolar and ultrasonic) as well as robotic vendor-specific drapes, seals and other single-use disposable accessories (Tables 5 and 6). Patient drapes, sutures, gowns, gloves and other disposables used in all three cohorts were excluded from the supply cost analysis. Disposable single-use instruments such as energy devices (monopolar, bipolar, ultrasonic or other advanced sealing devices) were included in the costs of LAVH cases. Capital equipment costs for all procedures were not included in instrumentation or supply costs. No protected health information was collected and the data was Institutional Review Board (IRB) exempt. With the exception of the co-author (S. McCarus), data were deidentified consistent with the US Centers for Medicare and Medicaid Services Limited Data Set guidelines,¹⁶ further preventing inference of surgeon/facility identities. As a real-world assessment, however, this study nevertheless has inherent limitations and flaws, addressed in Section 4.1.

2.1 | Selection of Senhance TLH versus da Vinci TLH versus traditional LAVH

Senhance and da Vinci TLH procedures were compared to traditional LAVH rather than TLH for several pragmatic reasons. Standard straight stick laparoscopic TLH cases are underrepresented in the CAVaLytics database compared to standard LAVH cases. In addition, these two techniques are more similar than they are different. Specifically, the steps of the surgery from port placement to sealing and transecting the uterine artery are similar. The biggest differences in techniques include the additional time of robotic set-up and docking for the Senhance and da Vinci cases and the surgeon return to the patient for the colpotomy and vaginal cuff closure in the LAVH.

Of note, all three techniques require an energy source (bipolar, monopolar, ultrasonic or other advanced seal/cut device) to seal and transect the infundibular, uteroovarian and uterine artery pedicles, and each approach includes similar uterine manipulator placement, port placement and dissection techniques. The time interval selected for comparison in this analysis is slightly different but is designed to reflect the commonality of technique: Senhance and da Vinci TLH console times include the cuff closure and are compared to the cut-to-close surgery time, whereas LAVH cut-to-close surgery time includes the cuff closure and is more similar to the console time when compared with Senhance and da Vinci TLH cases.



TABLE 4 LAVH data summary

Date	Surgeon	Procedure	Cockpit time (min)	Surgery elapsed time (min)	Room time (min)	Instrument costs
24/06/ 2020	Q	Total laparoscopic hysterectomy, bilateral salpingectomy, aspiration of right ovarian cyst, observational cystoscopy	NA	98	122	\$501
02/01/ 2020	R	Vaginal hysterectomy laparoscopic assisted (LAVH) excision of abdominal wall mass X2	NA	26	136	\$461
03/01/ 2020	S	Total laparoscopic hysterectomy bilateral salpingoophorectomy, excision left chest wall nodule	NA	88	118	\$515
06/01/ 2020	T	Laparoscopic total hysterectomy, cystoscopy, bilateral salpingectomy	NA	86	111	\$517
11/06/ 2020	U	Laparoscopic-assisted vaginal hysterectomy, bilateral salpingoophorectomy, anterior and posterior repair.	NA	123	164	\$500
13/02/ 2020	V	Laparoscopic total hysterectomy with bilateral salpingectomy and observational cystectomy	NA	154	176	\$490
29/05/ 2020	V	Total laparoscopic hysterectomy, bilateral salpingectomy, observational cystoscopy	NA	137	166	\$476
01/05/ 2020	W	Laparoscopic total hysterectomy	NA	133	170	\$510
21/05/ 2020	X	Laparoscopic-assisted vaginal hysterectomy, bilateral salpingectomy	NA	88	125	\$524
29/05/ 2020	X	Laparoscopic-assisted vaginal hysterectomy, right salpingoophorectomy	NA	105	130	\$448
16/01/ 2020	X	Vaginal hysterectomy laparoscopic assisted (LAVH) bilateral salpingectomy	NA	129	168	\$460
20/02/ 2020	Y	Laparoscopic-assisted vaginal hysterectomy bilateral salpingectomy	NA	134	172	\$485
05/03/ 2020	Y	Laparoscopic total hysterectomy bilateral salpingectomy	NA	108	145	\$460
20/02/ 2020	Y	Total laparoscopic assisted hysterectomy bilateral salpingectomy	NA	95	128	\$459
16/01/ 2020	Y	Total laparoscopic hysterectomy bilateral salpingectomies	NA	149	187	\$489
06/02/ 2020	Y	Vaginal hysterectomy laparoscopic assisted (LAVH) bilateral salpingoophorectomy, anterior and posterior repair	NA	111	156	\$467
05/03/ 2020	Y	Vaginal hysterectomy laparoscopic assisted bilateral salpingectomies	NA	84	131	\$522
20/02/ 2020	Z	Vaginal hysterectomy laparoscopic assisted (LAVH) bilateral salpingectomy	NA	115	149	\$456



TABLE 4 (Continued)

Date	Surgeon	Procedure	Cockpit time (min)	Surgery elapsed time (min)	Room time (min)	Instrument costs
09/03/ 2020	AA	Total laparoscopic hysterectomy, bilateral salpingectomy, cystoscopy	NA	180	215	\$489
01/10/ 2018	AB	Laparoscopic assisted hysterectomy vaginal	NA	69	126	\$492
09/11/ 2018	AB	Laparoscopic assisted hysterectomy vaginal	NA	77	107	\$480
30/11/ 2018	AB	Laparoscopic assisted hysterectomy vaginal	NA	85	124	\$509
18/03/ 2019	AB	Laparoscopic assisted hysterectomy vaginal	NA	90	122	\$483
22/03/ 2019	AB	Laparoscopic assisted hysterectomy vaginal	NA	76	113	\$487
22/04/ 2019	AB	Laparoscopic assisted hysterectomy vaginal	NA	132	171	\$504
25/10/ 2019	AB	Laparoscopic assisted hysterectomy vaginal	NA	114	147	\$518
15/11/ 2019	AB	Laparoscopic assisted hysterectomy vaginal	NA	76	109	\$454
18/11/ 2019	AB	Laparoscopic assisted hysterectomy vaginal	NA	74	102	\$500
24/01/ 2020	AB	Laparoscopic assisted hysterectomy vaginal	NA	60	100	\$506
26/06/ 2020	AB	Laparoscopic assisted hysterectomy vaginal	NA	85	121	\$456
25/06/ 2018	AB	Laparoscopic assisted hysterectomy vaginal with salpingoophorectomy	NA	105	143	\$478
21/06/ 2018	AB	Laparoscopic assisted hysterectomy vaginal with salpingectomy	NA	99	119	\$499
08/02/ 2019	AB	Laparoscopic assisted hysterectomy vaginal with salpingectomy	NA	66	93	\$470
07/06/ 2019	AB	Laparoscopic assisted hysterectomy vaginal with salpingectomy	NA	97	129	\$524
Average				101	138	\$488
Range				60–180 min	93–215 min	\$448–\$524



TABLE 5 Asensus Surgical Senhance instrument costs (US/EU; in \$)

U.S. catalog #	CF #	Catalog name	U.S. list price	Per use cost	U.S. catalog #	CF #	Catalog name	US list price	Per use cost
3 mm Monopolar instruments					5 mm Passive instruments				
X0007212	210-11010	Monopolar Maryland Dissector (Ø 3 mm × 280 mm)	\$1450	\$29	X0007002	200-11026	Allis Grasper (Ø 5 mm × 310 mm)	\$1200	\$24
X9007212	210-21010	Adapter, Monopolar 3 mm Maryland Dissector (Ø 3 mm × 280 mm)	\$4500	\$18	X9007002	200-21026	Adapter, Allis Grasper (Ø 5 mm × 310 mm)	\$4500	\$18
X0007215	210-11012	Monopolar Curved Metzenbaum Scissors (Ø 3 mm × 280 mm)	\$1200	\$24	X0007005	200-11030	Johan Grasper (Ø 5 mm × 310 mm)	\$1200	\$24
X9007215	210-21012	Adapter, Monopolar 3 mm Curved Metzenbaum Scissors (Ø 3 mm × 280 mm)	\$4500	\$18	X9007005	200-21030	Adapter, Johan Grasper (Ø 5 mm × 310 mm)	\$4500	\$18
3 mm Bipolar Instruments					X0007008	200-11034	Kocher Grasper (Ø 5 mm × 310 mm)	\$1200	\$24
X0007309	220-11010	Bipolar Maryland Dissector insert (Ø 3 mm × 280 mm)	\$1250	\$25	X9007008	200-21034	Adapter, Kocher Grasper (Ø 5 mm × 310 mm)	\$4500	\$18
X9007309	220-21010	Adapter, Bipolar 3 mm Maryland Dissector (Ø 3 mm × 280 mm)	\$4500	\$18	X0007011	200-11038	Strong Grasper (Ø 5 mm × 310 mm)	\$1200	\$24
X0007306	220-11012	Bipolar Grasping Forceps insert (Ø 3 mm × 280 mm)	\$1250	\$25	X9007011	200-21038	Adapter, Strong Grasper (Ø 5 mm × 310 mm)	\$4500	\$18
X9007306	220-21012	Adapter, Bipolar 3 mm Grasping Forceps (Ø 3 mm × 280 mm)	\$4500	\$18	X0007014	200-11042	Mixer Dissector (Ø 5 mm × 310 mm)	\$1200	\$24
X0007303	220-11014	Bipolar 3 mm Shaft (Ø 3 mm × 280 mm)	\$250		X9007014	200-21042	Adapter, Mixer Dissector (Ø 5 mm × 310 mm)	\$4500	\$18
3 mm Passive instruments					X0007017	200-11018	Babcock Forceps (Ø 5 mm × 310 mm)	\$1200	\$24
X0007203	200-11010	Atraumatic Single Action Grasper (Ø 3 mm × 280 mm)	\$1450	\$29	X9007017	200-21018	Adapter, Babcock Forceps (Ø 5 mm × 310 mm)	\$4500	\$18
X9007203	200-21010	Adapter, 3 mm Atraumatic Single Action Grasper (Ø 3 mm × 280 mm)	\$4500	\$18	X0007020	200-11045	Needle Holder Right (Ø 5 mm × 310 mm)	\$1200	\$24
X0007206	200-11012	Cobra Grasper (Ø 3 mm × 280 mm)	\$1450	\$29	X9007020	200-21045	Adapter, Needle Holder Right (Ø 5 mm × 310 mm)	\$4500	\$18



TABLE 5 (Continued)

U.S. catalog #	CF #	Catalog name	U.S. list price	Per use cost	U.S. catalog #	CF #	Catalog name	US list price	Per use cost
X9007206	200-21012	Adapter, 3 mm Cobra Grasper (Ø 3 mm × 280 mm)	\$4500	\$18	X0007023	200-11048	Needle Holder Left (Ø 5 mm × 310 mm)	\$1200	\$24
X0007209	200-11014	DeBaKey Grasper (Ø 3 mm × 280 mm)	\$1450	\$29	X9007023	200-21048	Adapter, Needle Holder Left (Ø 5 mm × 310 mm)	\$4500	\$18
X9007209	200-21014	Adapter, 3 mm DeBaKey Grasper (Ø 3 mm × 280 mm)	\$4500	\$18	X0007038	200-11050	Fundus Grasper (Ø 5 mm × 310 mm)	\$1200	\$24
X0007218	200-11016	Needle Holder (Ø 3 mm × 280 mm)	\$1450	\$29	X9007038	200-21050	Adapter, Fundus Grasper (Ø 5 mm × 310 mm)	\$4500	\$18
X9007218	200-21016	Adapter, 3 mm Needle Holder (Ø 3 mm × 280 mm)	\$4500	\$18	X0007003	200-11052	Allis Grasper, Long (Ø 5 mm × 410 mm)	\$1200	\$24
5 mm Monopolar instruments									
X0007026	210-11018	Monopolar Curved Metzenbaum Scissors (Ø 5 mm × 310 mm)	\$1000	\$20	X0007006	200-11054	Johan Grasper, Long (Ø 5 mm × 410 mm)	\$1200	\$24
X9007026	210-21018	Adapter, Monopolar Curved Metzenbaum Scissors (Ø 5 mm × 310 mm)	\$4500	\$18	X9007006	200-21054	Adapter, Johan Grasper, Long (Ø 5 mm × 410 mm)	\$4500	\$18
X0007029	210-11022	Monopolar Curved Metzenbaum Scissors Short Tip (Ø 5 mm × 310 mm)	\$1000	\$20	X0007009	200-11056	Kocher Grasper, Long (Ø 5 mm × 410 mm)	\$1200	\$24
X9007029	210-21022	Adapter, Monopolar Curved Metzenbaum Scissors Short Tip (Ø 5 mm × 310 mm)	\$4500	\$18	X9007009	200-21056	Adapter, Kocher Grasper, Long (Ø 5 mm × 410 mm)	\$4500	\$18
X0007032	210-11026	Monopolar Maryland Dissector (Ø 5 mm × 310 mm)	\$1200	\$24	X0007012	200-11058	Strong Grasper, Long (Ø 5 mm × 410 mm)	\$1200	\$24
X9007032	210-21026	Adapter, Monopolar Maryland Dissector (Ø 5 mm × 310 mm)	\$4500	\$18	X9007012	200-21058	Adapter, Strong Grasper, Long (Ø 5 mm × 410 mm)	\$4500	\$18
X0007035	210-11030	Monopolar L-Hook Electrode (Ø 5 mm × 310 mm)	\$1200	\$24	X0007015	200-11060	Mixer Dissector, Long (Ø 5 mm × 410 mm)	\$1200	\$24
X9007035	210-21030	Adapter, Monopolar L-Hook Electrode (Ø 5 mm × 310 mm)	\$4500	\$18	X9007015	200-21060	Adapter, Mixer Dissector, Long (Ø 5 mm × 410 mm)	\$4500	\$18

(Continues)



TABLE 5 (Continued)

U.S. catalog #	CF #	Catalog name	U.S. list price	Per use cost	U.S. catalog #	CF #	Catalog name	US list price	Per use cost
X0007027	210-11032	Monopolar Curved Metzenbaum Scissors, Long (Ø 5 mm × 410 mm)	\$1000	\$20	X0007018	200-11022	Babcock Forceps, Long (Ø 5 mm × 410 mm)	\$1200	\$24
X9007027	210-21032	Adapter, Monopolar Curved Metzenbaum Scissors, Long (Ø 5 mm × 410 mm)	\$4500	\$18	X9007018	200-21022	Adapter, Babcock Forceps, Long (Ø 5 mm × 410 mm)	\$4500	\$18
X0007030	210-11034	Monopolar Curved Metzenbaum Scissors Short Tip, Long (Ø 5 mm × 410 mm)	\$1000	\$20	X0007021	200-11062	Needle Holder Right, Long (Ø 5 mm × 410 mm)	\$1200	\$24
X9007030	210-21034	Adapter, Monopolar Curved Metzenbaum Scissors Short Tip, Long (Ø 5 mm × 410 mm)	\$4500	\$18	X9007021	200-21062	Adapter, Needle Holder Right, Long (Ø 5 mm × 410 mm)	\$4500	\$18
X0007033	210-11036	Monopolar Maryland Dissector, Long (Ø 5 mm × 410 mm)	\$1200	\$24	X0007024	200-11064	Needle Holder Left, Long (Ø 5 mm × 410 mm)	\$1200	\$24
X9007033	210-21036	Adapter, Monopolar Maryland Dissector, Long (Ø 5 mm × 410 mm)	\$4500	\$18	X9007024	200-21064	Adapter, Needle Holder Left, Long (Ø 5 mm × 410 mm)	\$4500	\$18
X0007036	210-11038	Monopolar L-Hook Electrode, Long (Ø 5 mm × 410 mm)	\$1200	\$24	X0007039	200-11066	Fundus Grasper, Long (Ø 5 mm × 410 mm)	\$1200	\$24
X9007036	210-21038	Adapter, Monopolar L-Hook Electrode, Long (Ø 5 mm × 410 mm)	\$4500	\$18	X9007039	200-21066	Adapter, Fundus Grasper, Long (Ø 5 mm × 410 mm)	\$4500	\$18
5 mm Bipolar Instruments									
X0005146	220-11017	Bipolar Large Grasping Forceps insert (Ø 5 mm × 310 mm)	\$1100	\$22	X9007619	300-11010	Senhance Ultrasonic Dissector (Ø 5.5 mm × 370 mm) (box of 10)	\$5000	\$500
X9000056	220-21017	Adapter, Bipolar Large Grasping Forceps (Ø 5 mm × 310 mm)	\$4500	\$18	X9007620	300-11011	Senhance Ultrasonic Transducer	\$2500	
X0005147	220-11015	Bipolar Curved Grasping Forceps insert (Ø 5 mm × 310 mm)	\$1100	\$22	X9007618	300-21011	Adapter, Senhance Ultrasonic	\$10,000	

TABLE 5 (Continued)

U.S. catalog #	CF #	Catalog name	U.S. list price	Per use cost	U.S. catalog #	CF #	Catalog name	U.S. list price	Per use cost
X9000057	220-21015	Adapter, Bipolar Curved Grasping Forceps (Ø 5 mm × 310 mm)	\$4500	\$18	X9007621	300-01010	Senhance Ultrasonic Generator	\$20,000	
X0005149	220-11019	Bipolar Maryland Dissector insert (Ø 5 mm × 310 mm)	\$1100	\$22	X9007641	300-01012	Senhance Ultrasonic Footswitch	\$1000	
X9000058	220-21019	Adapter, Bipolar Maryland Dissector (Ø 5 mm × 310 mm)	\$4500	\$18	X9007655	300-01020	Senhance Ultrasonic Generator Power Cable (Type B)	\$150	
X0005148	220-11021	Bipolar Curved Scissors insert (Ø 5 mm × 310 mm)	\$1100	\$22	Drapes				
X9000059	220-21021	Adapter, Bipolar Curved Scissors (Ø 5 mm × 310 mm)	\$4500	\$18	X0005151	800-91001	Senhance Manipulator Arm Sterile Drapes (box of 10 sterile 3-packs)	\$2000	200
X0005150	220-11023	Bipolar Shaft (Ø 5 mm × 310 mm)	\$200		X0005244	800-91002	Senhance Manipulator Arm Sterile Drapes (box of 10 individual sterile drapes)	\$1000	100
					Accessories				
					X0005436	800-01013	Velcro kit for sterile drape attachment (box of 10)	\$150	
					X0005712	800-01014	InstruSafe Sterilization Tray for Senhance Instruments and Adapters (49.8 cm L × 24.4 cm W × 10.5 cm H)	\$4500	
					X0007617	800-01015	InstruSafe Sterilization Tray for Senhance Endoscope Adapter (49.8 cm L × 24.4 cm W × 6.0 cm H)	\$2500	
					X9000067	800-01018	Cockpit Handle inserts (box of 2)	\$300	
					X0005202	800-01019	Monopolar Cable	\$500	
					X0005152	800-01020	Bipolar Cable - Erbe	\$500	
					X0007819	800-01021	Bipolar Cable - Covidien/Valleylab/CONMED	\$500	
					X0008311	800-01003	Monopolar Cable, 4 mm Socket, for Erbe, 5 m	\$500	
					X0008312	800-01004	Monopolar Cable, 4 mm Socket, for 8 mm Bovie, 5 m	\$500	
					X0008313	800-01005	Monopolar Neutral Cable, for Erbe Nessy, 4.5 m	\$500	
					X0008314	800-01006	Monopolar Neutral Cable, International, REM, 4.5 m	\$500	
					X0008315	800-01007	Bipolar Cable, U.S. Forceps (angled), for Erbe, 5 m	\$500	
					X0008316	800-01008	Bipolar Cable, U.S. Forceps (angled w/cap), 5 m	\$500	
					X0008272	800-01023	3D Glasses	\$50	
					X0008254	800-01024	3D Clip-ons	\$50	



TABLE 6 Intuitive Surgical da Vinci instrument costs (US/EU; in \$)

Commonly used instruments and accessories	Size	Part	Price	Uses	Quantity	Per use
Hot shears	8 mm	470179	\$3200	10	1	\$320.00
Permanent cautery hook	8 mm	470183	\$2000	10	1	\$200.00
Permanent cautery hook spatula	8 mm	470184	\$2000	10	1	\$200.00
Maryland bipolar forceps	8 mm	470172	\$2700	10	1	\$270.00
Fenestrated bipolar forceps	8 mm	470205	\$2700	10	1	\$270.00
Force bipolar	8 mm	470405	\$3100	10	1	\$310.00
Curved bipolar dissector	8 mm	470344	\$2700	10	1	\$270.00
Micro bipolar forceps	8 mm	470171	\$2900	10	1	\$290.00
Long bipolar grasper	8 mm	470400	\$2900	10	1	\$290.00
Medium large clip applier	8 mm	470327	\$1400	100	1	\$14.00
Large clip applier	8 mm	470230	\$1400	100	1	\$14.00
Small clip applier	8 mm	470401	\$2800	100	1	\$28.00
Large needle driver	8 mm	470006	\$2200	10	1	\$220.00
Mega suture cut needle driver	8 mm	470309	\$2400	10	1	\$240.00
Mega needle driver	8 mm	470194	\$2200	10	1	\$220.00
Large suture cut needle driver	8 mm	470296	\$2400	10	1	\$240.00
ProGrasp forceps	8 mm	470093	\$2200	10	1	\$220.00
Tenaculum forceps	8 mm	470207	\$2200	10	1	\$220.00
Long tip forceps	8 mm	470048	\$2800	10	1	\$280.00
Tip-up fenestrated grasper	8 mm	470347	\$2200	10	1	\$220.00
Small graptor (grasping retractor)	8 mm	470318	\$2400	10	1	\$240.00
Cadiere forceps	8 mm	470049	\$2100	10	1	\$210.00
Cobra grasper	8 mm	470190	\$2200	10	1	\$220.00
Potts scissors	8 mm	470001	\$1950	10	1	\$195.00
Round tip scissors	8 mm	470007	\$2035	10	1	\$203.50
Resano forceps	8 mm	470181	\$2200	10	1	\$220.00
Atrial retractor short right	8 mm	470246	\$3500	10	1	\$350.00
Dual blade retractor	8 mm	470249	\$3500	10	1	\$350.00
Black diamond micro forceps	8 mm	470033	\$3000	15	1	\$200.00
Cardiac probe grasper	8 mm	470215	\$2400	10	1	\$240.00
DeBakey forceps	8 mm	470036	\$2000	10	1	\$200.00
Harmonic ACE curved shears	8 mm	480275	\$3270	1	6	\$545.00
EndoWrist suction irrigator	8 mm	480299	\$1590	1	6	\$265.00
Vessel sealer	8 mm	480322	\$3570	1	6	\$595.00
Arm drape	NA	470015	\$1040	NA	20	\$52.00
Column drape	NA	470341	\$360	NA	20	\$18.00
5–8 mm Universal seal	5–8 mm	470361	\$180	NA	10	\$18.00
8 mm Cannula	8 mm	470002	\$600	NA	1	NA
8 mm Cannula, long	8 mm	470004	\$650	NA	1	NA
8 mm Blunt obturator	8 mm	470008	\$550	NA	1	NA



TABLE 6 (Continued)

Commonly used instruments and accessories	Size	Part	Price	Uses	Quantity	Per use
8 mm Blunt obturator, long	8 mm	470009	\$590	NA	1	NA
8 mm Bladeless obturator	8 mm	470357	\$150	NA	6	\$25.00
8 mm Bladeless obturator, long (disposable)	8 mm	470358	\$150	NA	6	\$25.00
8 mm Bladeless obturator (optical)	8 mm	470359	\$180	NA	6	\$30.00
8 mm Bladeless obturator, long (optical)	8 mm	470360	\$180	NA	6	\$30.00

TABLE 7 Summary analysis

Comparative results of Senhance vs. da Vinci (in benign hysterectomy)					
Parameter	Senhance (n = 26)		da Vinci (n = 56)		p Value
	Median	IQR	Median	IQR	
Console time (min)	91.5	68–114	96	69.5–122	0.898
Surgery elapsed time (min)	138.5	119–172.5	108.5	88–127.5	<0.001
Instrument costs (\$)	\$559	\$162–624	\$1393	\$1150–1393	<0.001
Median cost savings by Senhance (\$)	−\$834.00				NA
Comparative results of Senhance vs. LAVH (in benign hysterectomy)					
Parameter	Senhance (n = 26)		LAVH (n = 34)		p Value
	Median	IQR	Median	IQR	
Console time (min)	91.5	68-114	NA	NA	NA
Surgery elapsed time (min)	138.5	119-172.5	97.5	84-123	<0.001
Instrument costs (\$)	\$559	\$162-624	\$498	\$467-506	0.336
Median cost savings by LAVH (\$)	\$61.00				NA

2.2 | Data source for da Vinci and laparoscopic cases

All da Vinci and LAVH data were obtained from the CAVAlytics database, protected by applicable US Health Insurance Portability and Accountability Act and the European Union General Data Protection Regulation privacy and security policies. Subject to data use agreements between the hospitals and CAVA, data are aggregated for independent benchmarking of key performance indicators without commercial biases from robotic or equipment vendors. Although average performance metrics are available from Intuitive Surgical, more detailed case- and surgeon-level data can be accessed and analysed with the CAVAlytics database, which is not available in the public domain. Blinded and aggregated data is also used to establish robotic and laparoscopic surgery performance benchmarks for clinical, operational and financial metrics. Data used herein did not include PHI and was IRB exempt. Endpoints included OR room time, console time (for Senhance and da Vinci), surgery time (for LAVH) and average instrument cost per case.

Vendor-specific supplies unique to the case (i.e., Asensus Surgical and Intuitive Surgical instruments and accessories) were included in the analysis, as well as unique disposable laparoscopic devices for LAVH cases. Supplies that are common to each of the three case types such as patient drapes, gloves, gowns and so on were removed

from the analysis given that these supplies are similar across all modalities and do not represent incremental costs of minimally invasive surgery.

Statistical analysis included comparison of instrument costs (Senhance vs. da Vinci vs. LAVH), console times (Senhance vs. da Vinci), and total operative time (Senhance vs. da Vinci vs. LAVH) using the nonparametric Mann–Whitney test. *p* Values were not adjusted for multiple comparisons and may not be interpreted as confirmatory but rather descriptive.

Senhance instruments were assigned a per-case instrument cost based on Asensus' commercial price guide, assuming an adaptor with 250 lives and an insert with 50 lives. da Vinci instruments were similarly assigned a per-case instrument cost based on life limits of 10 uses each and Intuitive's commercial pricing, as of 1 June 2020. Instrument pricing is the same between the United States and Europe for both vendors.

3 | RESULTS

This is the first comparative assessment of the Senhance surgical system in benign hysterectomy. Summary analysis of the three cohorts is presented in Table 7. Findings demonstrated a median Senhance benign hysterectomy instrument cost savings per case of \$834



compared to similar da Vinci cases; this difference in median instrument costs between Senhance (\$559) and da Vinci (\$1393) was statistically significant ($p < 0.001$). Median benign hysterectomy console times for Senhance cases were 91.5 min compared to da Vinci console times at 96 min, which was not statistically significant. It was noted that the total surgery elapsed time is longer for Senhance cases compared to the da Vinci cases, which can lead to less efficient use of OR resources. This is likely longer in the Senhance cases due to the surgeons' and crews' lack of experience with the new Senhance technology, compared with the da Vinci technology which they had used previously. In addition to the console time, which is surgeon dependent, the robotic set-up time, including port placement decisions and docking, are included in the total surgery elapsed time.

Compared to LAVH, Senhance median instrument costs unique to the case were \$559 compared to \$489 for LAVH, which was not statistically significant ($p = 0.336$). The majority of cost in the LAVH cases is related to single-use disposable energy devices such as LigaSure, EnSeal or Harmonic ACE shears.

Additional findings include statistical significance of longer operating times for Senhance TLH (median: 138.5 min) compared to LAVH (97.5 min) ($p < 0.001$). However, when comparing the average console time of Senhance TLH (91.5 min) to the operative time of LAVH (101 min), there is no statistical significance ($p = 0.6772$).

4 | DISCUSSION

As is commonly known, the increase in robotic surgery adoption in gynaecology has been challenged because of its associated high costs and longer operative times.^{17,18} It appears these historical barriers—higher per-case instrument costs and longer case times—are lowering as robotic surgeons become more experienced in robotic best practices.^{6,7} With the inclusion of a new technology such as Senhance, laparoscopic surgeons can leverage aspects of robotic surgery, such as instrument control, image stability, and 3D visualisation, while maintaining the patient benefits of minimally invasive surgery together with surgeon familiarity of laparoscopic techniques^{19,20} at lower instrumentation costs—a key objective of facility's seeking to improve surgical contribution margins.

It bears repeating that, despite the fact that the Senhance hysterectomy operative times were significantly longer than the LAVH (due in large measure to increased time associated with docking, port placement, etc.), when comparing the core operative time—that is, the console time of the Senhance hysterectomy versus the LAVH operative time—the difference is not significant. Moreover, overall times have improved over the past 15 years with da Vinci technology as experience of surgeons and operative teams has increased.^{21,22} It can be reasonably posited, therefore, that the difference in overall operative and console times of Senhance TLH cases will also likely decrease with surgeon and operative team experience and will likely approach parity with da Vinci as port placement and docking times

for Senhance improve; however, further assessment of this parameter is required.

Moreover, as previously discussed, the complete operation for all steps of the hysterectomy is most closely represented by the console time of the robotic cases compared to the total time of the LAVH cases in order to capture all steps of the technique including cuff closure.

Over the past decade, the decision by laparoscopic and open gynaecologic surgeons to adopt robotic surgery has become increasingly widespread,^{2,6} with approximately 35% of all benign hysterectomies performed robotically in the United States.^{17,23,24} This increase in robotic benign hysterectomy cases is a result of many factors, including surgeon preference attributed to robotic technologies as well as patient preferences.²⁵

Despite the widespread adoption of robotic surgery in gynaecology, surgeons often struggle to maintain adequate robotic case volumes due to the recent decline in utilisation of hysterectomy in benign conditions such as abnormal uterine bleeding. Notably, clinical quality and consistent surgical outcomes are not as favourable for low-volume robotic surgeons in gynaecology (which is similarly true for other robotic service lines), thus increasing risk and decreasing patient safety.^{6,26} Longer case times and decreased operational efficiencies also result in increased costs. In fact, the prevalence of low-volume gyn surgeons—though performing the majority of gyn robotic procedures—contributes to higher overall surgical complication rates, longer lengths of stays, and higher cost of care compared to high-volume gyn surgeons.^{2,27}

Several other points bear illuminating. Regarding the comparative case times, even though this real-world study examined surgeons' initial independent LAVH case, it should be noted that these surgeons were already experienced in laparoscopy, meaning there is inherent efficiency expected. Set-up for traditional laparoscopy is also less demanding than robotic set-up for both da Vinci and Senhance.

A second point relates to the benefits associated with a surgeon being able to sit perioperatively. One recent study of 289 gynaecologic surgeons cited that those who managed robotic ergonomics effectively reported a lower rate of physical discomfort associated with performing surgery ($p < 0.05$).²⁸

A third point of note is that, for surgeons learning the Senhance system, familiar port placement and instrumentation can speed learning curve adoption, while advantages of an open console, 3D visualisation, and haptic feedback are all part of the operation. Such capabilities fill a gap for common cases such as benign hysterectomy, which have been vigorously challenged historically as inappropriate da Vinci cases due to their associated higher cost.^{17,29,30} However, being able to achieve the advantages of robotics at a lower cost per case versus da Vinci—and with costs similar to but not statistically lower than LAVH—suggests the Senhance system should garner further consideration.

Although not addressed in this analysis, a final parallel consideration involves the needs of lower-volume gyn surgeons. Specifically, many lower-volume surgeons (surgeons who perform less than an average of two robotic cases monthly) struggle with the increased



technical demands required to transition from traditional laparoscopy to da Vinci robotic surgery, which often makes additional training and consistent robot utilisation difficult to achieve and sustain.³¹ Such assessment may prove to be a worthwhile prospective exploration.

4.1 | Limitations

As a retrospective, pragmatic, real-world assessment, the three patient populations herein assessed—although inclusive of cases performed by learning curve surgeons—were similar but not strictly matched with regards to patient age, body mass index, comorbidities, uterine size/weight, presence of uterine or other pelvic pathology, length of stay, pain measures and post-op complications. Despite the fact that these clinical endpoints were not available in the retrospective data sets, it is known that the surgeons selected did not exclusively perform Senhance, da Vinci or LAVH procedures over the timeframe analysed. Other familiar approaches to hysterectomy (abdominal, vaginal or laparoscopic) were utilised by each, suggesting some initial case selection bias. The bias in selecting *initial learning curve cases* was thus universal across each group, and most likely favoured less clinically complex, and therefore more similar cases, selected by the surgeons for their first independent cases. The methodology of extracting the comparative robotic and LAVH data points used in this analysis from a proprietary database may also raise the question of potential bias as well as the fact that this methodology is not widely accepted in the medical literature, and presents an acknowledged limitation of real-world, pragmatic assessments.

An additional limitation is the small numbers of da Vinci and LAVH cases per surgeon; sometimes only one case was available from low-volume surgeons. Qualifying cases of initial independent cases with complete supply cost and time metrics were selected in an effort to achieve slightly larger cohorts of cases and surgeons, thereby gaining more data to compensate for the smaller individual surgeon numbers. Senhance first-time users also had previous robotic experience; it may have provided a more robust assessment had the Senhance users been a totally robotic-naïve population.

This assessment also relies on small sample sizes; 7 of 28 Senhance cases were performed by one laparoscopic surgeon (Table 4, surgeon E) whose case and console times were notably faster than the other five surgeons in this cohort, as well as faster than the average da Vinci cohort case times. While this surgeon's performance reduced the average Senhance case time in this limited series, it begs the question whether, and to what degree, experienced laparoscopic surgeons might achieve faster benign hysterectomy robotic case and console times on Senhance compared to the da Vinci robot, at least in their learning curve. To better assess this finding, future comparative research is called for inclusive of case-matched demographic, clinical and cost comparisons. Additional areas of research should also include same-surgeon experience and comparison between Senhance TLH, laparoscopic TLH and da Vinci TLH.

Finally, this analysis was supported by industry, which opens the door to criticisms such as nonrandomisation and bias associated with the cost of consumables reported to be better for Senhance versus da Vinci cases.

5 | CONCLUSION

On the basis of the findings in these initial, similar-case cohort comparisons, the Senhance system appears to offer a cost-effective minimally invasive surgical option in benign hysterectomy surgery compared to the da Vinci, with comparable case time; and statistically comparable costs to LAVH albeit with longer case times, at least during the learning curve period.

CONFLICT OF INTEREST

Herbert Coussons and Josh Feldstein are employed by CAVA Robotics International, which received support from Asensus Surgical to perform independent analysis of data and drafting of this manuscript. Steve McCarus has no conflicts of interest and has nothing to disclose.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Coussons H, Feldstein J, McCarus S. Senhance surgical system in benign hysterectomy: A real-world comparative assessment of case times and instrument costs versus da Vinci robotics and laparoscopic-assisted vaginal hysterectomy procedures. *Int J Med Robot.* 2021; e2261. <https://doi.org/10.1002/rcs.2261>