Robot-assisted Procedures in General Surgery Data Companion: Cholecystectomy and Ventral and Inguinal Hernia Repairs

December 2021

U.S. Department of Veterans Affairs
Veterans Health Administration
Health Services Research & Development Service

Recommended citation: Kondo K, Jacob RL, Mederos MA, et al. Robot-assisted Procedures in General Surgery Data Companion: Cholecystectomy and Ventral and Inguinal Hernia Repairs. Washington, DC: Evidence Synthesis Program, Health Services Research and Development Service, Office of Research and Development, Department of Veterans Affairs. VA ESP Project #05-226; 2021. Available at: https://www.hsrd.research.va.gov/publications/esp/reports.cfm.

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This report was prepared by the Evidence Synthesis Program Coordinating Center located at the **Portland VA Health Care System**, directed by Mark Helfand, MD, MPH, MS and funded by the Department of Veterans Affairs, Veterans Health Administration, Health Services Research and Development.

The findings and conclusions in this document are those of the author(s) who are responsible for its contents and do not necessarily represent the views of the Department of Veterans Affairs or the United States government. Therefore, no statement in this article should be construed as an official position of the Department of Veterans Affairs. No investigators have any affiliations or financial involvement (*eg*, employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties) that conflict with material presented in the report.

PREFACE

The VA Evidence Synthesis Program (ESP) was established in 2007 to provide timely and accurate syntheses of targeted health care topics of importance to clinicians, managers, and policymakers as they work to improve the health and health care of Veterans. These reports help:

- Develop clinical policies informed by evidence;
- Implement effective services to improve patient outcomes and to support VA clinical practice guidelines and performance measures; and
- Set the direction for future research to address gaps in clinical knowledge.

The program comprises three ESP Centers across the US and a Coordinating Center located in Portland, Oregon. Center Directors are VA clinicians and recognized leaders in the field of evidence synthesis with close ties to the AHRQ Evidence-based Practice Center Program. The Coordinating Center was created to manage program operations, ensure methodological consistency and quality of products, interface with stakeholders, and address urgent evidence needs. To ensure responsiveness to the needs of decision-makers, the program is governed by a Steering Committee composed of health system leadership and researchers. The program solicits nominations for review topics several times a year via the program website.

Comments on this report are welcome and can be sent to Nicole Floyd, Deputy Director, ESP Coordinating Center at Nicole.Floyd@va.gov.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Nader N. Massarweh, Meike Niederhausen, Apoorva Salvi, and Elizabeth Hooker, for data analysis and statistical consultation.

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BACKGROUND

General surgery is the largest and fastest-growing specialty to adopt robotic surgery in recent years, with a reported 8.4-fold increase in the United States (US) nationally from 2012 to 2018.[1,2] Cholecystectomy, inguinal hernia repair, and ventral hernia repair are the 3 most commonly performed operations in general surgery and comprise the majority of cases done with the robotic platform.[3]

In 2020, the Department of Veterans Affairs (VA) Evidence Synthesis Program (ESP) published a systematic review comparing the clinical- and cost-effectiveness of robot-assisted cholecystectomy, inguinal hernia repair, and ventral hernia repair to traditional open and laparoscopic approaches. Across all 3 procedures, robot-assisted surgery was associated with similar clinical outcomes, a longer operative time (moderate to high certainty of evidence [COE], depending on procedure), and shorter post-operative length of stay (moderate COE) when compared to traditional open and laparoscopic surgery. Confidence in other intra- and post-operative findings was limited due to the lack of controlled trials, inconsistent findings, and imprecision. Moreover, the review found scant information about the use and effectiveness of robot-assisted surgery for these procedures in the Veterans Health Administration (VHA). Only 2 studies published through March 2020 examined robot-assisted general surgery in VHA settings, and both were small, single center studies using data from 7 to 11 years ago.

Compared to the general US population and to Veterans ineligible for VA health care benefits, those served by the VHA tend to be older, and are more likely to experience both single and multiple chronic conditions,[4,5] have a mental health condition,[6] and to live in rural communities with limited access to health care and other services.[7] Given the small number of studies conducted in VHA settings, the small samples sizes, and the age of the articles, the applicability of findings from the published literature to the VHA may be limited.

In this study, which augments findings from the ESP systematic review of the published literature, we analyzed the VHA's administrative and registry data to examine geographic variation in the use of robot-assisted general surgery, how use has changed over time, and explored whether clinical outcomes differ as compared to traditional general surgery.

METHODS

TOPIC DEVELOPMENT

This topic was developed as a follow-up to a 2020 ESP systematic review examining the clinical and cost effectiveness of robot-assisted cholecystectomies, inguinal hernia repairs, and ventral hernia repairs.[8]

The Key Questions (KQs) for this data analysis were:

KQ1. What were the national and regional trends in the utilization of robot-assisted surgery for cholecystectomy, ventral hernia repair, and inguinal hernia repair in the VHA between January 2015 and December 2019?

KQ2. Between January 2015 and September 2019, how were clinical outcomes in the VHA similar or different for robot-assisted versus laparoscopic and open surgical approaches for cholecystectomies, ventral hernia repairs, and inguinal hernia repairs?

DATA SOURCES

VA Corporate Data Warehouse (CDW)

The VHA's Corporate Data Warehouse (CDW) is a centralized relational data architecture comprising data from several VHA clinical and administrative systems.[9-11] CDW includes data from Veterans Information System Technology Architecture (VistA), the VHA's electronic health record (EHR) system, from 1999 to the present, including all inpatient and outpatient surgical procedures. Inpatient procedures are coded using both International Classification of Diseases (ICD) procedure codes, and Current Procedural Terminology (CPT) coding. Outpatient procedures are coded using CPT and Healthcare Common Procedure Coding System (HCPCS) codes and modifiers.[12]

Observational Medical Outcomes Partnership (OMOP)

The Observational Medical Outcomes Partnership (OMOP) is a concept-based community-supported common data model (CDM).[13] A CDM uses standardized terminology and vocabularies to allow for collaborative research and analysis across health information sources and health systems.[14] The Department of Veterans Affairs' VA Informatics and Computing Infrastructure (VINCI) began to transform CDW data into OMOP in 2015. Data transformation processes are described elsewhere.[15]

VA Surgical Quality Improvement Plan (VASQIP)

The VA Surgical Quality Improvement Plan (VASQIP) contains surgical quality data related to the procedures and select outcomes within 30 days of the procedure. Trained VASQIP nurses review electronic medical records to abstract detailed perioperative variables for each VASQIP case. Higher volume cases are limited to no more than 5 per 8-day abstraction cycle. Data are limited to a maximum of 36 per 8-day cycle. VASQIP data include CPT codes. Description of VASQIP data and methods have been described elsewhere.[16]

CASE IDENTIFICATION

Case Identification for Key Question 1

To examine the utilization of robots in general surgery procedures, we identified all cholecystectomy, ventral hernia repair, and inguinal hernia repair cases performed in VHA facilities from January 1, 2015 through December 31, 2019. We accessed CDW data using the OMOP procedure occurrence table. See Table 1 for a list of included CPT codes for each procedure and surgical approach. Of note, indications for open cholecystectomy are clinically different than laparoscopic or robotic cholecystectomy and are therefore not a useful comparison for our analyses.

We excluded cases associated with patients who had CPT codes for both a cholecystectomy and a hernia repair with the same procedure date, as well as those that indicated a small bowel resection (CPT 44120) on the same procedure date. For cholecystectomies, if we identified more than 1 case associated with the same patient on the same date, we included only the case with the earliest start time (See Table 2).

Classification of bilateral inguinal hernia repairs

We identified bilateral inguinal hernia repairs using the CPT modifier code 50. In addition, when a Veteran had 2 inguinal hernia repairs on the same date, we classified them as a single bilateral procedure. If either of the repairs were recurrent, we classified the bilateral procedure as recurrent.

Classification of robot-assisted procedures

We identified robot-assisted procedures by the presence of Healthcare Common Procedure Coding System (HCPCS) code S2900 in addition to the CPT code.

Table 1. CPT Codes for Case Identification

	Open	Laparoscopic	Robotic
Cholecystectomy			
	--	47562, 47563, 47564	Laparoscopic codes + S2900
Ventral Hernia Repair			
Primary	49560, 49561, 49570, 49572	49652, 49653, 49654, 49655	Open or laparoscopic code + S2900
Recurrent	49565, 49566	49656, 49657	Open or laparoscopic code + S2900
Inguinal Hernia Repair			
Unilateral			
Primary	49505, 49507	49650	Open or laparoscopic code + S2900
Recurrent	49520, 49521	49651	Open or laparoscopic + S2900
Bilateral			

Primary	49505 + modifier code 50 or 2 inguinal hernia repair codes on the same day	49650 + modifier code 50 or 2 unilateral inguinal hernia repair codes, ≥1 of which was laparoscopic	Open laparoscopic code + S2900
Recurrent	49520 + modifier code 50 or 2 recurrent inguinal hernia repair codes	49651 + modifier code 50 or 2 inguinal hernia repair codes, ≥1 of which was laparoscopic and recurrent	Open or laparoscopic code + S2900

Case Identification for Key Question 2

To examine outcomes associated with robot-assisted cholecystectomies and inguinal and ventral hernia repairs, we started with the cases we included for KQ1, and identified those that were included in VASQIP.

We excluded cases that were flagged as emergent procedures, associated with patients with more than 1 procedure on the same procedure date, indicated as a conversion from 1 surgical approach to another, those for which the surgical approach was unclear, and those that had an operative time considered implausible by clinical experts (*eg*, less than 10 minutes; see Table 2 for detail).

Table 2. Case Identification Criteria by Key Question

	KQ1: Robot Utilization	KQ2: Outcomes Associated with Robot-Assisted Surgery
Data Source	CDW/OMOP	VASQIP
Inclusion	See Table 1	KQ1 cases that were included in VASQIP
Exclusion	Any case missing VISN	Cases flagged as an emergent procedure
	Cases associated with patients who have CPT codes for both cholecystectomies and hernia repairs with the same procedure date	Cases associated with patients with more than 1 procedure on the same procedure date.
		Cases for which the surgical approach was unclear
	Any case that also has CPT 44120	Cases that indicated conversion from 1 approach to another
	Additional cholecystectomy cases with the same procedure date	Cholecystectomy and inguinal hernia repair cases with documented operative times of less than 10 minutes or more than 6 hours
		Ventral hernia cases with documented operative times of less than 10 minutes or more than 12 hours

Note. We kept the cholecystectomy with the earliest start time. VASQIP data were only available through September 30, 2019.
Abbreviations. CDW=Corporate Data Warehouse; CPT=current procedural terminology; KQ=key question; OMOP=Observational Medical Outcomes Partnership; VASQIP=VA Surgical Quality Improvement Plan; VISN=Veterans Integrated Services Network

Patient Characteristics

For KQ2, we included gender, age (in years), race, ethnicity, current smoking, body mass index (BMI), and pre-operative hospital length of stay (LOS; in days). Patient characteristics were recorded at the time of the surgical procedure. We did not assume that each case was

independent, for if during our study period a Veteran had the same procedure more than once, they may appear more than once. BMI outliers were determined using the IQR method (lower bound of Q1-1.5*IRR, upper bound of Q3 + 1.5*IQR). BMI values beyond the lower and upper bounds were excluded from the BMI analysis.

OUTCOMES

For KQ2, we examined the following intraoperative and post-surgical outcomes: operative time, and post-operative hospital LOS, systemic sepsis, myocardial infarction, blood loss requiring greater than 4 units of blood, pneumonia, pulmonary embolism, post-operative acute renal failure, superficial surgical site infection, 30-day mortality, and presence of at least 1 of 23 post-operative VASQIP outcomes (see Appendices A and B for definitions).

ANALYSES

For KQ1, the raw proportion of robotic procedures during the study period was reported for cholecystectomy, ventral hernia repair, and inguinal hernia repair separately for each procedure type and in aggregate. Data were then analyzed to characterize trends in the utilization of robotic operations for all 3 procedures during the study period. The proportion of robotic procedures in 2019 were divided by the proportion of robotic procedures in 2015 to determine a fold-difference. The annual trend in proportional use of each surgical approach was estimated using linear regression with the study year modeled as a continuous variable.[2] We used χ^2 analysis to compare the proportion of hernia type with the surgical approach. For example, the proportion of robotic inguinal hernia repairs done for bilateral recurrent hernias were compared with the proportion of non-robotic repairs done for bilateral recurrent inguinal hernias. *P*-values < 0.05 were considered statistically significant.

For KQ2, we used χ^2 tests for differences in proportions of outcomes by surgical approach and Fisher's exact test for differences in proportions among cells with an expected count of less than 5. Relative differences in post-operative LOS (IRR) by surgical approach were compared using unadjusted negative binomial regression, specifying nested correlation structures (patients within hospitals). Relative differences in operative time by surgical approach (IRR) were compared using unadjusted gamma regression, specifying a log link and nested correlation structures (patients within hospitals). Due to very few observations among recurrent ventral hernia repairs and recurrent inguinal hernia repairs, Fisher's exact test was used to compare differences in proportions in pre-operative LOS categories (0-1 days, 2-5 days, and greater than 5 days). The clinical outcomes data were descriptive; we did not adjust for confounding covariates. All analyses were performed using the FREQ and GENMOD procedures in SAS Enterprise Guide 8.2 using two-sided tests and an alpha of 0.05. Cell sizes between 1 and 10 are suppressed to protect Veteran privacy per established guidance.[17]

There were a number of VISN boundary changes during our study period, reducing the number of VISNs from 21 to 18. To allow for consistency in tracking the utilization of robot-assisted procedures, data are aligned to 2019 (current) VISN boundaries.

This study examined VHA administrative data. It was approved by the VHA Institutional Review Board in Portland, OR (IRB Exempt Study #04584).

RESULTS

KQ1. What were the national and regional trends in the utilization of robot-assisted surgery for cholecystectomy, ventral hernia repair, and inguinal hernia repair in the VHA between 2015 and 2019?

We identified 119,191 unique general surgery procedures meeting inclusion criteria. Of these, 5,689 operations (4.77%) were performed with robot assistance (see Table 3). From 2015 to 2019, robot-assisted operations increased from 1.49% to 10.55% (7.08-fold change; slope, 2.14% per year; 95% CI (0.79, 3.49). Furthermore, there was a concurrent decline in other approaches (*ie*, open and laparoscopic) during the same time period. The largest change was observed from 2018 to 2019 with an increase of robotic procedures from 5.74% to 10.55%. See Figure 1A and Table 3 for more detail.

Table 3. Robot-Assisted Surgeries Across Procedures: Percent by Type per Year 2015-2019

Procedure Type	2015 %	2016 %	2017 %	2018 %	2019 %	Total %	Fold Change (2015/2019)	Annual Slope % (95% CI)	*p* Value
All Procedures									
Robotic	1.49	2.45	3.90	5.74	10.55	4.77	7.08	2.14 (0.79, 3.49)	0.015
Laparoscopic	41.76	42.78	43.12	43.14	41.52	42.47	0.99	-0.01 (-0.91, 0.88)	
Open	56.76	54.77	52.98	51.12	47.94	52.76	0.84	-2.13 (-2.61, -1.65)	
Cholecystectomy									
Robotic	1.66	2.39	2.74	4.86	8.07	3.94	4.87	1.53 (0.43, 2.63)	0.021
Laparoscopic	98.34	97.61	97.26	95.14	91.93	96.06	0.93	-1.53 (-2.63, -0.43)	
Ventral Hernia Repair									
Robotic	1.51	3.37	5.31	7.08	13.94	6.22	9.23	2.86 (1.04, 4.68)	0.016
Laparoscopic	41.28	42.26	41.06	38.54	36.41	39.93	0.88	-1.35 (-2.61, -0.08)	
Open	57.21	54.37	53.63	54.38	49.65	53.85	0.87	-1.51 (-3.02, -0.01)	
Inguinal Hernia Repair									
Robotic	1.41	2.20	3.96	5.74	10.59	4.69	7.51	2.19 (0.84, 3.54)	0.014
Laparoscopic	18.47	19.58	20.73	21.01	20.61	20.06	1.12	0.57 (-0.05, 1.19)	
Open	80.11	78.22	75.31	73.26	68.80	75.24	0.89	-2.76 (-3.56, -1.96)	

Note. Percentages may not total 100% due to rounding error.
Abbreviations. CI=confidence interval

Regionally, each of the 18 Veterans Integrated Services Networks (VISNs) had at least 1 robotic system throughout the entire study period. The number of robotic systems in VHA facilities increased from 48 in 2015 to 93 in 2019 (see Appendix C; Jason Lamb, Director Government Accounts, Intuitive Surgical, email communication, June 2021). By 2019, a robot-assisted operation was performed for at least 1 of the 3 general surgery procedures in every VISN. However, over the course of the study period 5 VISNs (1, 5, 7, 8, 15) reported no robot utilization for any of the 3 procedures in at least 1 calendar year. VISNs 1 and 5 reported no robot utilization in 3 of 5 years, and VISN 15 reported no robot utilization in 2 of 5 years (see Table 4 for more detail). The largest increases in procedures performed with robot-assistance were seen in the Northeast, Midwest, and on the West Coast.

Figure 1: Temporal Trends in Utilization of Robot-Assisted Surgery for 3 Common General Surgery Procedures

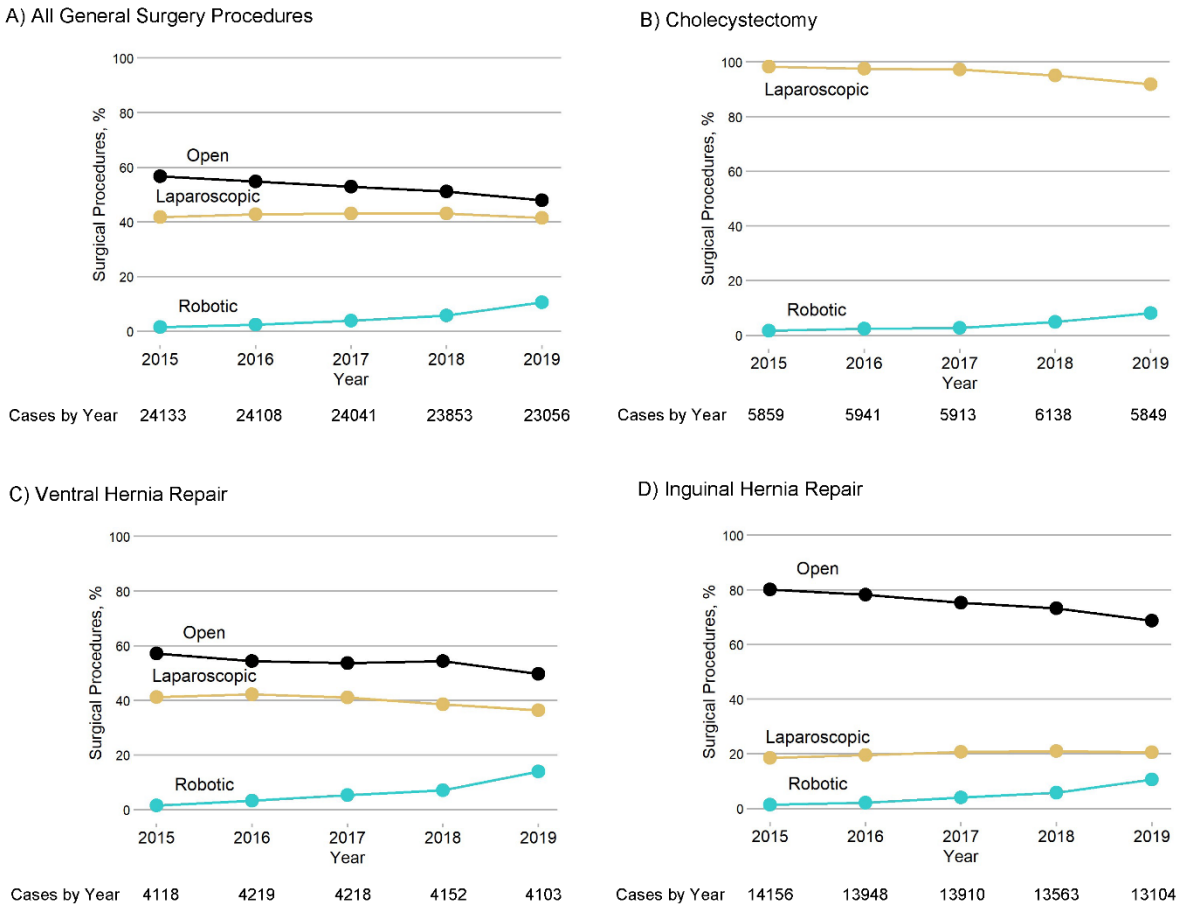

Table 4. Longitudinal Trends in Use of 3 General Surgery Procedures by Approach and Across VISNs

	2015, *n* (%)			2016, *n* (%)			2017, *n* (%)			2018, *n* (%)			2019, *n* (%)		
VISN	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**
1	---	422 (44.1)	536 (55.9)	<11 (<1.2)	415 (44.4)	>509 (>54.4)	---	408 (43.7)	525 (56.3)	---	404 (47.5)	446 (52.5)	<11 (<1.3)	351 (41.5)	>484 (>57.2)
2	27 (2.6)	378 (35.9)	648 (61.5)	47 (4.6)	406 (39.5)	574 (55.9)	125 (11.1)	414 (36.8)	585 (52.0)	271 (22.7)	373 (31.2)	550 (46.1)	382 (34.1)	285 (25.4)	453 (40.4)
4	20 (2.2)	324 (36.1)	554 (61.7)	37 (4.3)	299 (34.8)	524 (60.9)	71 (8.1)	319 (36.2)	490 (55.7)	116 (12.3)	315 (33.3)	515 (54.4)	178 (19.7)	249 (27.5)	477 (52.8)
5	---	319 (38.0)	521 (62.0)	---	303 (39.0)	473 (61.0)	<11 (<1.4)	328 (42.3)	>436 (>56.3)	---	356 (46.7)	407 (53.3)	46 (6.1)	344 (45.7)	363 (48.2)
6	11 (0.7)	731 (48.1)	777 (51.2)	41 (2.7)	800 (52.3)	690 (45.1)	91 (5.2)	874 (50.4)	769 (44.3)	124 (8.1)	719 (47.2)	679 (44.6)	292 (17.8)	733 (44.7)	615 (37.5)
7	<11 (<0.9)	474 (40.9)	>675 (>58.2)	<11 (<0.9)	535 (44.3)	>663 (>54.8)	<11 (<0.9)	529 (44.7)	>643 (>54.4)	---	524 (44.0)	667 (56.0)	<11 (<1)	453 (40.8)	>646 (>58.2)
8	<11 (<0.5)	876 (42.3)	>1185 (>57.2)	---	885 (41.1)	1270 (58.9)	<11 (<0.5)	1084 (46.4)	>1239 (>53.1)	<11 (<0.5)	1191 (50.5)	>1155 (>49.0)	134 (5.7)	1073 (45.9)	1132 (48.4)
9	<11 (<1)	495 (43.2)	>641 (>55.9)	<11 (<0.9)	517 (44.0)	>648 (>55.1)	<11 (<0.9)	553 (47.1)	>609 (>51.9)	<11 (0.9)	581 (48.9)	>597 (>50.2)	46 (3.9)	630 (53.3)	507 (42.9)
10	12 (0.6)	1004 (47.3)	1106 (52.1)	38 (1.8)	1070 (50.9)	995 (47.3)	65 (3.1)	1089 (51.2)	974 (45.8)	110 (5.4)	977 (48.2)	940 (46.4)	158 (8.5)	848 (45.8)	846 (45.7)
12	13 (1.3)	383 (38.2)	606 (60.5)	11 (1.1)	392 (37.7)	638 (61.3)	20 (2.0)	404 (41.2)	557 (56.8)	67 (6.7)	392 (39.0)	547 (54.4)	91 (9.7)	354 (37.7)	495 (52.7)
15	<11 (<1.1)	389 (40.6)	>559 (>58.3)	---	415 (41.5)	585 (58.5)	<11 (<1.3)	343 (41.4)	>474 (>57.2)	---	423 (47.8)	462 (52.2)	<11 (<1.3)	337 (40.1)	>492 (>58.6)
16	<11 (<0.7)	641 (42.1)	>872 (>57.2)	50 (3.1)	588 (36.5)	974 (60.4)	67 (4.5)	543 (36.2)	888 (59.3)	45 (2.8)	638 (40.0)	911 (57.2)	143 (8.9)	735 (45.5)	737 (45.6)
17	88 (6.7)	482 (36.6)	746 (56.7)	145 (10.4)	541 (38.9)	704 (50.6)	117 (9.5)	462 (37.4)	657 (53.2)	141 (11.7)	376 (31.2)	690 (57.2)	204 (16.4)	408 (32.8)	632 (50.8)
19	<11 (<0.7)	689 (45.8)	>803 (>53.4)	19 (1.3)	654 (46.4)	735 (52.2)	48 (3.4)	653 (45.9)	723 (50.8)	84 (6.6)	532 (41.9)	654 (51.5)	129 (10.1)	547 (43.0)	597 (46.9)

	2015, *n* (%)			2016, *n* (%)			2017, *n* (%)			2018, *n* (%)			2019, *n* (%)		
VISN	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**
20	<11 (<1.1)	435 (42)	>590 (>56.9)	<11 (<1.1)	453 (45.5)	>532 (>53.4)	15 (1.5)	379 (39)	577 (59.4)	37 (3.8)	461 (47.3)	477 (48.9)	107 (12.8)	327 (39.0)	404 (48.2)
21	33 (2.2)	492 (32.1)	1008 (65.8)	27 (1.9)	508 (35.2)	909 (63.0)	68 (4.9)	469 (33.5)	863 (61.6)	106 (7.3)	502 (34.6)	844 (58.1)	237 (17.6)	445 (33.0)	667 (49.4)
22	103 (5.0)	836 (40.6)	1118 (54.4)	110 (5.4)	881 (43.1)	1052 (51.5)	184 (8.7)	885 (41.6)	1057 (49.7)	224 (10.8)	883 (42.4)	975 (46.8)	262 (13.0)	851 (42.3)	901 (44.7)
23	29 (2.0)	707 (49.3)	698 (48.7)	58 (4.1)	651 (46.4)	693 (49.4)	53 (4.0)	631 (48.1)	629 (47.9)	33 (2.5)	642 (47.8)	668 (49.7)	17 (1.4)	602 (50.3)	577 (48.2)

Note. Data are coarsened to suppress small cells and protect Veteran privacy.[17]
Abbreviations. Lap.=laparoscopic; VISN=Veterans Integrated Services Network

Cholecystectomy

There were 29,700 cholecystectomies performed during the study period, of which 1,171 were robot-assisted (3.94%; see Table 5). The proportion of robot-assisted cholecystectomies increased from 1.66% in 2015 to 8.07% in 2019 (4.87-fold change; slope, 1.53% per year; 95% CI (0.43, 2.63) with a concomitant decrease in laparoscopic cholecystectomies (see Figure 1B and Table 3). Regionally, VISNs reporting at least 1 robot-assisted cholecystectomy increased from 12 to 16 during the study period. VISN 2 (New York and New Jersey) had the largest proportional increase in robot-assisted cholecystectomies performed (7.9% to 36.5%). See Table 6 for more detail.

Table 5. Comparison of Operative Approach for Each of the 3 General Surgery Procedures (for Hernia Surgery: Includes Primary/Recurrance and Laterality)

Procedure Type	Robotic, *n* (%)	Laparoscopic, *n* (%)	Open, *n* (%)
Cholecystectomy			
Total	1,171 (3.94)	28,529 (96.06)	---
Ventral Hernia			
Primary	1,232 (6.70)	7,850 (42.70)	9,308 (50.60)
Recurrent	62 (2.60)	459 (19.00)	1,899 (78.50)
Total	1,294 (6.22)	8,309 (39.93)	11,207(53.85)
Inguinal Hernia			
Total	3,224 (4.69)	13,780 (20.06)	51,677 (75.24)
Unilateral			
Primary	2,554 (4.40)	10,399 (17.90)	45,207 (77.70)
Recurrent	428 (7.10)	1,679 (28.00)	3,881 (64.80)
Total	2,982 (4.65)	12,078 (18.83)	49,088 (76.52)
Bilateral			
Primary	117 (3.70)	1,037 (32.70)	2,022 (63.70)
Recurrent	125 (9.20)	665 (49.00)	567 (41.80)
Total	242 (5.34)	1,702 (37.55)	2,589 (57.11)

Table 6. Longitudinal Trends in Cholecystectomies by Approach and Across VISNs

	2015, *n* (%)		2016, *n* (%)		2017, *n* (%)		2018, *n* (%)		2019, *n* (%)	
VISN	**Robotic**	**Lap.**	**Robotic**	**Lap.**	**Robotic**	**Lap.**	**Robotic**	**Lap.**	**Robotic**	**Lap.**
1	---	197 (100.0)	---	226 (100.0)	---	217 (100.0)	---	196 (100.0)	---	181 (100.0)
2	17 (7.9)	199 (92.1)	21 (9.3)	204 (90.7)	39 (14.4)	231 (85.6)	62 (23.9)	197 (76.1)	92 (36.5)	160 (63.5)
4	13 (7.0)	174 (93.0)	12 (6.0)	187 (94.0)	18 (8.1)	203 (91.9)	29 (13.1)	193 (86.9)	17 (9.3)	166 (90.7)
5	---	202 (100.0)	---	185 (100.0)	---	198 (100.0)	---	225 (100.0)	<11 (<5.2)	>199 (>94.8)
6	<11 (<3.0)	>358 (>97.0)	<11 (<3.1)	>347 (>96.9)	<11 (<3.0)	>358 (>97.0)	30 (8.1)	341 (91.9)	62 (16.4)	317 (83.6)
7	<11 (<4.0)	>262 (>96)	---	323 (100.0)	---	330 (100.0)	0 (0.0)	310 (100.0)	<11 (<4.4)	>240 (>95.6)
8	---	449 (100.0)	---	470 (100.0)	<11 (<2.1)	>521 (>97.9)	<11 (<1.9)	>569 (>98.1)	22 (4.0)	527 (96.0)
9	---	352 (100.0)	---	365 (100.0)	---	365 (100.0)	---	393 (100.0)	<11 (2.9)	>364 (>97.1)
10	<11 (<2.2)	>492 (>97.8)	26 (5.3)	463 (94.7)	26 (5.1)	484 (94.9)	48 (10.0)	433 (90.0)	47 (10.4)	403 (89.6)
12	<11 (<4.9)	>215 (>95.1)	<11 (<4.8)	>219 (>95.2)	<11 (<5.2)	>200 (>94.8)	10 (4.1)	231 (95.9)	<11 (<5.0)	>207 (>95.0)
15	---	234 (100.0)	---	261 (100.0)	---	224 (100.0)	---	245 (100.0)	---	198 (100.0)
16	<11 (<2.7)	>401 (>97.3)	14 (3.4)	401 (96.6)	14 (3.7)	362 (96.3)	11 (2.4)	440 (97.6)	54 (11.6)	411 (88.4)

	2015, *n* (%)		2016, *n* (%)		2017, *n* (%)		2018, *n* (%)		2019, *n* (%)	
VISN	**Robotic**	**Lap.**	**Robotic**	**Lap.**	**Robotic**	**Lap.**	**Robotic**	**Lap.**	**Robotic**	**Lap.**
17	31 (8.2)	347 (91.8)	40 (9.9)	365 (90.1)	23 (6.0)	358 (94.0)	36 (10.7)	300 (89.3)	48 (13.1)	319 (86.9)
19	<11 (<2.8)	>376 (>97.2)	<11 (<3.2)	>337 (>96.8)	<11 (<3.1)	>339 (>96.9)	15 (4.3)	331 (95.7)	27 (7.5)	333 (92.5)
20	---	271 (100.0)	---	241 (100.0)	<11 (<5.4)	>191 (>94.6)	<11 (<4.3)	>243 (>95.7)	21 (10.1)	186 (89.9)
21	<11 (<3.3)	>323 (>96.7)	<11 (<3.3)	>326 (>96.7)	<11 (<3.4)	>310 (>96.6)	13 (3.8)	331 (96.2)	18 (5.8)	290 (94.2)
22	<11 (<2.2)	>483 (>97.8)	11 (2.1)	508 (97.9)	15 (2.8)	519 (97.2)	35 (6.0)	553 (94.0)	45 (7.8)	535 (92.2)
23	<11 (<2.9)	>366 (>97.1)	<11 (<3.2)	>334 (>96.8)	---	301 (100.0)	---	296 (100.0)	<11 (<3.5)	>305 (>96.5)

Note. Data are coarsened to suppress small cells and protect Veteran privacy.[17]
Abbreviations. Lap.=laparoscopic; VISN=Veterans Integrated Services Network

Ventral Hernia Repair

Of the 20,810 ventral hernia repairs identified, 1,294 were performed with robot assistance (6.22%). The proportion of robot-assisted repairs increased from 1.51% to 13.94% during the study period (9.23-fold change; slope, 2.86% per year; 95% CI [1.04, 4.68]) with concurrent declines in both open and laparoscopic approaches (see Figure 1C and Table 3). Across the study period, 6.7% of primary ventral hernias were robot-assisted. However, robot-assisted procedures accounted for only 2.6% of recurrent ventral hernia repairs (see Table 5).

In 2015, 14 of 18 VISNs performed at least 1 robot-assisted ventral hernia repair. By the end of the study period, all VISNs had performed at least 1 ventral hernia repairs robotically, and for 4 VISNs (2, 4, 17, 21), robot-assisted surgeries accounted for more than a quarter of their ventral hernia repairs. See Table 7 for detail.

Table 7. Longitudinal Trends in Ventral Hernia Repairs by Approach and Across VISNs

	2015, *n* (%)			2016, *n* (%)			2017, *n* (%)			2018, *n* (%)			2019, *n* (%)		
VISN	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**
1	---	49 (28.7)	122 (71.3)	---	40 (26.8)	109 (73.2)	---	38 (23.9)	121 (76.1)	0 (0.0)	26 (21.3)	96 (78.7)	<11 (<8.0)	24 (17.4)	>103 (>74.6)
2	<11 (<6.7)	75 (45.5)	>79 (>47.9)	14 (7.5)	94 (50.3)	79 (42.2)	22 (11.2)	83 (42.3)	91 (46.4)	53 (23.8)	65 (29.1)	105 (47.1)	80 (39.2)	51 (25.0)	73 (35.8)
4	<11 (<7.1)	84 (54.5)	>59 (>38.3)	<11 (<8.0)	59 (42.8)	>68 (>49.3)	22 (14.5)	46 (30.3)	84 (55.3)	41 (21.8)	59 (31.4)	88 (46.8)	53 (32.3)	28 (17.1)	83 (50.6)
5	---	39 (29.1)	95 (70.9)	---	52 (39.7)	79 (60.3)	---	42 (37.2)	71 (62.8)	---	37 (35.9)	66 (64.1)	15 (12.9)	42 (36.2)	59 (50.9)
6	<11 (<3.3)	170 (50.9)	>153 (>45.8)	11 (3.0)	214 (58.2)	143 (38.9)	28 (6.4)	270 (61.4)	142 (32.3)	17 (5.3)	161 (50.3)	142 (44.4)	89 (22.4)	172 (43.2)	137 (34.4)
7	<11 (<6.6)	74 (44.6)	>81 (>48.8)	---	79 (41.8)	110 (58.2)	<11 (<7.2)	63 (41.2)	>79 (>51.6)	---	55 (31.4)	120 (68.6)	---	68 (40.7)	99 (59.3)
8	---	159 (49.2)	164 (50.8)	---	194 (54.8)	160 (45.2)	---	184 (47.7)	202 (52.3)	<11 (<2.7)	210 (51)	>191 (>46.4)	33 (7.8)	218 (51.5)	172 (40.7)
9	<11 (<6.4)	42 (24.4)	>119 (>69.2)	<11 (<6.3)	39 (22.4)	>124 (>71.3)	<11 (<5.6)	50 (25.4)	>136 (>69.0)	<11 (<7.0)	35 (22.2)	>112 (>70.9)	19 (9.4)	65 (32.2)	118 (58.4)
10	<11 (<2.8)	190 (48.2)	>193 (>49)	<11 (<2.4)	256 (56.3)	>188 (>41.3)	16 (3.6)	263 (58.4)	171 (38.0)	23 (5.0)	246 (53.7)	189 (41.3)	28 (7.5)	195 (52.3)	150 (40.2)
12	<11 (<6.2)	84 (47.2)	>83 (>46.6)	<11 (<6.0)	82 (45.1)	>89 (>48.9)	---	90 (55.6)	72 (44.4)	20 (10.6)	91 (48.1)	78 (41.3)	19 (10.8)	76 (43.2)	81 (46)
15	---	61 (36.3)	107 (63.7)	---	56 (33.5)	111 (66.5)	---	50 (38.2)	81 (61.8)	---	72 (39.8)	109 (60.2)	<11 (<7.5)	58 (39.7)	>77 (>52.7)
16	<11 (<3.7)	127 (43.1)	>157 (>53.2)	20 (6.9)	94 (32.6)	174 (60.4)	20 (7.4)	78 (28.7)	174 (64)	14 (5.3)	71 (26.9)	179 (67.8)	22 (7.5)	98 (33.3)	174 (59.2)
17	<11 (<4.7)	75 (31.9)	>149 (>63.4)	29 (9.9)	107 (36.4)	158 (53.7)	17 (7.1)	74 (31.1)	147 (61.8)	30 (13.4)	60 (26.8)	134 (59.8)	74 (30.3)	59 (24.2)	111 (45.5)
19	<11 (<4.4)	79 (31.3)	>162 (>64.3)	12 (5.5)	61 (28.0)	145 (66.5)	15 (6.4)	63 (26.7)	158 (66.9)	16 (8.3)	50 (26)	126 (65.6)	16 (7.5)	36 (17)	160 (75.5)

	2015, *n* (%)			2016, *n* (%)			2017, *n* (%)			2018, *n* (%)			2019, *n* (%)		
VISN	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**
20	<11 (<7.2)	48 (31.4)	>94 (>61.4)	---	31 (21.7)	112 (78.3)	<11 (<8.1)	34 (25.0)	>91 (>66.9)	<11 (<7.2)	64 (42.1)	>77 (>50.7)	21 (13.9)	44 (29.1)	86 (57.0)
21	<11 (<4.8)	79 (32.1)	>156 (>63.4)	12 (6.2)	76 (39.6)	104 (54.2)	30 (16.3)	42 (22.8)	112 (60.9)	31 (13.5)	49 (21.3)	150 (65.2)	60 (29.9)	35 (17.4)	106 (52.7)
22	<11 (<3.0)	182 (50.0)	>171 (>47.0)	<11 (<3.2)	185 (53.0)	>153 (>43.8)	28 (6.9)	190 (47.1)	185 (45.9)	30 (8.5)	170 (48.3)	152 (43.2)	34 (10.5)	165 (50.8)	126 (38.8)
23	<11 (<5.1)	83 (38.8)	>120 (>56.1)	23 (9.5)	64 (26.6)	154 (63.9)	14 (6.7)	72 (34.3)	124 (59.0)	<11 (<5.3)	79 (37.8)	>119 (>56.9)	<11 (<6.5)	60 (35.5)	>98 (>58.0)

Note. Data are coarsened to suppress small cells and protect Veteran privacy.[17]
Abbreviations. Lap.=laparoscopic; VISN=Veterans Integrated Services Network

Inguinal Hernia Repair

There were 68,681 inguinal hernia repairs during the study period, of which 3,224 were performed robotically (4.69%). From 2015 to 2019, robot-assisted repairs increased from 1.41% to 10.59% (7.51-fold change; slope, 2.19% per year; 95% CI (0.84, 3.54). During the same period, there was a concurrent decrease in open repairs, but the proportion of repairs done laparoscopically remained stable (see Figure 1D and Table 3). Nearly 85% of hernia repairs were for primary unilateral inguinal hernias (n = 58,160). Of those, 4.4% were performed robotically, while 7.1% of recurrent unilateral inguinal hernias were repaired robotically. Among primary bilateral inguinal hernia repairs, 3.7% were performed robotically, and when either 1 or both sides had a recurrence, 9.2% of bilateral inguinal hernias were repaired with robot-assistance (see Table 5).

In 2015, 13 of 18 VISNs performed at least 1 robot-assisted inguinal hernia repair. However, by the end of the study period, all 18 VISNs had performed at least 1 inguinal hernia repair with robot-assistance. See Table 8 for detail.

Table 8. Longitudinal Approach in Inguinal Hernia Repairs by Approach and Across VISNs

	2015, *n* (%)			2016, *n* (%)			2017, *n* (%)			2018, *n* (%)			2019, *n* (%)		
VISN	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**
1	---	176 (29.8)	414 (70.2)	<11 (<2.0)	149 (26.6)	>400 (>71.4)	---	153 (27.5)	404 (72.5)	---	182 (34.2)	350 (65.8)	---	146 (27.7)	381 (72.3)
2	---	104 (15.5)	568 (84.5)	12 (2.0)	108 (17.6)	495 (80.5)	64 (9.7)	100 (15.2)	494 (75.1)	156 (21.9)	111 (15.6)	445 (62.5)	210 (31.6)	74 (11.1)	380 (57.2)
4	<11 (<2.0)	66 (11.8)	>480 (>86.2)	21 (4.0)	53 (10.1)	449 (85.9)	31 (6.1)	70 (13.8)	406 (80.1)	46 (8.6)	63 (11.8)	427 (79.7)	108 (19.4)	55 (9.9)	394 (70.7)
5	---	78 (15.5)	426 (84.5)	---	66 (14.3)	394 (85.7)	<11 (<2.4)	88 (19.0)	>365 (>78.7)	---	94 (21.6)	341 (78.4)	23 (5.4)	100 (23.4)	304 (71.2)
6	<11 (<1.3)	197 (24.1)	>608 (>74.5)	29 (3.6)	229 (28.4)	547 (68.0)	57 (6.2)	241 (26.1)	627 (67.8)	77 (9.3)	217 (26.1)	537 (64.6)	141 (16.3)	244 (28.3)	478 (55.4)
7	<11 (<1.5)	129 (17.9)	>581 (>80.6)	<11 (<1.6)	133 (19.1)	>553 (>79.3)	---	136 (19.4)	564 (80.6)	---	159 (22.5)	547 (77.5)	---	136 (19.7)	556 (80.3)
8	<11 (<0.8)	268 (20.6)	>1021 (>78.5)	---	221 (16.6)	1110 (83.4)	---	371 (26.2)	1045 (73.8)	<11 (<0.8)	404 (29.6)	>950 (>69.6)	79 (5.8)	328 (24.0)	960 (70.2)
9	---	101 (16.2)	522 (83.8)	<11 (<1.7)	113 (17.7)	>513 (>80.5)	<11 (<1.8)	138 (22.6)	>462 (>75.6)	<11 (<1.7)	153 (24.0)	>474 (>74.3)	26 (4.3)	191 (31.5)	389 (64.2)
10	<11 (<0.9)	317 (25.9)	>897 (>73.2)	<11 (<0.9)	351 (30.3)	>797 (>68.8)	23 (2.0)	342 (29.3)	803 (68.8)	39 (3.6)	298 (27.4)	751 (69.0)	83 (8.1)	250 (24.3)	696 (67.6)
12	<11 (<1.8)	77 (12.9)	>510 (>85.3)	<11 (<1.7)	86 (13.7)	>532 (>84.6)	13 (2.1)	110 (18.1)	485 (79.8)	37 (6.4)	70 (12.2)	469 (81.4)	65 (11.9)	67 (12.3)	414 (75.8)
15	<11 (<2.0)	94 (16.9)	>452 (>81.1)	---	98 (17.1)	474 (82.9)	<11 (<2.3)	69 (14.6)	>393 (>83.1)	---	106 (23.1)	353 (76.9)	---	81 (16.3)	415 (83.7)
16	<11 (<1.3)	104 (12.7)	>702 (>85.9)	16 (1.8)	93 (10.2)	800 (88.0)	33 (3.9)	103 (12.1)	714 (84.0)	20 (2.3)	127 (14.4)	732 (83.3)	67 (7.8)	226 (26.4)	563 (65.8)

	2015, *n* (%)			2016, *n* (%)			2017, *n* (%)			2018, *n* (%)			2019, *n* (%)		
VISN	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**	**Robotic**	**Lap.**	**Open**
17	50 (7.1)	60 (8.5)	593 (84.4)	76 (11.0)	69 (10.0)	546 (79.0)	77 (12.5)	30 (4.9)	510 (82.7)	75 (11.6)	16 (2.5)	556 (85.9)	82 (13.0)	30 (4.7)	521 (82.3)
19	<11 (<1.3)	225 (26.0)	>628 (>72.7)	<11 (<1.3)	248 (29.5)	>583 (>69.2)	31 (3.7)	242 (28.9)	565 (67.4)	53 (7.2)	151 (20.6)	528 (72.1)	86 (12.3)	178 (25.4)	437 (62.3)
20	---	116 (19.0)	496 (81.0)	<11 (<1.8)	181 (29.6)	>420 (>68.6)	<11 (<1.7)	144 (22.7)	>478 (>75.5)	27 (4.7)	149 (26.2)	393 (69.1)	65 (13.5)	97 (20.2)	318 (66.2)
21	17 (1.8)	85 (8.9)	851 (89.3)	<11 (<1.2)	101 (11.0)	>803 (>87.8)	30 (3.4)	113 (12.6)	751 (84.0)	62 (7.1)	122 (13.9)	694 (79.0)	159 (18.9)	120 (14.3)	561 (66.8)
22	92 (7.7)	163 (13.6)	944 (78.7)	91 (7.7)	188 (16.0)	896 (76.3)	141 (11.9)	176 (14.8)	872 (73.3)	159 (13.9)	160 (14)	823 (72.1)	183 (16.5)	151 (13.6)	775 (69.9)
23	13 (1.5)	255 (30.2)	577 (68.3)	33 (4.0)	244 (29.9)	539 (66.1)	39 (4.9)	258 (32.2)	505 (63.0)	23 (2.7)	267 (31.9)	548 (65.4)	11 (1.5)	227 (31.9)	473 (66.5)

Note. Data are coarsened to suppress small cells and protect Veteran privacy.
Abbreviations. Lap.=laparoscopic; VISN=Veterans Integrated Services Network

KQ2. Between 2015 and 2019, how were clinical outcomes in the VHA similar or different for robot-assisted versus laparoscopic and open surgical approaches for cholecystectomies, ventral hernia repairs, and inguinal hernia repairs?

Between January 2015 and September 2019, we identified 21,652 cholecystectomies, 9,214 ventral hernia repairs, and 51,324 inguinal hernia repairs meeting inclusion criteria (see Table 9). Table 10 shows patient characteristics by procedure and surgical approach. Overall, Veterans undergoing all procedures were predominantly White males with a mean age between 58 and 65 years.

Table 9. Procedure Breakdown by Surgical Approach and Indication

Procedure Type					*n* (%)
Cholecystectomy			**Laparoscopic**		20,866 (96.37)
			Robotic		786 (3.63)
				Total	21,652
Ventral Hernia Repair	*Primary*		**Open**		6,026 (78.21)
			Laparoscopic		1,432 (18.59)
			Robotic		247 (3.21)
				Total	7,705
	Recurrent		**Open**		1,184 (78.46)
			Laparoscopic		289 (19.15)
			Robotic		36 (2.39)
				Total	1,509
Inguinal Hernia Repair	*Primary*	*Unilateral*	**Open**		36,935 (80.10)
			Laparoscopic		7,628 (16.54)
			Robotic		1,550 (3.36)
				Total	46,113
		Bilateral	**Open**		146 (48.34)
			Laparoscopic		140 (46.36)
			Robotic		16 (5.30)
				Total	302
	Recurrent	*Unilateral*	**Open**		3,115 (65.76)
			Laparoscopic		1,346 (28.41)
			Robotic		276 (5.83)
				Total	4,737
		Bilateral	**Open**		>120 (>69.80)
			Laparoscopic		41 (23.84)
			Robotic		<11 (<6.40)
				Total	172

Note. Data are coarsened to suppress small cells and protect Veteran privacy.[17]

Table 10. Patient Characteristics for General Surgery Procedures by Surgical Approach

Characteristic	Laparoscopic	Robotic	Open
Cholecystectomy			
Sex (Male), *n* (%)	17368 (83.2%)	648 (82.4%)	
Age (Years), Mean (SD)	58.61 (14.49)	58.06 (14.34)	
Hispanic, *n* (%)	1694 (8.1%)	59 (7.5%)	
Race			
AI/AN, AAPI, NH	597 (2.9%)	19 (2.4%)	
Black or African American	2545 (12.2%)	115 (14.6%)	
White	16338 (78.3%)	599 (76.2%)	
Declined to Answer or Unknown	1386 (6.6%)	53 (6.7%)	
Current Smoker (Yes), *n* (%)	5338 (25.6%)	200 (25.4%)	
BMI, Mean (SD)	30.07 (5.39)	30.42 (5.39)	
Ventral Hernia			
Sex (Male), *n* (%)	1555 (90.4%)	259 (91.5%)	6450 (89.5%)
Age (Years), Mean (SD)	61.25 (11.13)	61.61 (11.09)	60.13 (12.29)
Hispanic, *n* (%)	142 (8.3%)	14 (4.9%)	356 (4.9%)
Race			
AI/AN, AAPI, NH	21 (1.2%)	<11 (<3.9%)	158 (2.2%)
Black or African American	260 (15.1%)	43 (15.2%)	1058 (14.7%)
White	1344 (78.1%)	223 (78.8%)	5610 (77.8%)
Declined to Answer or Unknown	96 (5.6%)	<11 (<3.9%)	384 (5.3%)
Current Smoker (Yes), *n* (%)	420 (24.4%)	53 (18.7%)	1972 (27.4%)
BMI, Mean (SD)	30.67 (4.98)	31.24 (4.89)	30.35 (5.13)
Inguinal Hernia			
Sex (Male), *n* (%)	9094 (99.3%)	1833 (99.1%)	40128 (99.5%)
Age (Years), Mean (SD)	61.26 (12.86)	61.02 (12.9)	64.72 (12.43)
Hispanic, *n* (%)	451 (4.9%)	160 (8.6%)	2196 (5.4%)
Race			
AI/AN, AAPI, NH	155 (1.7%)	49 (2.6%)	744 (1.8%)
Black or African American	1287 (14.1%)	274 (14.8%)	6699 (16.6%)
White	7116 (77.7%)	1392 (75.2%)	30431 (75.5%)
Declined to Answer or Unknown	597 (6.5%)	135 (7.3%)	2445 (6.1%)
Current Smoker (Yes), *n* (%)	2719 (29.7%)	469 (25.4%)	11747 (29.1%)
BMI, Mean (SD)	26.11 (3.81)	26.77 (3.9)	25.98 (3.86)

Note. Data are coarsened to suppress small cells and protect Veteran privacy.[17]
Abbreviations. AI/AN = American Indian/Alaska Native; AAPI = Asian American Pacific Islander; BMI = body mass index; NH = Native Hawaiian; SD = standard deviation.

Operative Times

Operative times were consistently longer for robot-assisted procedures across surgeries and indications (see Table 11). Robot-assisted cholecystectomy took longer than the laparoscopic approach (IRR [SE] = 0.83 [0.01], 95% CI [0.81, 0.86]). Operative times for robot-assisted ventral and inguinal hernia repairs were longer for all comparisons (see Table 11 for detail). The largest differences in operative times were observed among primary ventral hernia repairs, with open surgeries taking a mean 0.50 times of those that were robot-assisted, (primary ventral hernia; 95% CI [0.47, 0.53])**.**

Table 11. Uncontrolled Operative Times by Surgical Approach

Procedural Approach				Mean (SD)	IRR (SE)	95% CI
Cholecystectomy			**Laparoscopic**	1.54 (0.73)	0.83 (0.01)	0.81, 0.86
			Robotic	1.86 (0.72)	REF	REF
Ventral Hernia Repair	*Primary*		**Open**	1.48 (1.12)	0.50 (0.01)	0.47, 0.53
			Laparoscopic	1.98 (1.05)	0.67 (0.02)	0.63, 0.71
			Robotic	2.95 (1.25)	REF	REF
	Recurrent		**Open**	2 (1.3)	0.67 (0.05)	0.58, 0.77
			Laparoscopic	2.13 (1.11)	0.72 (0.05)	0.62, 0.83
			Robotic	2.98 (1.22)	REF	REF
Inguinal Hernia Repair	*Primary*	*Unilateral*	**Open**	1.29 (0.57)	0.60 (0.01)	0.59, 0.62
			Laparoscopic	1.44 (0.63)	0.67 (0.01)	0.66, 0.69
			Robotic	2.14 (0.83)	REF	REF
		Bilateral	**Open**	1.97 (0.84)	0.85 (0.07)	0.73, 0.99
			Laparoscopic	1.93 (0.82)	0.83 (0.07)	0.71, 0.97
			Robotic	2.33 (0.68)	REF	REF
	Recurrent	*Unilateral*	**Open**	1.42 (0.71)	0.66 (0.02)	0.62, 0.69
			Laparoscopic	1.56 (0.69)	0.72 (0.02)	0.68, 0.76
			Robotic	2.17 (0.86)	REF	REF
		Bilateral	**Open**	1.84 (0.99)	0.56 (0.07)	0.44, 0.72
			Laparoscopic	2.08 (0.83)	0.63 (0.08)	0.49, 0.82
			Robotic	3.3 (1.16)	REF	REF

Note. Reference group is robot-assisted for all procedures, see Table 8 for Ns for surgical procedure and indication.
Abbreviations: CI= confidence interval; IRR=incidence rate ratio; MD=mean difference; REF=reference group; SD=standard deviation; SE=standard error

Postoperative Length of Stay (LOS)

Across all procedures and surgical approaches, postoperative LOS was generally low with mean values between 1 and 5 days (see Table 12). Compared to the robot-assisted approach, postoperative LOS for open primary ventral hernia repairs was 1.59 times longer (IRR = 1.59, 95% CI [1.24, 2.04]). Length of stay for Veterans receiving laparoscopic surgery was 1.21 times longer than robotic, but this was not statistically significant (IRR = 1.21, 95% CI [0.94, 1.57]). For recurrent ventral hernia repairs, the open approach had postoperative LOS that was 2.44 times longer than the robotic approach (95% CI, [1.6, 3.71]), and laparoscopic was 1.8 times

longer (95% CI [1.12, 2.9]). We found no statistically significant differences in postoperative LOS by surgical approach for cholecystectomies or inguinal hernia repairs (see Table 12).

Table 12. Uncontrolled Post-Operative Length of Stay by Surgical Approach

Procedural Approach				Mean (SD)	IRR (SE)	95% CI
Cholecystectomy			**Laparoscopic**	2.53 (5.58)	1.15 (0.1)	0.96, 1.37
			Robotic	2.21 (2.59)	REF	REF
Ventral Hernia Repair	*Primary*		**Open**	4.69 (5.12)	1.59 (0.2)	1.24, 2.04
			Laparoscopic	3.58 (3.3)	1.21 (0.16)	0.94, 1.57
			Robotic	2.95 (3.25)	REF	REF
	Recurrent		**Open**	4.88 (5.65)	2.44 (0.52)	1.6, 3.71
			Laparoscopic	3.6 (4.54)	1.8 (0.44)	1.12, 2.9
			Robotic	2 (1.32)	REF	REF
Inguinal Hernia Repair	*Primary*	*Unilateral*	**Open**	2.77 (4.62)	0.99 (0.26)	0.59, 1.65
			Laparoscopic	2.29 (2.81)	0.82 (0.22)	0.48, 1.4
			Robotic	2.81 (4.78)	REF	REF
		Bilateral	**Open**	3.44 (6.5)	1.32 (0.62)	0.52, 3.33
			Laparoscopic	1.65 (1.36)	0.64 (0.27)	0.28, 1.44
			Robotic	2.6 (2.61)	REF	REF
	Recurrent	*Unilateral*	**Open**	2.42 (3.31)	1.16 (0.5)	0.5, 2.69
			Laparoscopic	1.61 (1.13)	0.77 (0.33)	0.33, 1.79
			Robotic	2.09 (3.05)	REF	REF
		Bilateral	**Open**	2.6 (1.96)	1.73 (0.57)	0.91, 3.29
			Laparoscopic	1.2 (0.42)	0.8 (0.21)	0.48, 1.33
			Robotic	1.5 (0.71)	REF	REF

Note. Reference group is robot-assisted for all procedures, see Table 8 for Ns for surgical procedure and indication.
Abbreviations: CI=confidence interval; IRR=incidence rate ratio; MD=mean difference; REF=reference group; SD=standard deviation; SE=standard error

Surgical Complications

Complications were infrequent across all procedures. Serious complications occurred in less than 4% of Veterans regardless of surgical approach. No Veteran receiving robot-assisted ventral hernia repairs reported a superficial surgical site infection, compared to 1.6% of open surgery recipients, and 0.7% of laparoscopic patients ($p < 0.01$). Of the Veterans who had an open ventral hernia repair, 4.9% experienced 1 or more VASQIP complication (Appendix B); however, there was no difference between groups. There were no differences in complications by surgical approach for cholecystectomies or for inguinal hernia repairs (see Table 13).

Table 13. Intraoperative and Postoperative Outcomes for General Surgery Procedures by Approach, Uncontrolled

Outcome	Cholecystectomy		Ventral Hernia Repair			Inguinal Hernia Repair		
	Robotic	Lap.	Robotic	Lap.	Open	Robotic	Lap.	Open
Systemic Sepsis, *n* (%)	<11 (<1.4%)	123 (0.6%)	<11 (<3.9%)	12 (0.7%)	31 (0.4%)	<11 (<0.6%)	13 (0.1%)	32 (0.1%)
Myocardial Infarction, *n* (%)	---	27 (0.1%)	---	<11 (<0.6%)	13 (0.2%)	<11 (<0.6%)	11 (0.1%)	28 (0.1%)
Bleeding (req >4 units), *n* (%)	---	<11 (<0.1%)	---	<11 (<0.6%)	---	<11 (<0.6%)	---	<11 (0%)
Pneumonia, *n* (%)	<11 (<1.4%)	63 (0.3%)	<11 (<3.9%)	<11 (<0.6%)	41 (0.6%)	---	<11 (<0.1%)	40 (0.1%)
Pulmonary Embolism, *n* (%)	---	33 (0.2%)	---	<11 (<0.6%)	23 (0.3%)	<11 (<0.6%)	<11 (<0.1%)	22 (0.1%)
Post-op. Acute Renal Failure, *n* (%)	---	12 (0.1%)	---	<11 (<0.6%)	<11 (<0.1%)	---	<11 (<0.1%)	<11 (0%)
Superficial Surgical Site Infection, *n* (%)	<11 (<1.4%)	100 (0.5%)	**---**	**12 (0.7%)**	**112 (1.6%)**	<11 (<0.6%)	14 (0.2%)	81 (0.2%)
1+ VASQIP Complication, *n* (%)	20 (2.5%)	623 (3.0%)	<11 (<3.9%)	59 (3.4%)	355 (4.9%)	22 (1.2%)	102 (1.1%)	384 (1.0%)
30-day Mortality, *n* (%)	<11 (<1.4%)	50 (0.2%)	<11 (<3.9%)	<11 (<0.6%)	17 (0.2%)	<11 (<0.6%)	<11 (<0.1%)	34 (0.1%)

Note. Bolded values indicate significant differences between groups, $p<0.01$. Data are coarsened to suppress small cells and protect Veteran privacy.[17]
Abbreviations. Lap.=laparoscopic; Post-op.=postoperative; req=requiring; VASQIP=VA Surgical Quality Improvement Plan

DISCUSSION

Our findings highlight the growth of robot utilization for general surgery procedures within the VHA. We found a 7-fold increase in the use of robot-assisted surgery for the 3 procedures combined, with 2.14% annual growth from 2015 to 2019. This trend was associated with a concurrent decrease in laparoscopic cholecystectomy, open and laparoscopic ventral hernia repair, and open inguinal hernia repairs. Robot-assisted ventral hernia repair demonstrated the largest growth with an absolute increase of 12.43% and annual growth of 2.86%.

Findings from a recent study examining VASQIP data from 2008-2019 suggest that the rate of robot-assisted inguinal hernia repairs may have been as high as 19.6% in 2019.[18] This estimate was based on primary but not recurrent hernia repairs, and it is unclear if and how bilateral hernias were accounted for. Moreover, the VASQIP nurses (trained medical record abstractors) abstract only a sample of cases for high-volume operations such as inguinal hernia repair. The cases included in our utilization analysis come from CDW, which includes all inpatient and outpatient surgical procedures performed at VHA facilities. Given that only a portion of cases are included in VASQIP, it is possible they may have overestimated the proportion of robot-assisted hernia repairs performed.[16]

Regionally, the growth of robot utilization varied, but all VISNs adopted robotic surgery for 1 or more of these procedures during the study period. The diffusion of robotic surgery occurred primarily in populous regions along the East Coast, Midwest, and West Coast. Previous work has demonstrated geographic variations in hospital services in the VHA.[19,20] It is unclear what the drivers of variation are within the highly centralized VHA, but they are likely related to the regional utilization of robotic surgery in civilian health care systems and similarly to the association of VHA hospitals with academic medical centers. In the civilian sector, competition and market demand have occurred predominantly in densely populated regions with strong buying power.[21-23] From 2015 to 2019, the increase in VHA robotic systems along the coasts and Midwest mirrors the regional acquisitional growth for *all* surgical robots in the US during the same time period (see Appendix D; Jason Lamb, Director Government Accounts, Intuitive Surgical, email communication, June 2021). The similar geographic distribution of robotic systems in the VHA and nationally might reflect the progressive culture of surgery in these regions.

Our findings largely corroborated findings from the published literature. The 2020 ESP systematic review found moderate to high certainty evidence that all 3 robot-assisted procedures were associated with longer operative times than conventionally performed procedures.[8] Our findings were consistent: in VHA facilities, operative time was significantly longer for all 3 robot-assisted general surgery procedures. In addition, the review found moderate certainty evidence that post-operative length of stay was shorter in patients who had undergone robot-assisted ventral hernia repairs which was similar to our finding in VHA settings. Finally, our findings that post-operative length of stay was comparable in patients who had undergone robot-assisted and laparoscopic cholecystectomies was similar to the ESP systematic review's findings from the published literature. Of note, however, for inguinal hernia repairs the review found moderate certainty evidence that LOS for robot-assisted procedures was shorter, but we found no difference in post-operative LOS by approach for inguinal hernia repairs. Finally, our findings that there were no significant differences in the comparative effects of surgical approach on intra- and post-operative complications were tempered by low event rates, which is in keeping

with the review's conclusions of insufficient to low certainty evidence for most intra- and post-operative outcomes.[8]

It is unclear whether the longer operative times are transient and reflect surgeon and operating room (OR) staff learning curves, or if they rather represent the additional time needed to use the robotic platform.[18,24-27] In a recent study using Computer Patient Record System (CPRS) data comparing robot-assisted and laparoscopic cholecystectomies performed at the VA North Texas Health Care System, investigators divided operative time into 3 distinct categories, pre-operative time, operative time, and post-operative time (n = 612). They defined operative time as the skin-to-skin time (*ie*, first incision to dressing wounds). They found that operative times were similar in skin-to-skin operative time, that pre- and post-operative times were longer, and that pre-operative time decreases with more experience.[28] The operative time variable in VASQIP used in both our study and by Holleran and colleagues[18] does not include pre-operative time, but begins at the first incision and ends after the procedures are complete and instruments and sponges are counted.

In their VASQIP study of inguinal hernia repairs, Holleran and colleagues controlled for confounding demographics and clinical and operative characteristics. They found that although robot-assisted operative times remained significantly higher than laparoscopic and open surgical approaches, they decreased significantly over the study period. In contrast to our unadjusted results, they found that post-operative LOS for robotic surgery was 94% longer compared to laparoscopic, and 33% longer compared to open surgery.[18]

The procedures included in this analysis generally have low complication rates and short hospital stays. As such, making comparisons for these outcomes between techniques is limited. The ESP review concluded that there was insufficient to low certainty for most of the outcomes they examined.[8] We identified only 1 significant difference when examining complications: the rate of surgical site infections in ventral hernia repairs favored robotic surgery. Our findings differ substantially from Holleran and colleagues' recent VASQIP study, which found that after controlling for confounding covariates, compared to both laparoscopic and open approaches, robot-assisted inguinal hernia repairs had nearly 5 to 6 times the odds of 1 or more VASQIP complication.[18] Contrary to our unadjusted analysis, these findings suggest that robot-assisted inguinal hernia repairs may place Veterans at higher risk, and that our unadjusted findings may be reflective of patient selection bias. As a large, integrated learning health care system with robust research and quality improvement programs, the VHA has a unique advantage in serving its patient population. To better elucidate the benefits and harms of robot-assisted general surgery, rigorously controlled trials are warranted. Further, quality improvement and/or work related to implementation may help to shed light on regional differences in utilization, surgeon and OR staff learning curve, operative time, and the overarching question of cost versus benefit.

LIMITATIONS

There are several limitations to our analysis. The data were obtained retrospectively from 2 large databases that are susceptible to inexact coding and reporting error. Robot-assisted procedures were only identified if the S2900 modifier was utilized, which likely led to underestimation of cases. A 2020 VA Office of Inspector General (OIG) audit of the governance of robotic surgical systems reported that the National Surgery Office (NSO) underreported the number of robotic surgical procedures by more than 2,300 cases in 2018, largely due to the lack of policy requiring

the addition of the S2900 modifier.[29] Although we don't know how many of the missing cases from 2018 are relevant to our analysis, and how many may be missing from other years, it is possible that our findings would be significantly different. In addition, our analysis was designed to be descriptive, and we did not control for confounding patient characteristics that may have contributed to selection bias when choosing a surgical approach. Given the high rates of obesity and chronic illness in the Veteran population served by the VHA, as well as the significantly different adjusted findings associated with robot-assisted inguinal hernia repair presented by Holleran and colleagues,[18] it is likely our findings would differ had we used a risk adjusted model or multivariate analysis. Finally, a large majority of Veterans included in our analysis were non-Hispanic White males. Our findings may be less applicable to Veterans who are female, transgender, and Black, Indigenous, and People of Color (BIPOC).

CONCLUSION

This exploratory analysis of VHA data, meant to augment the 2020 ESP systematic review, found that from 2015 to 2019 utilization of the robotic platform for general surgery procedures across the VHA increased over time. There was variation in robotic utilization across VISNs, with a larger percentage observed on the East Coast, Midwest, and West Coast. Our unadjusted findings that operative times were longer, that post-operative LOS was in most cases shorter, and that the impact on outcomes remains unclear, were consistent with the conclusions of the 2020 ESP systematic review.[8]

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APPENDIX A. VASQIP VARIABLES

VASQIP Variables		Definition	Scoring
1 or more VASQIP complication	SCORE1	If the patient had surgical complications, score1=1, if no complications, score1=0	0 or 1
Myocardial infarction	CDMI	During surgery or 30 days post; A new transmural acute myocardial infarction occurring during surgery or within 30 days following surgery as manifested by new Q-waves on ECG. Non-Q-wave infarctions should be entered under "OTHER".	0 or 1
Bleeding req > 4 units PRBCs	OTHBLEED	Any transfusion (including autologous) of packed red blood cells or whole blood given from the time the patient leaves the operating room up to and including 72 hours postoperatively. Enter "YES" for five or more units of packed red blood cell units in the postoperative period including hanging blood from the OR that is finished outside of the OR. If the patient receives shed blood, autologous blood, cell saver blood or pleurovac postoperatively, this is counted if greater than four units. The blood may be given for any reason.	0 or 1
Systemic sepsis	OTHSYSEP	Within 30 days postop; If the primary physician or the chart states that the patient had systemic sepsis within the 30 days postoperatively, choose from the following choices for sepsis. If neither is present follow these definitions and choose the most applicable: Sepsis: Definitive evidence of infection, plus evidence of a systemic response to infection. This systemic response is manifested by 2 or more of the following conditions: Temp >38 degrees C or <36 degrees C Septic Shock: Sepsis with hypotension despite adequate fluid resuscitation combined with perfusion abnormalities that may include, but are not limited to, lactic acidosis, oliguria, or an acute alteration in mental status. Patients who are on inotropic or vasopressor agents may not be hypotensive at the time that perfusion abnormalities are measured. -HR >90 bpm -RR >20 breaths/min or PaCO2 <32 mmHg(<4.3 kPa) -WBC >12,000 cell/mm3, <4000 cells/mm3, or >10% immature (band) forms	0 or 1

VASQIP Variables		Definition	Scoring
Pneumonia - outcome	OUPNEUMO	Inflammation of the lungs caused primarily by bacteria, viruses, and/or chemical irritants, usually manifested by chills, fever, pain in the chest, cough, purulent, bloody sputum. Enter "YES" if the patient has pneumonia meeting the CDC definition of pneumonia below AND pneumonia not present preoperatively. Pneumonia must meet 1 of the following 2 criteria: -Criterion 1. Rales or dullness to percussion on physical examination of chest AND any of the following: New onset of purulent sputum or change in character of sputum Organism isolate from blood culture Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy -Criterion 2. Chest radiographic examination shows new or progressive infiltrate, consolidation, cavitation, or pleural effusion AND any of the following: New onset of purulent sputum or change in character of sputum Organism isolated from the blood Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy Isolation of virus or detection of viral antigen in respiratory secretions Diagnostic single antibody titer (IgM) or fourfold increase in paired serum samples (IgG) for pathogen Histopathologic evidence of pneumonia	0 or 1
Pulmonary embolism	PULEMBOL	Lodging of a blood clot in a pulmonary artery with subsequent obstruction of blood supply to the lung parenchyma. The blood clots usually originate from the deep leg veins or the pelvic venous system. Enter "YES" if the patient has a V-Q scan interpreted as high probability of pulmonary embolism or a positive pulmonary arteriogram or positive CT scan. Treatment usually consists of: -Initiation of anticoagulation therapy -Placement of mechanical interruption (e.g. Greenfield Filter), for patients in whom anticoagulation is contraindicated or already instituted.	0 or 1
Acute renal failure (post-op)	OPRENAFL	In a patient who did not require dialysis preoperatively, worsening of renal dysfunction postoperatively requiring hemodialysis, ultrafiltration, or peritoneal dialysis. TIP: If the patient refuses dialysis the answer is Yes to this variable, because he/she did require dialysis.	0 or 1

VASQIP Variables		Definition	Scoring
Superficial surgical site infection	SUPINFEC	Use the following Centers for Disease Control (CDC) definition: Superficial incisional SSI is an infection that occurs within 30 days after the operation and infection involves only skin or subcutaneous tissue of the incision and at least 1 of the following: -Purulent drainage, with or without laboratory confirmation, from the superficial incision. -Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision. -At least 1 of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat and superficial incision is deliberately opened by the surgeon, unless incision is culture-negative. -Diagnosis of superficial incisional SSI by the surgeon or attending physician. Excludes the following conditions as SSI: -Stitch abscess (minimal inflammation and discharge confined to the points of suture penetration). -Infected burn wound. -Incisional SSI that extends into the fascial and muscle layers (see deep incisional SSI).	0 or 1
Death within 30 days in PIMS	POSTCODE	Death within 30 days (oprymd - dtdeath)	0 or 1
Pre-operative hospital stay	PRHLOS	Length of pre-operative hospital stay (in days)	# days
Post-operative hospital stay	POHOLOS	Length of post-operative hospital stay (in days)	# days
Operative Time	OPTIME	Total operation time in hours	hours. minutes

APPENDIX B. ONE OR MORE VASQIP COMPLICATION: LIST OF COMPLICATIONS

Label		VASQIP Definition	Scoring
Return to OR within 30 days	**RETURNOR**	Returns to the operating room include all surgical procedures that required the patient to be taken to the surgical operating room for intervention of any kind within 30 days of the procedure will automatically be entered by the software.	0 or 1
Cardiac arrest requiring CPR	**CDARREST**	The absence of cardiac rhythm or presence of chaotic cardiac rhythm that results in loss of consciousness requiring the initiation of any component of basic and/or advanced cardiac life support.	0 or 1
Myocardial infarction	**CDMI**	A new transmural acute myocardial infarction occurring during surgery or within 30 days following surgery as manifested by new Q-waves on ECG. Non-Q-wave infarctions should be entered under "OTHER".	0 or 1
Coma lasting > 24 hours post-op	**CNSCOMA**	This is defined as significantly impaired level of consciousness (exclude transient disorientation or psychosis) for greater than 24 hours during the postoperative hospitalization.	0 or 1
Cerebral vascular accident (CVA)/Stroke	**CNSCVA**	Patient develops an embolic, thrombotic, or hemorrhagic vascular accident or stroke with motor, sensory, or cognitive dysfunction (*eg*, hemiplegia, hemiparesis, aphasia, sensory deficit, impaired memory) that persist for 24 or more hours.	0 or 1
Peripheral nerve injury	**NEURODEF**	Peripheral nerve damage may result from damage to the nerve fibers, cell body, or myelin sheath during surgery. Peripheral nerve injuries (*eg*, motor, sensory, and mixed motor/sensory injury) to the cervical plexus, brachial plexus, ulnar plexus, lumbar-sacral plexus (sciatic nerve), perineal nerve, and/or the femoral nerve should be included.	0 or 1
Clostridium difficile colitis	**CDIFCOLITIS**	C. difficile-associated disease occurs when the normal intestinal flora is altered, allowing C. difficile to flourish in the intestinal tract and produce a toxin that causes a watery diarrhea. C. difficile diarrhea is confirmed by the presence of a toxin in a stool specimen. Answer yes only if you have a positive culture for C. difficile with a toxin assay and/or diagnosis of C. difficile documented in the chart.	0 or 1

Label		VASQIP Definition	Scoring
Bleeding req > 4 units PRBCs	**OTHBLEED**	Any transfusion (including autologous) of packed red blood cells or whole blood given from the time the patient leaves the operating room up to and including 72 hours postoperatively. Enter "YES" for five or more units of packed red blood cell units in the postoperative period including hanging blood from the OR that is finished outside of the OR. If the patient receives shed blood, autologous blood, cell saver blood or pleurovac postoperatively, this is counted if greater than four units. The blood may be given for any reason.	0 or 1
Deep vein thrombosis (DVT)/ Thrombophlebitis	**OTHDVT**	The identification of a new blood clot or thrombus within the venous system, which may be coupled with inflammation. This diagnosis is confirmed by a duplex, venogram or CT scan. The patient must be treated with anticoagulation therapy, and/or placement of a vena cava filter or clipping of the vena cava.	0 or 1
Graft/prosthesis failure	**OTHGRAFL**	Mechanical failure of an extracardiac vascular graft or prosthesis including myocutaneous flaps and skin grafts requiring return to the operating room or a balloon angioplasty.	0 or 1
Prolonged ileus	**OTHOBSTR**	Ileus is obstruction of the intestines from a variety of causes including mechanical obstruction, peritonitis, adhesions, or post-surgically as a result of functional dysmotility by the bowel. Bowel obstruction is any hindrance to the passage of the intestinal contents. Prolonged ileus or obstruction is defined as longer than 5 days postoperatively.	0 or 1
Systemic sepsis	**OTHSYSEP**	If the primary physician or the chart states that the patient had systemic sepsis within the 30 days postoperatively, choose from the following choices for sepsis. If neither is present follow these definitions and choose the most applicable: (1) Sepsis: Definitive evidence of infection, plus evidence of a systemic response to infection. This systemic response is manifested by 2 or more of the following conditions: Temp >38 degrees C or <36 degrees C (2) Septic Shock: Sepsis with hypotension despite adequate fluid resuscitation combined with perfusion abnormalities that may include, but are not limited to, lactic acidosis, oliguria, or an acute alteration in mental status. Patients who are on inotropic or vasopressor agents may not be hypotensive at the time that perfusion abnormalities are measured. - HR >90 bpm - RR >20 breaths/min or PaCO2 <32 mmHg (<4.3 kPa)	0 or 1

Label		VASQIP Definition	Scoring
		WBC >12,000 cell/mm3, <4000 cells/mm3, or >10% immature (band) forms	
Failure to wean > 48 hours	**FAILWEAN**	On ventilator >48 hours post-operative	0 or 1
Pneumonia	**OUPNEUMO**	Inflammation of the lungs caused primarily by bacteria, viruses, and/or chemical irritants, usually manifested by chills, fever, pain in the chest, cough, purulent, bloody sputum. Enter "YES" if the patient has pneumonia meeting the CDC definition of pneumonia below AND pneumonia not present preoperatively. Pneumonia must meet 1 of the following 2 criteria: -Criterion 1. Rales or dullness to percussion on physical examination of chest AND any of the following: a. New onset of purulent sputum or change in character of sputum b. Organism isolate from blood culture c. Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy OR -Criterion 2. Chest radiographic examination shows new or progressive infiltrate, consolidation, cavitation, or pleural effusion AND any of the following: a. New onset of purulent sputum or change in character of sputum b. Organism isolated from the blood c. Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy d. Isolation of virus or detection of viral antigen in respiratory secretions e. Diagnostic single antibody titer (IgM) or fourfold increase in paired serum samples (IgG) for pathogen f. Histopathologic evidence of pneumonia	0 or 1
Pulmonary embolism	**PULEMBOL**	Lodging of a blood clot in a pulmonary artery with subsequent obstruction of blood supply to the lung parenchyma. The blood clots usually originate from the deep leg veins or the pelvic venous system. Enter "YES" if the patient has a V-Q scan interpreted as high probability of pulmonary embolism or a positive pulmonary arteriogram or positive CT scan. Treatment usually consists of: -Initiation of anticoagulation therapy -Placement of mechanical interruption (*eg*, Greenfield Filter), for patients in whom anticoagulation is contraindicated or already instituted.	0 or 1

Label		VASQIP Definition	Scoring
Reintubation for respiratory/ cardiac failure	**REINTUB**	Patient required placement of an endotracheal tube and mechanical or assisted ventilation because of the onset of respiratory or cardiac failure manifested by severe respiratory distress, hypoxia, hypercarbia, or respiratory acidosis. In patients who were intubated for their surgery, unplanned intubation occurs after they have been extubated after surgery. In patients who were not intubated during surgery, intubation at any time after their surgery is considered unplanned.	0 or 1
Acute renal failure	**OPRENAFL**	In a patient who did not require dialysis preoperatively, worsening of renal dysfunction postoperatively requiring hemodialysis, ultrafiltration, or peritoneal dialysis.	0 or 1
Progressive renal insufficiency	**RENAINSF**	The reduced capacity of the kidney to perform its function as evidenced by a rise in creatinine of >2 mg/dl from preoperative value, but with no requirement for dialysis.	0 or 1
Urinary tract infection	**URNINFEC**	Postoperative symptomatic urinary tract infection must meet 1 of the following 2 criteria from the CDC definition: 1. One of the following: fever (>38 degrees C), urgency, frequency, dysuria, or suprapubic tenderness AND a urine culture of > 105 colonies/ml urine with no more than 2 species of organisms OR 2. Two of the following: fever (>38 degrees C), urgency, frequency, dysuria, or suprapubic tenderness AND any of the following: -Dipstick test positive for leukocyte esterase and/or nitrate -Pyuria (>10 WBCs/cc or > 3 WBC/hpf of unspun urine) -Organisms seen on Gram stain of unspun urine -Two urine cultures with repeated isolation of the same uropathogen with >102 colonies/ml urine in non-voided specimen -Urine culture with < 105 colonies/ml urine of single uropathogen in patient being treated with appropriate antimicrobial therapy -Physician's diagnosis -Physician institutes appropriate antimicrobial therapy	0 or 1
Wound disruption/ dehiscence	**DEHIS**	Separation of the layers of a surgical wound, which may be partial or complete, with disruption of the fascia.	0 or 1

Label		VASQIP Definition	Scoring
Organ/Space SSI	**ORGSPCSSI**	An infection that occurs within 30 days after the operation and the infection appears to be related to the operation and the infection involves any part of the anatomy (*eg*, organs or spaces), other than the incision, which was opened or manipulated during and operation and at least 1 of the following: -Purulent drainage from a drain that is placed through a stab wound into the organ/space -Organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space -An abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination -Diagnosis of an organ/space SSI by a surgeon or attending physician	0 or 1
Superficial surgical site infection	**SUPINFEC**	Use the following CDC definition: Deep Incision SSI is an infection that occurs within 30 days after the operation and the infection appears to be related to the operation and infection involved deep soft tissues (*eg*, fascial and muscle layers) of the incision and at least 1 of the following: -Purulent drainage from the deep incision but not from the organ/space component of the surgical site. -A deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least 1 of the following signs or symptoms: fever (> 38 C), localized pain, or tenderness, unless site is culture-negative. -An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination. -Diagnosis of a deep incision SSI by a surgeon or attending physician.	0 or 1

Label		VASQIP Definition	Scoring
Deep wound surgical site infection	**WNDINFD**	Use the following CDC definition: Deep Incision SSI is an infection that occurs within 30 days after the operation and the infection appears to be related to the operation and infection involved deep soft tissues (*eg*, fascial and muscle layers) of the incision and at least 1 of the following: -Purulent drainage from the deep incision but not from the organ/space component of the surgical site. -A deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least 1 of the following signs or symptoms: fever (> 38 C), localized pain, or tenderness, unless site is culture-negative. -An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination. -Diagnosis of a deep incision SSI by a surgeon or attending physician.	0 or 1

Note. The variable “1 or more VASQIP complications” is scored as a 0 or 1. If any of the above complications has a score of 1, the score for "1 or more VASQIP complications" will also have a 1.

APPENDIX C. ROBOTIC SYSTEMS BY VHA FACILITY AND YEAR

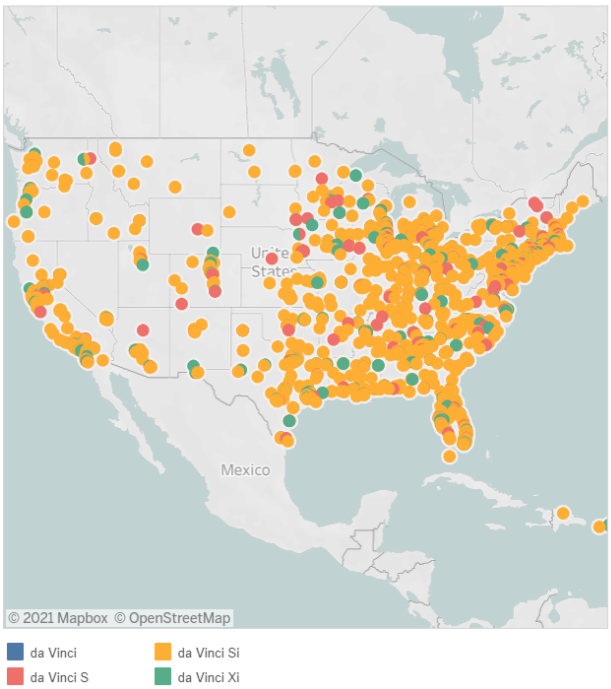
Facility		2015	2017	2019
VISN 1				
VA Boston Healthcare System, West Roxbury Division		1	1	1
VA Connecticut Healthcare System West Haven Campus		1	1	1
	Total	*2*	*2*	*2*
VISN 2				
Albany VA Medical Center: Samuel S. Stratton		1	1	1
East Orange Campus of the VA New Jersey Health Care System		1	1	1
James J. Peters VA Medical Center (Bronx, NY)		1	1	2
Manhattan Campus of VA NY Harbor Healthcare System		1	1	2
Syracuse VA Medical Center		1	1	3
VA Western New York Healthcare System at Buffalo		1	1	1
	Total	*6*	*6*	*10*
VISN 4				
Philadelphia VA Medical Center		1	1	2
VA Pittsburgh Healthcare System, University Drive Campus		1	2	2
	Total	*2*	*3*	*4*
VISN 5				
Washington DC VA Medical Center		1	1	2
	Total	*1*	*1*	*2*
VISN 6				
Durham VA Medical Center		1	1	1
Hampton VA Medical Center		0	0	1
Hunter Holmes McGuire VA Medical Center		1	1	2
Salisbury - W.G. (Bill) Hefner VA Medical Center		1	2	3
	Total	*3*	*4*	*7*
VISN 7				
Birmingham VA Medical Center		1	1	2
Ralph H. Johnson VA Medical Center		1	1	2
VA Medical Center - Augusta		1	1	2
William Jennings Bryan Dorn VA Medical Center		0	0	1
	Total	*3*	*3*	*7*
VISN 8				
James A. Haley Veterans' Hospital		0	1	2
Malcom Randall VA Medical Center		0	1	1
Miami VA Medical Center		1	1	1
VAMC Lake Nona		0	0	1
	Total	*1*	*3*	*5*
VISN 9				

Facility		2015	2017	2019
Lexington VA Medical Center		1	1	1
Mountain Home VAMC-Johnson City		0	0	1
Robley Rex VA Medical Center		0	0	2
Tennessee Valley Healthcare System - Nashville Campus		0	0	1
	Total	*1*	*1*	*5*
VISN 10				
Cincinnati VA Medical Center		1	1	1
John D. Dingell VA Medical Center		1	1	2
Louis Stokes Cleveland Dept Veteran Affairs Medical Center		1	1	1
Richard L. Roudebush VA Medical Center		1	1	2
VA Ann Arbor Healthcare System		1	1	1
	Total	*5*	*5*	*7*
VISN 12				
Clement J. Zablocki Veterans Affairs Medical Center		1	1	2
Edward Hines Jr. VA Hospital		1	2	1
Jesse Brown VA Medical Center		1	1	2
William S. Middleton Memorial Veterans Hospital		1	1	1
	Total	*4*	*5*	*6*
VISN 15				
VA St. Louis Health Care System - Jefferson Barracks Division		1	1	2
	Total	*1*	*1*	*2*
VISN 16				
G.V. (Sonny) Montgomery VA Medical Center		0	0	1
John L. McClellan Memorial Veterans Hospital		0	0	1
Michael E. Debakey VA Medical Center		2	3	3
Oklahoma City VA Medical Center		0	1	1
Southeast Louisiana Veterans Health Care System		0	2	2
	Total	*2*	*6*	*8*
VISN 17				
Central Texas Veterans Health Care System		0	0	1
South Texas Veterans Health Care System		1	1	2
VA North Texas Health Care System: Dallas VA Medical Center		3	2	2
	Total	*4*	*3*	*5*
VISN 18				
New Mexico VA Health Care System		1	1	1
Phoenix VA Health Care System		0	1	2
Southern Arizona VA Healthcare System		1	1	2
	Total	*2*	*3*	*5*
VISN 19				
Rocky Mountain Regional VA Medical Center		0	0	1
VA Eastern Colorado Health Care System		1	2	0

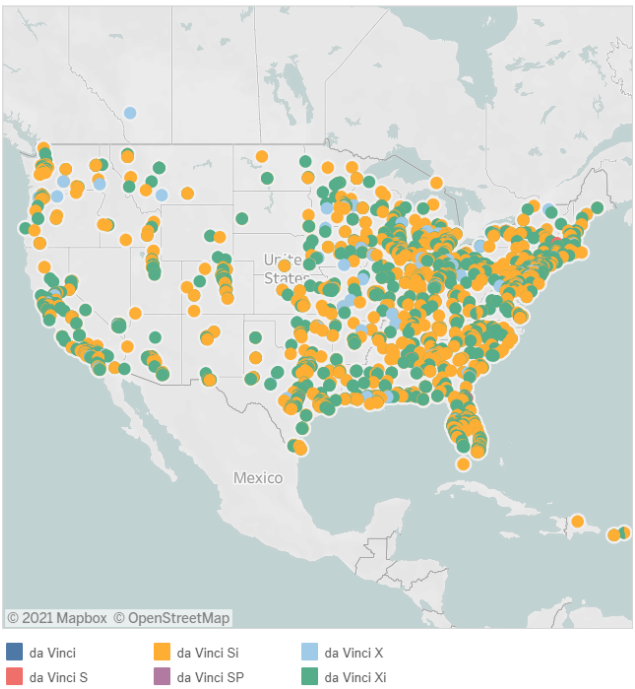
Facility		**2015**	**2017**	**2019**
VA Salt Lake City Health Care System		1	1	1
	Total	*2*	*3*	*2*
VISN 20				
Portland VA Health Care System		0	1	1
VA Puget Sound Health Care System - Seattle Division		1	1	1
	Total	*1*	*2*	*2*
VISN 21				
San Francisco VA Medical Center		1	1	2
VA Northern California Health Care System		1	1	1
VA Palo Alto Healthcare System		2	1	1
VA Southern Nevada Healthcare System (VASNHS)		0	1	1
	Total	*4*	*4*	*5*
VISN 22				
VA Greater Los Angeles Health Care System		1	1	1
VA Loma Linda Healthcare System		1	2	2
VA Long Beach Healthcare System		0	1	1
VA San Diego Healthcare System		1	2	3
	Total	*3*	*6*	*7*
VISN 23				
Minneapolis VA Health Care System		1	1	1
Omaha VA Medical Center		0	1	1
	Total	*1*	*2*	*2*
	VISN Total	*48*	*63*	*93*

APPENDIX D: DISTRIBUTION OF ROBOTIC SYSTEMS NATIONALLY

dV Active Installs - 2015



dV Active Installs - 2019



Provided by: Jason Lamb, Director Government Accounts, Intuitive Surgical, email communication, June 2021