

Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eTable 1. Implementation Timeline of ERAS Colorectal (CR) and Hip Fracture (HF) Pathways Across KPNC Facilities Throughout 2014

Site	Implementation month in 2014											Number	
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Colorectal	Hip Fracture
1	CR	HIP										210	227
2	HIP	CR										330	504
3			CR				HIP					134	202
4			CR						HIP			138	229
5				CR			HIP					215	320
6				CR					HIP			240	278
7				CR						HIP		290	327
8				CR						HIP		59	--
9						HIP				CR		213	339
10							CR	HIP				55	157
11							CR	HIP				169	252
12							CR		HIP			124	125
13							CR		HIP			104	141
14							HIP		CR			96	178
15							HIP		CR			131	286
16							HIP			CR		285	179
17							CR				HIP	157	265
18								CR	HIP			342	451
19								HIP	CR			296	372
20								CR	HIP			180	170

Numbers in right sided columns indicate the total number patients from each facility across the study period.

eTable 2. Estimated Deployment Schedule for Key Organizational and Implementation Elements for ERAS Program Implementation in Kaiser Permanente Northern California Designed at the Outset of the Program Design

Element	Estimated Timeline
Phase 1	
Steering Committee structure established	Q3 2013 – Q4 2013
Project goals and metrics defined	Q2 2013 – Q4 2013
ERAS Pathways developed	Q2 2013 – Q4 2013
ERAS Pathways socialized	Q3 2013 – Q4 2013
Phase 2	
Alpha Pilot projects initiated	Q1 2014
Learnings from Alpha Pilots incorporated	Q1 2014 – Q2 2014
Beta Pilot projects initiated	Q2 2014
Evaluation for full Regional spread	Q2 2014
Phase 3	
Learnings consolidated into playbook	Q2 2014
ERAS Summit	End of Q2 2014
Implementation across Northern California	Q3 2014 – Q4 2014

Q: quarter

eTable 3. International Classification of Disease, Ninth Edition, Clinical Modification Hospital Procedure Codes Used to Identify ERAS Colorectal Target Patients and ERAS Hip Fracture Target Patients

COLORECTAL Surgery	
Procedure Code	Description
17.31	Laparoscopic multiple segmental resection of large intestine
17.32	Laparoscopic cecectomy
17.33	Laparoscopic right hemicolectomy
17.34	Laparoscopic resection of transverse colon
17.35	Laparoscopic left hemicolectomy
17.36	Laparoscopic sigmoidectomy
17.39	Other laparoscopic partial excision of large intestine
45.71	Open and other multiple segmental resection of large intestine
45.72	Open and other cecectomy
45.73	Open and other right hemicolectomy
45.74	Open and other resection of transverse colon
45.75	Open and other left hemicolectomy
45.76	Open and other sigmoidectomy
45.79	Other and unspecified partial excision of large intestine
45.81	Laparoscopic total intra-abdominal colectomy
45.82	Open total intra-abdominal colectomy
45.83	Other and unspecified total intra-abdominal colectomy
45.93	Other small-to-large intestinal anastomosis
45.94	Large-to-large intestinal anastomosis
45.95	Anastomosis to anus
46.03	Exteriorization of large intestine
46.04	Resection of exteriorized segment of large intestine
46.1	Colostomy, not otherwise specified
46.11	Temporary colostomy
46.13	Permanent colostomy
46.2	Ileostomy, not otherwise specified
46.21	Temporary ileostomy
46.22	Continent ileostomy
46.23	Other permanent ileostomy
48	Proctotomy
48.1	Proctostomy
48.4	Pull-through resection of rectum, not otherwise specified
48.41	Soave submucosal resection of rectum
48.42	Laparoscopic pull-through resection of rectum
48.43	Open pull-through resection of rectum
48.49	Other pull-through resection of rectum
48.5	Abdominoperineal resection of the rectum, not otherwise specified
48.51	Laparoscopic abdominoperineal resection of the rectum
48.52	Open abdominoperineal resection of the rectum
48.59	Other abdominoperineal resection of the rectum
48.61	Transsacral rectosigmoidectomy
48.63	Other anterior resection of rectum
48.65	Duhamel resection of rectum
48.69	Other resection of rectum

HIP FRACTURE Surgery	
Procedure Code	Description
78.55	Internal fixation of bone without fracture reduction, femur
79.05	Closed reduction of fracture without internal fixation, femur
79.15	Closed reduction of fracture with internal fixation, femur
79.35	Open reduction of fracture with internal fixation, femur
81.51	Total hip replacement
81.52	Partial hip replacement
With Diagnosis Code	
733.1	Pathologic fracture, unspecified site
733.1	Pathologic fracture of neck of femur
734	Stress fracture of femoral neck
808.1	Open fracture of acetabulum
820	Closed fracture of intracapsular section of neck of femur, unspecified
820	Closed fracture of epiphysis (separation) (upper) of neck of femur
820	Closed fracture of midcervical section of neck of femur
820	Closed fracture of base of neck of femur
820.1	Other closed transcervical fracture of neck of femur
820.1	Open fracture of intracapsular section of neck of femur, unspecified
820.1	Open fracture of epiphysis (separation) (upper) of neck of femur
820.1	Open fracture of midcervical section of neck of femur
820.2	Other open transcervical fracture of neck of femur
820.2	Closed fracture of trochanteric section of neck of femur
820.2	Closed fracture of intertrochanteric section of neck of femur
820.2	Closed fracture of subtrochanteric section of neck of femur
820.3	Open fracture of trochanteric section of neck of femur, unspecified
820.3	Open fracture of intertrochanteric section of neck of femur
820.3	Open fracture of subtrochanteric section of neck of femur
820.8	Closed fracture of unspecified part of neck of femur
820.9	Open fracture of unspecified part of neck of femur

eTable 4. AHRQ Clinical Classification Software Categories of Comparator Cohorts for the Enhanced Recovery After Surgery Colorectal Resection and Hip Fracture

Colorectal Resection Comparator Procedure List			Hip Fracture Comparator Procedure List		
CCS Category	CCS Level 2 Code	Number (%)	CCS Category	CCS Level 2 Code	Number (%)
Gastrectomy	9.6	2,360 (42.5)	Fracture or dislocation	14.3	832 (54.6)
Nephrectomy	10.3	1,070 (19.3)	Lower extremity amputation	14.1	455 (29.9)
Hernia repair	9.18	817 (14.7)	Arthroplasty	14.7	175 (11.5)
Other lower GI surgery	9.28	542 (9.8)	Spinal fusion	14.11	61 (4.0)
Cholecystectomy	9.16	471 (8.5)			
Small bowel resection	9.7	138 (2.5)			
Excision; peritoneal adhesion lysis	9.22	97 (1.8)			
Appendectomy	9.12	61 (1.1)			

eTable 5. Proportion of Patients in the ERAS Target and Comparator Surgical Populations with National Surgical Quality Improvement Program (NSQIP) Data Available for Comparison

	NSQIP data available
ERAS Colorectal	
Pre-implementation	1,015 (53.7)
Post-implementation	1,391 (74.1)
Gastrointestinal comparator	
Pre-implementation	883 (31.5)
Post-implementation	1,073 (39.0)
ERAS Hip Fracture	
Pre-implementation	780 (31.4)
Post-implementation	1,507 (59.9)
Orthopedic comparator	
Pre-implementation	113 (16.3)
Post-implementation	156 (18.8)

NSQIP data abstraction was regionalized in January 2014 along with a decision to standardize the NSQIP participation model to 'Multispecialty/Targeted' for all medical centers, preferentially targeting colorectal and hip fracture patients.

eTable 6. Patient and Hospitalization Characteristics of ERAS Focus Populations and Corresponding Comparator Groups

	Colorectal Resection cohort		Hip Fracture cohort	
	ERAS group	Comparator	ERAS group	Comparator
	<i>n</i> = 3,768	<i>n</i> = 5,556	<i>n</i> = 5,002	<i>n</i> = 1,523
Number pre-implementation	1,890 (50.2)	2,803 (50.4)	2,529 (49.8)	692 (45.4)
Age, years	62.7 (14.1)	54.1 (15.1)	79.5 (11.8)	65.6 (16.8)
Comorbidity (COPS2)	27.7 (30.5)	25.3 (29.8)	43.7 (40.4)	46.3 (47.2)
Severity of illness (LAPS2)	20.0 (12.7)	17.6 (6.8)	57.5 (29.9)	54.6 (31.4)
Direct ICU Admit	11 (0.3)	5 (0.1)	35 (0.7)	41 (2.7)
Admission to surgery, hrs	2.2 (1.7 – 2.9)	2.0 (1.6 – 2.7)	15.8 (6.3 – 23.3)	21.0 (14.7 – 31.0)
Surgery duration, hrs	2.7 (1.9 – 3.8)	1.4 (0.9 – 2.7)	1.0 (0.7 – 1.4)	1.4 (0.8 – 2.1)
Hospital length of stay, days	4.3 (3.2 – 6.4)	2.1 (1.2 – 4.1)	3.5 (2.7 – 4.8)	3.7 (2.7 – 5.6)
Hospital mortality	22 (0.6)	9 (0.2)	77 (1.5)	15 (1.0)
Discharge to home	3,624 (96.2)	5,486 (98.7)	1,217 (24.0)	862 (56.6)

eTable 7. Process Metrics Attainment Before (Pre) and After (Post) Enhanced Recovery After Surgery Implementation Among Colorectal Resection and Hip Fracture Groups With Their Respective Comparators

	ERAS: Colorectal					Comparator			
	Number	Pre	Post	p-value		Number	Pre	Post	p-value
MOBILITY									
Early Ambulation	3,687	415 (22.3)	1,032 (56.5)	<0.001		5,576	1,471 (52.3)	1,830 (66.3)	<0.001
Sustained Ambulation	3,685	1,603 (86.2)	1,735 (95.0)	<0.001		5,525	2,311 (83.5)	2,546 (92.7)	<0.001
Hrs to first ambulation	3,717	20.3 (13.5-26.1)	10.3 (6.7-18.6)	<0.001		5,377	9.8 (5.5 – 21.0)	7.1 (4.5 – 16.4)	<0.001
NUTRITION									
No prolonged fast	3,767	69 (3.7)	247 (13.2)	<0.001		5,624	153 (5.4)	164 (5.9)	0.39
Early Nutrition	3,767	245 (13.0)	736 (39.2)	<0.001		5,624	493 (17.4)	592 (21.2)	<0.001
Hours to first nutrition	3,680	27.0 (18.4-54.1)	16.4 (7.0-23.2)	<0.001		4,001	21.2 (13.3 – 33.9)	19.8 (8.6 – 27.5)	<0.001
PAIN and SEDATION									
Benzodiazepine usage	3,767	267 (14.1)	233 (12.4)	0.12		5,624	286 (10.1)	221 (7.9)	0.005
Morphine equivalents, mg	3,604	52.4 (23.0 – 102.0)	30.6 (13.9 – 65.5)	<0.001		5,438	38.1 (21.0 – 69.0)	33.3 (18.5 – 59.9)	<0.001
Acceptable Pain score, %	3,761	75.9 (60.0 – 88.7)	73.8 (59.3 – 88.4)	0.14		5,612	67.9 (52.6 – 83.3)	64.7 (50.0 – 79.2)	<0.001

	ERAS: Hip Fracture					Comparator			
	Number	Pre	Post	p-value		Number	Pre	Post	p-value
MOBILITY									
Early Ambulation	4,619	66 (2.8)	481 (21.2)	<0.001		1,403	97 (15.1)	195 (25.6)	<0.001
Sustained Ambulation	4,616	356 (15.2)	719 (31.7)	<0.001		1,393	157 (24.7)	307 (40.6)	<0.001
Hrs to first ambulation	3,189	25.3 (18.1 – 46.4)	17.3 (11.6 – 25.5)	<0.001		1,015	20.0 (12.3 – 38.2)	17.2 (8.4 – 25.3)	0.001
NUTRITION									
No prolonged fast	5,002	32 (1.3)	122 (4.9)	<0.001		1,523	15 (2.2)	28 (3.4)	0.16
Early Nutrition	5,002	1,134 (45.6)	1,436 (57.1)	<0.001		1,523	397 (57.4)	526 (63.3)	0.02
Hours to first nutrition	4,915	12.6 (6.5 – 17.5)	10.3 (4.9 – 15.7)	<0.001		1,480	8.2 (4.0 – 15.8)	7.4 (3.8 – 15.0)	0.10
PAIN and SEDATION									
Benzodiazepine usage	5,002	316 (12.7)	251 (10.0)	0.002		1,523	86 (12.4)	95 (11.4)	0.55
Morphine equivalents, mg	4,887	38.9 (22.0 – 66.5)	27.0 (13.5 – 48.3)	<0.001		1,402	40.8 (21.0 – 78.5)	39.0 (17.7 – 74.1)	0.09
Acceptable Pain score, %	4,988	68.2 (54.3 – 82.1)	72.7 (57.1 – 85.7)	<0.001		1,523	63.0 (47.5 – 77.9)	63.9 (47.4 – 80.0)	0.57

eTable 8. Interrupted Time-Series Analysis of Changes in Process Metrics in ERAS vs Comparator Groups in the Pre- and Post-implementation Phases

	Comparison Type						
	Baseline Difference	Pre-period slope		Pre to Post Difference		Post-period slope	
	<i>ERAS relative to Comparator</i>	<i>Comparator</i>	<i>ERAS relative to Comparator</i>	<i>Comparator</i>	<i>ERAS relative to Comparator</i>	<i>Comparator</i>	<i>ERAS relative to Comparator</i>
Colorectal							
Early Ambulation	0.43	1.02	1.00	1.06	1.97	0.99	1.00
Sustained ambulation	0.98	1.02	0.99	0.96	1.07	0.99	1.00
Hours to ambulation	1.62	0.97	1.01	0.98	0.88	1.02	0.98
No prolonged fast	1.04	1.00	1.01	1.12	1.55	0.99	1.01
Early nutrition	1.01	1.01	1.05	1.19	1.66	0.98	0.97
Hours to nutrition	1.24	1.00	0.98	0.90	0.79	1.00	0.99
Benzodiazepine usage	1.34	1.01	0.99	0.76	1.32	0.99	0.99
Opioid usage	1.28	0.99	0.99	0.93	0.97	1.01	0.99
Acceptable pain score	1.10	0.99	1.00	1.03	1.00	1.00	1.00
Hip Fracture							
Early Ambulation	0.32	1.03	1.10	0.93	2.31	1.04	0.92
Sustained ambulation	0.78	1.08	1.05	0.99	0.95	0.93	0.96
Hours to ambulation	1.07	1.01	0.97	1.10	0.76	0.96	1.05
No prolonged fast	0.78	1.00	0.99	0.93	1.58	1.01	0.99
Early nutrition	0.79	1.01	1.00	0.97	1.15	1.00	1.00
Hours to nutrition	1.26	0.98	1.00	1.63	0.66	0.97	1.03
Benzodiazepine usage	0.87	0.99	0.98	1.17	0.88	0.97	1.05
Opioid usage	1.06	0.99	1.02	0.95	0.76	1.03	0.96
Acceptable pain score	1.04	1.01	1.00	0.97	1.09	0.99	1.00

Rate ratio estimates are based on generalized linear models with log-link and either Poisson distribution (binary outcomes) or Gaussian distribution (continuous outcomes). Ratios are indicative of: (1) baseline differences between the ERAS and comparator groups ('Baseline Difference'); (2) differences in the slope of change during the pre-period ('Pre-period slope'); (3) differences at the implementation period ('Pre to Post Difference'); and (4) differences in the slope of change during the post-period ('Post-period slope'). Significant p-values are indicated for p<0.05 (light blue) and p≤0.01 (dark blue).

eTable 9. Difference-in-Difference Risk Ratios for ERAS Patient Process Metrics After Program Implementation Among Colorectal Resection and Hip Fracture Cohorts

	Difference-in-Difference Estimates							
	Colorectal resection vs comparator				Hip fracture vs comparator			
	Rate Ratio	95% CI	p-value	Rate Ratio	95% CI	p-value		
Process Metrics								
<i>Mobility</i>								
Early Ambulation	1.99	1.80 – 2.21	<0.001	4.44	3.19 – 6.21	<0.001		
Sustained Ambulation	0.99	0.96 – 1.02	0.58	1.26	1.04 – 1.54	0.02		
Hours to first ambulation	0.84	0.76 – 0.94	0.002	0.73	0.62 – 0.87	<0.001		
<i>Nutrition</i>								
No prolonged fast	3.30	2.36 – 4.62	<0.001	2.42	1.17 – 5.03	0.02		
Early Nutrition	2.47	2.09 – 2.93	<0.001	1.13	1.03 – 1.25	0.01		
Hours to first nutrition	0.62	0.56 – 0.69	<0.001	0.80	0.68 – 0.95	0.01		
<i>Analgesia and sedation</i>								
Benzodiazepine usage	1.11	0.88 – 1.41	0.35	0.85	0.62 – 1.17	0.33		
Opiate equivalent, mg	0.79	0.71 – 0.89	<0.001	0.73	0.63 – 0.85	<0.001		
Acceptable Pain score, %	1.03	1.00 – 1.05	0.02	1.04	1.01 – 1.08	0.02		

eTable 10. Outcome Metrics Before (Pre) and After (Post) Enhanced Recovery After Surgery Implementation Among Colorectal Resection and Hip Fracture Groups With Their Respective Comparators

	ERAS: Colorectal			Comparator		
	Pre	Post	p-value	Pre	Post	p-value
Hospital length of stay, d	5.1 (3.4 – 7.1)	4.2 (3.1 – 6.2)	<0.001	2.2 (1.3 – 4.2)	2.0 (1.2 – 3.6)	<0.001
Hospital mortality	16 (0.9)	6 (0.3)	0.03	3 (0.1)	7 (0.3)	0.20
Discharge to home	1,808 (95.7)	1,816 (96.7)	0.10	2,797 (98.6)	2,752 (98.7)	0.61
30-day readmission	348 (18.6)	364 (19.4)	0.50	238 (8.4)	251 (9.0)	0.40
Postoperative complications	184 (18.1)	204 (14.7)	0.02	62 (6.9)	85 (7.7)	0.46
Major complications	42 (4.1)	39 (2.8)	0.07	9 (1.0)	25 (2.3)	0.03

	ERAS: Hip Fracture			Comparator		
	Pre	Post	p-value	Pre	Post	p-value
Hospital length of stay, d	3.6 (2.8 – 4.8)	3.2 (2.6 – 4.7)	<0.001	3.8 (2.7 – 5.6)	3.7 (2.7 – 5.7)	0.70
Hospital mortality	35 (1.4)	42 (1.7)	0.45	7 (1.0)	8 (1.0)	0.92
Discharge to home	541 (21.7)	676 (26.9)	<0.001	392 (56.7)	470 (56.6)	0.97
30-day readmission	299 (12.2)	342 (13.8)	0.09	102 (14.9)	143 (17.4)	0.19
Postoperative complications	240 (30.8)	375 (24.9)	0.003	29 (25.7)	44 (28.2)	0.64
Major complications	25 (3.2)	56 (3.7)	0.53	4 (3.5)	11 (7.1)	0.22

eFigure. Number of Monthly Patients in the ERAS Colorectal Resection and Hip Fracture Groups and in the Corresponding Gastrointestinal (GI) and Orthopedic (Ortho) Comparator Groups

