



**Effect of monitoring surgical outcomes using control charts to reduce major adverse events in patients: cluster randomised trial**

This appendix has been provided by the authors to give readers additional information about their work

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## Appendix. Operations and Procedures Codes

Operation	Surgical procedure	Procedure code	Detailed operation
Appendectomy	Laparoscopic appendectomy	HHFA016	Laparoscopic appendectomy
Appendectomy	Laparoscopic appendectomy	HHFA025	Laparoscopic appendectomy with peritoneal lavage for peritonitis
Appendectomy	Open appendectomy	HHFA001	Open iliac appendectomy
Appendectomy	Open appendectomy	HHFA011	Open appendectomy
Appendectomy	Open appendectomy	HHFA020	Open appendectomy with peritoneal lavage for peritonitis
Bariatric surgery	Gastric banding	HFKA002	Open gastric banding replacement for morbid obesity
Bariatric surgery	Gastric banding	HFKA001	Laparoscopic gastric banding replacement for morbid obesity
Bariatric surgery	Gastric banding	HFMA009	Open gastric banding for morbid obesity
Bariatric surgery	Gastric banding	HFMA011	Open gastric banding repositioning /removal
Bariatric surgery	Gastric banding	HFMC007	Laparoscopic gastric banding for morbid obesity
Bariatric surgery	Gastric banding	HFMC008	Laparoscopic gastric banding repositioning/removal
Bariatric surgery	Roux-en-Y gastric bypass	HFCA001	Open gastric bypass for morbid obesity
Bariatric surgery	Roux-en-Y gastric bypass	HFCC003	Laparoscopic gastric bypass for morbid obesity
Bariatric surgery	Sleeve gastrectomy	HHFA011	Open sleeve gastrectomy
Bariatric surgery	Sleeve gastrectomy	HHFC018	Laparoscopic sleeve gastrectomy
Cholecystectomy	Laparoscopic cholecystectomy	HMFC004	Laparoscopic cholecystectomy
Cholecystectomy	Open cholecystectomy	HMFA007	Open cholecystectomy
Colorectal surgery	Ostomy and Hartman procedure reversal	HHMA003	Open colostomy reversal
Colorectal surgery	Ostomy and Hartman procedure reversal	HHMC001	Laparoscopic colostomy reversal
Colorectal surgery	Rectal surgery	HJFA001	Open rectosigmoid resection with pull through of the colon in the retro rectal space and coloanal anastomosis
Colorectal surgery	Rectal surgery	HJFA002	Open rectosigmoidectomy with colorectal anastomosis
Colorectal surgery	Rectal surgery	HJFA004	Laparoscopic rectosigmoidectomy with colorectal anastomosis
Colorectal surgery	Rectal surgery	HJFA006	Open rectosigmoidectomy with coloanal anastomosis
Colorectal surgery	Rectal surgery	HJFA007	Transanal abdominoperineal resection
Colorectal surgery	Rectal surgery	HJFA017	Laparoscopic rectosigmoidectomy with coloanal anastomosis
Colorectal surgery	Rectal surgery	HJFA019	Laparoscopic abdominoperineal resection
Colorectal surgery	Rectal surgery	HJFC031	Laparoscopic rectosigmoidectomy without immediate anastomosis
Colorectal surgery	Rectopexy	HJDC001	Laparoscopic rectopexy
Colorectal surgery	Segmental colectomy	HHFA002	Laparoscopic left colectomy with splenic flexure mobilisation with immediate anastomosis
Colorectal surgery	Segmental colectomy	HHFA006	Open left colectomy with splenic flexure mobilisation with immediate anastomosis
Colorectal surgery	Segmental colectomy	HHFA008	Laparoscopic right colectomy with immediate anastomosis
Colorectal surgery	Segmental colectomy	HHFA009	Open right colectomy with immediate anastomosis
Colorectal surgery	Segmental colectomy	HHFA010	Laparoscopic left colectomy without splenic flexure mobilisation with immediate anastomosis
Colorectal surgery	Segmental colectomy	HHFA014	Open left colectomy without splenic flexure mobilisation without immediate anastomosis
Colorectal surgery	Segmental colectomy	HHFA017	Open left colectomy without splenic flexure mobilisation with immediate anastomosis
Colorectal surgery	Segmental colectomy	HHFA018	Open transverse colectomy
Colorectal surgery	Segmental colectomy	HHFA023	Laparoscopic transverse colectomy
Colorectal surgery	Segmental colectomy	HHFA024	Open left colectomy with splenic flexure mobilisation without immediate anastomosis
Colorectal surgery	Total colectomy or coloproctectomy	HHFA004	Laparoscopic total colectomy with ileo rectal anastomosis
Colorectal surgery	Total colectomy or coloproctectomy	HHFA005	Laparoscopic total colectomy without immediate anastomosis
Colorectal surgery	Total colectomy or coloproctectomy	HHFA021	Open total colectomy without immediate anastomosis
Colorectal surgery	Total colectomy or coloproctectomy	HHFA022	Open total colectomy with ileo rectal anastomosis
Colorectal surgery	Total colectomy or coloproctectomy	HHFA028	Laparoscopic total proctocolectomy with ileo anal anastomosis
Colorectal surgery	Total colectomy or coloproctectomy	HHFA029	Laparoscopic total proctocolectomy without immediate anastomosis

Colorectal surgery	Total colectomy or colectomy	HHFA030	Open total proctocolectomy without immediate anastomosis
Colorectal surgery	Total colectomy or colectomy	HHFA031	Open total proctocolectomy with ileo anal anastomosis
Colorectal surgery	Total colectomy or colectomy	HJFA012	Open secondary proctectomy with ileo anal anastomosis after initial total colectomy
Colorectal surgery	Total colectomy or colectomy	HJFC023	Laparoscopic secondary proctectomy with ileo anal anastomosis after initial total colectomy
Oesophageal and gastric surgery	Fundoplication	HFMA003	Open fundoplication without division of short gastric vessels
Oesophageal and gastric surgery	Fundoplication	HFMA008	Open fundoplication with division of short gastric vessels
Oesophageal and gastric surgery	Fundoplication	HFMC001	Laparoscopic fundoplication with division of short gastric vessels
Oesophageal and gastric surgery	Fundoplication	HFMC004	Laparoscopic fundoplication without division of short gastric vessels
Oesophageal and gastric surgery	Oesophagectomy	HEFA001	Oesophagectomy with oesophago-gastric anastomosis by left thoracic phrenotomy (sweet procedure)
Oesophageal and gastric surgery	Oesophagectomy	HEFA002	Oesophagectomy with oesophago-gastric anastomosis by three field-laparotomy, right thoracotomy and cervical anastomosis (McKeown procedure)
Oesophageal and gastric surgery	Oesophagectomy	HEFA003	Open transthoracic oesophagectomy with laparoscopic gastric tube formation
Oesophageal and gastric surgery	Oesophagectomy	HEFA004	Transhiatal oesophagectomy by laparotomy and cervicotomy
Oesophageal and gastric surgery	Oesophagectomy	HEFA005	Oesophagectomy with oesophagojejunostomy by thoraco laparotomy
Oesophageal and gastric surgery	Oesophagectomy	HEFA006	Total oesophagectomy with oesophagocoloplasty by laparotomy and cervicotomy
Oesophageal and gastric surgery	Oesophagectomy	HEFA007	Total oesophagectomy with oesophagocoloplasty by laparotomy, thoracotomy and cervicotomy
Oesophageal and gastric surgery	Oesophagectomy	HEFA008	Total oesophago laryngo pharyngectomy with pharyngogastric anastomosis
Oesophageal and gastric surgery	Oesophagectomy	HEFA009	Open (thoracotomy and laparotomy) oesophagectomy and oesophagocoloplasty
Oesophageal and gastric surgery	Oesophagectomy	HEFA011	Open (thoracotomy and laparotomy) oesophagectomy and oesophagojejunostomy
Oesophageal and gastric surgery	Oesophagectomy	HEFA012	Open (thoracotomy and laparotomy) oesophagectomy and oesogastric anastomosis
Oesophageal and gastric surgery	Oesophagectomy	HEFA013	Oesophagectomy and oesogastric anastomosis by thoraco laparotomy
Oesophageal and gastric surgery	Oesophagectomy	HEFA016	Oesophagectomy and oesophagocoloplasty by thoraco laparotomy
Oesophageal and gastric surgery	Oesophagectomy	HEFA017	Open (laparotomy and cervicotomy) oesophago laryngo pharyngectomy and oesophagocoloplasty
Oesophageal and gastric surgery	Oesophagectomy	HEFA018	Open (thoracotomy and cervicotomy) oesophagectomy with laparoscopic gastric tube formation
Oesophageal and gastric surgery	Oesophagectomy	HEPA006	Open oesophago-cardiomyotomy without fundoplication
Oesophageal and gastric surgery	Oesophagectomy	HEPC002	Laparoscopic oesophago-cardiomyotomy without fundoplication
Oesophageal and gastric surgery	Oesophagectomy	HEPC003	Laparoscopic oesophago-cardiomyotomy with fundoplication
Oesophageal and gastric surgery	Gastrectomy	HFFA002	Open antrectomy with gastroduodenostomy
Oesophageal and gastric surgery	Gastrectomy	HFFA005	Open total gastrectomy with oesophagojejunostomy
Oesophageal and gastric surgery	Gastrectomy	HFFA006	Open antrectomy with gastrojejunostomy
Oesophageal and gastric surgery	Gastrectomy	HFFA008	Open partial degastrogastrectomy with gastrojejunostomy or with gastrojejunostomy
Oesophageal and gastric surgery	Gastrectomy	HFFA009	Open gastric wedge resection
Oesophageal and gastric surgery	Gastrectomy	HFFC001	Laparoscopic gastric wedge resection
Oesophageal and gastric surgery	Gastrectomy	HFFC002	Laparoscopic antrectomy with gastrojejunostomy
Oesophageal and gastric surgery	Gastrectomy	HFFC012	Laparoscopic antrectomy with gastroduodenostomy
Oesophageal and gastric surgery	Gastrectomy	HFFC017	Laparoscopic total gastrectomy with oesophagojejunostomy
Oesophageal and gastric surgery	Gastrectomy	HFMA005	Open completion gastrectomy with oesophagojejunostomy
Oesophageal and gastric surgery	Gastrojejunostomy	HFCA004	Open gastrojejunostomy
Oesophageal and gastric surgery	Gastrojejunostomy	HFCC022	Laparoscopic gastrojejunostomy
Oesophageal and gastric surgery	Hiatal hernia repair	LLMA006	Open hiatal hernia repair without mesh
Oesophageal and gastric surgery	Hiatal hernia repair	LLMA010	Open hiatal hernia repair with mesh
Oesophageal and gastric surgery	Hiatal hernia repair	LLMC004	Laparoscopic hiatal hernia repair without mesh
Hepatopancreatic surgery	Laparoscopic hepatectomy	HLFC002	Laparoscopic hepatic lobectomy
Hepatopancreatic surgery	Laparoscopic hepatectomy	HLFC003	Laparoscopic atypical liver resection
Hepatopancreatic surgery	Laparoscopic hepatectomy	HLFC004	Laparoscopic liver monosegmentectomy

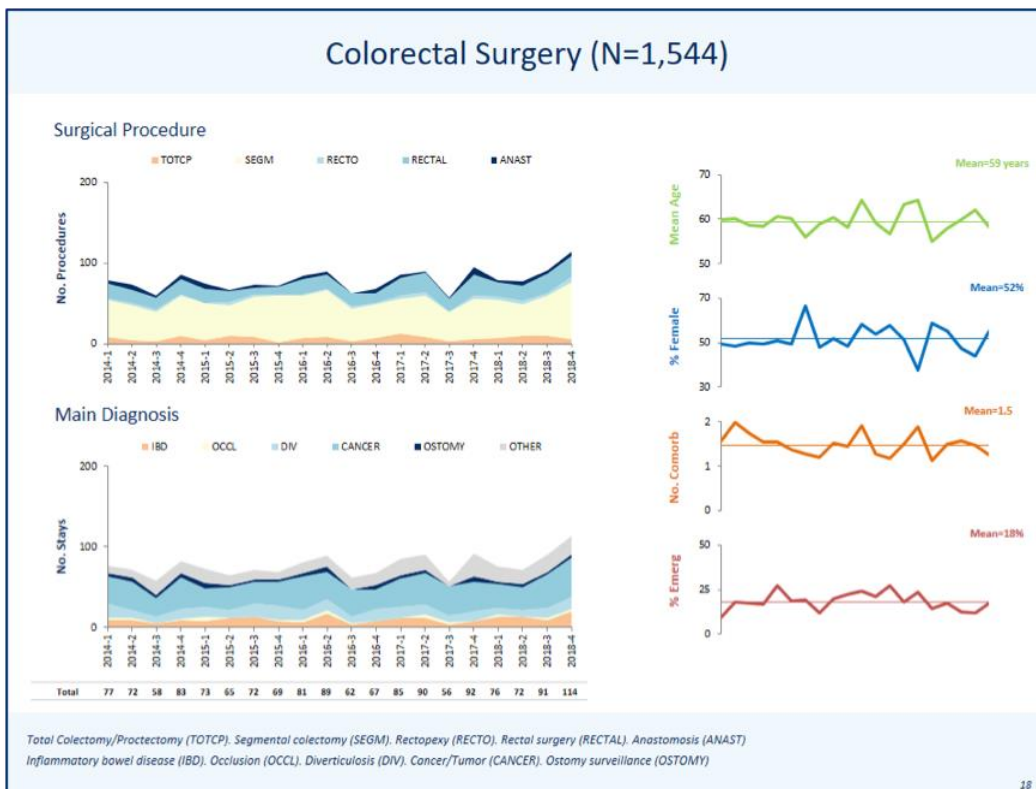
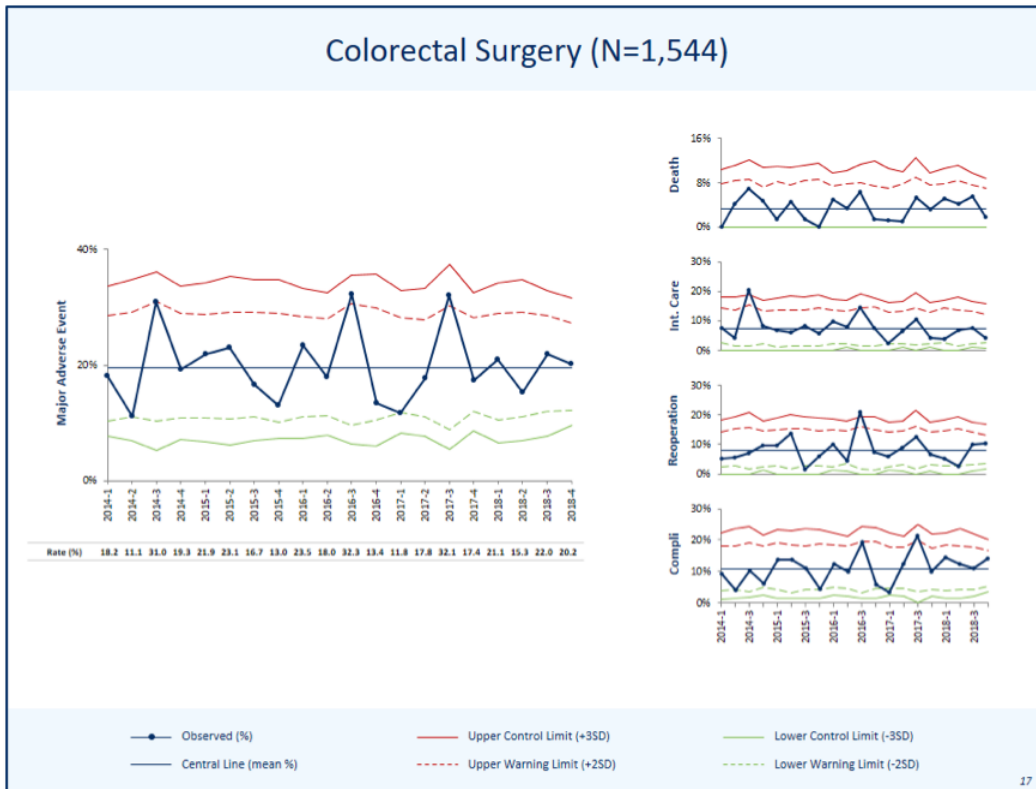
Hepatopancreatic surgery	Laparoscopic hepatectomy	HLFC027	Laparoscopic liver bisegmentectomy
Hepatopancreatic surgery	Laparoscopic hepatectomy	HLFC032	Laparoscopic liver trisegmentectomy
Hepatopancreatic surgery	Laparoscopic hepatectomy	HLFC037	Laparoscopic left hepatectomy
Hepatopancreatic surgery	Laparoscopic pancreatectomy	HNFC001	Laparoscopic pancreatic enucleation
Hepatopancreatic surgery	Laparoscopic pancreatectomy	HNFC002	Laparoscopic left pancreatectomy with splenectomy
Hepatopancreatic surgery	Laparoscopic pancreatectomy	HNFC028	Laparoscopic left pancreatectomy with splenic preservation
Hepatopancreatic surgery	Open hepatectomy	HLFA004	Open extended right hepatectomy with segment 1 resection
Hepatopancreatic surgery	Open hepatectomy	HLFA005	Open right hepatic lobectomy
Hepatopancreatic surgery	Open hepatectomy	HLFA006	Open liver trisegmentectomy
Hepatopancreatic surgery	Open hepatectomy	HLFA007	Open extended left hepatectomy with segment 1 resection
Hepatopancreatic surgery	Open hepatectomy	HLFA009	Open liver bisegmentectomy
Hepatopancreatic surgery	Open hepatectomy	HLFA010	Open central hepatectomy
Hepatopancreatic surgery	Open hepatectomy	HLFA011	Open left hepatic lobectomy
Hepatopancreatic surgery	Open hepatectomy	HLFA017	Open right hepatectomy
Hepatopancreatic surgery	Open hepatectomy	HLFA018	Open left hepatectomy
Hepatopancreatic surgery	Open hepatectomy	HLFA019	Open atypical liver resection
Hepatopancreatic surgery	Open hepatectomy	HLFA020	Open liver monosegmentectomy
Hepatopancreatic surgery	Open hepatectomy	HMFA009	Open bile duct resection with hepatico jejunostomy
Hepatopancreatic surgery	Open hepatectomy	HMFA010	Open resection of extra pancreatic and common bile duct with hepatico jejunostomy
Hepatopancreatic surgery	Open pancreatectomy	HNFA001	Open central pancreatectomy with pancreatico-enteric anastomosis
Hepatopancreatic surgery	Open pancreatectomy	HNFA002	Open left pancreatectomy with splenic preservation and pancreaticogastrostomy or pancreaticojejunostomy
Hepatopancreatic surgery	Open pancreatectomy	HNFA004	Open total pancreaticoduodenectomy with splenectomy
Hepatopancreatic surgery	Open pancreatectomy	HNFA005	Open pancreatic enucleation
Hepatopancreatic surgery	Open pancreatectomy	HNFA006	Open duodenum-preserving total or subtotal pancreatectomy with splenectomy
Hepatopancreatic surgery	Open pancreatectomy	HNFA007	Open pancreaticoduodenectomy
Hepatopancreatic surgery	Open pancreatectomy	HNFA008	Open left pancreatectomy with splenic preservation
Hepatopancreatic surgery	Open pancreatectomy	HNFA010	Pancreaticojejunostomy or pancreaticogastrostomy
Hepatopancreatic surgery	Open pancreatectomy	HNFA011	Open duodenum-preserving total or subtotal pancreatectomy with splenic preservation
Hepatopancreatic surgery	Open pancreatectomy	HNFA013	Open left pancreatectomy with splenectomy
Hernia repair	Laparoscopic incisional hernia repair	LMMC015	Laparoscopic incisional hernia repair with mesh
Hernia repair	Laparoscopic inguinal hernia repair	LMMC002	Laparoscopic unilateral inguinal hernia repair with mesh
Hernia repair	Laparoscopic inguinal hernia repair	LMMC020	Laparoscopic umbilical hernia repair with mesh after age 16
Hernia repair	Open direct hernia repair	LMMA006	Open umbilical hernia repair with mesh after age 16
Hernia repair	Open direct hernia repair	LMMA009	Open umbilical hernia repair without mesh after age 16
Hernia repair	Open incisional hernia repair	LMMA004	Open incisional hernia repair with mesh
Hernia repair	Open incisional hernia repair	LMMA010	Open incisional hernia repair without mesh
Hernia repair	Open inguinal hernia repair	LMMA001	Open bilateral inguinal hernia repair with mesh
Hernia repair	Open inguinal hernia repair	LMMA011	Open femoral hernia repair
Hernia repair	Open inguinal hernia repair	LMMA012	Open unilateral inguinal hernia repair with mesh
Hernia repair	Open inguinal hernia repair	LMMA016	Open unilateral inguinal hernia repair without mesh under local anaesthesia
Hernia repair	Open inguinal hernia repair	LMMA017	Open unilateral inguinal hernia repair without mesh under general anaesthesia
Hernia repair	Open inguinal hernia repair	LMMA018	Open bilateral inguinal hernia repair without mesh under general anaesthesia

## Appendix. Components of Control Chart–Based Program

A tutorial to reproduce the control chart program with slideshows, videos and logbook is available at: <http://shewhart.univ-lyon1.fr/>.

Key elements on how to develop and interpret a p-chart for clinical practice and how to successfully integrate this tool within a comprehensive approach can also be found online at: <https://academic.oup.com/intqhc/article/22/5/402/1786749>. This includes an open access tutorial accompanied with supplementary material and tools containing fictive data, parameter calculations and chart plotting, so that the reader can easily replicate the method.

Sample slideshow with set of control charts on the colorectal surgery used during team meetings.



## Appendix. Compliance with Control Chart–Based Program Implementation

Compliance of individual hospitals with program implementation.

Intervention components	Implementation score (N = 20 hospitals)	Details
Duos formation	Duo formed with a surgeon: 100%	<ul style="list-style-type: none"> <li>◦ Duos not with 2 surgeons: 60%</li> <li>◦ Turnover within duo during the study: 20%</li> </ul>
Training sessions participation	Participation in all 3 training sessions: 90%	Training sessions: 1   2   3 <ul style="list-style-type: none"> <li>◦ Number of hospitals: 20   20   18</li> <li>◦ Number of participants: 37   36   33</li> <li>◦ Satisfaction score (/10): 8.2   8.0   8.7</li> <li>◦ Investment score (/10): 8.9   8.3   8.0</li> </ul>
Logbook maintenance	Logbook updated until the end: 45%	<ul style="list-style-type: none"> <li>◦ Mean number of changes recorded per hospital: 19.5</li> <li>◦ Type of changes (n = 390):               <ul style="list-style-type: none"> <li>- Patient: 10%</li> <li>- Healthcare worker: 18%</li> <li>- Equipment: 10%</li> <li>- Organization: 31%</li> <li>- Clinical practice: 9%</li> <li>- Unspecified: 22%</li> </ul> </li> </ul>
Poster display	8 posters displayed in operating room: 35%	<ul style="list-style-type: none"> <li>◦ Posters transmitted: 100%</li> <li>◦ Mean number of posters displayed per hospital: 5.0</li> <li>◦ Selfie of duo with the first poster displayed: 100%</li> </ul>
Control chart team meetings	8 team meetings held: 60%	<ul style="list-style-type: none"> <li>◦ Slideshows transmitted: 100%</li> <li>◦ Mean number of team meeting per hospital: 6.9</li> <li>◦ Mean duration of team meeting (min): 53.9</li> <li>◦ Mean number of participants per team meeting: 9.3</li> <li>◦ Selfie of team meeting: 50%</li> </ul>
Improvement plan implementation	At least one improvement plan tested: 95%	<ul style="list-style-type: none"> <li>◦ Mean number of improvement plans tested per hospital: 3.1</li> <li>◦ Type of improvement actions (n = 61):               <ul style="list-style-type: none"> <li>- Patient: 6%</li> <li>- Healthcare worker: 13%</li> <li>- Equipment: 5%</li> <li>- Organization: 70%</li> <li>- Clinical practice: 6%</li> </ul> </li> </ul>

Compliance of each hospital with program implementation was measured based on a previously designed six-items scoring: duo formed with a surgeon, participation in all 3 training sessions, logbook updated over 2 years until the end, posters displayed in operating room every quarter, team meetings held for interpreting control charts every quarter, at least one concrete action tested for care improvement.

Hospital Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Duo formed with a surgeon	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
Participation in all 3 training sessions	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		18
Logbook updated until the end	1	1	1	1	1	1	1	1	1	1											9
8 posters displayed in operating room	1	1	1	1	1				1									1			7
8 team meetings held	1	1	1	1	1	1	1	1	1		1	1	1								12
At least one improvement action tested	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		19
Implementation Score	6	6	6	6	6	5	5	5	5	4	4	4	4	3	3	3	3	3	2	2	4.3
Compliance degree	High									Moderate									Poor		

**Table S1. Patient Characteristics Across Operative Procedures by Study Group**

<b>Operative procedure</b>	<b>Total (N = 155 362)</b>	<b>Intervention (n = 75 047)</b>	<b>Control (n = 80 315)</b>
<b>Hernia repair</b>	<b>36 567</b>	<b>17 617</b>	<b>18 950</b>
Main diagnosis			
Uncomplicated inguinal or incisional hernia	29 046 (79.4)	14 126 (80.2)	14 920 (78.7)
Complicated inguinal or incisional hernia	4803 (13.1)	2405 (13.7)	2398 (12.7)
Other	2718 (7.4)	1086 (6.2)	1632 (8.6)
Surgical procedure			
Open inguinal hernia repair	11 897 (32.5)	5608 (31.8)	6289 (33.2)
Open incisional hernia repair	11 604 (31.7)	4954 (28.1)	6650 (35.1)
Open direct hernia repair	6631 (18.1)	3383 (19.2)	3248 (17.1)
Laparoscopic inguinal hernia repair	4740 (13.0)	2803 (15.9)	1937 (10.2)
Laparoscopic incisional hernia repair	1695 (4.6)	869 (4.9)	826 (4.4)
<b>Colorectal surgery</b>	<b>32 919</b>	<b>15 830</b>	<b>17 089</b>
Main diagnosis			
Cancer	15 960 (48.5)	8300 (52.4)	7660 (44.8)
Other	7437 (22.6)	3197 (20.2)	4240 (24.8)
Diverticulosis	4749 (14.4)	2103 (13.3)	2646 (15.5)
Ostomy surveillance	2448 (7.4)	1034 (6.5)	1414 (8.3)
Inflammatory bowel disease	1552 (4.7)	760 (4.8)	792 (4.6)
Bowel occlusion	773 (2.3)	436 (2.8)	337 (2.0)
Surgical procedure			
Segmental colectomy	17 899 (54.4)	9038 (57.1)	8861 (51.9)
Rectal surgery	7100 (21.6)	3529 (22.3)	3571 (20.9)
Rectopexy	3474 (10.6)	1213 (7.7)	2261 (13.2)
Ostomy and Hartman procedure reversal	2345 (7.1)	1002 (6.3)	1343 (7.9)
Total colectomy or coloproctectomy	2101 (6.4)	1048 (6.6)	1053 (6.2)
<b>Cholecystectomy</b>	<b>30 765</b>	<b>14 872</b>	<b>15 893</b>
Main diagnosis			
Other cholecystitis	11 613 (37.7)	5366 (36.1)	6247 (39.3)
Acute cholecystitis	9511 (30.9)	5077 (34.1)	4434 (27.9)
Gallstone without cholecystitis	6299 (20.5)	2921 (19.6)	3378 (21.3)
Other	2744 (8.9)	1236 (8.3)	1508 (9.5)
Gallbladder cancer	598 (1.9)	272 (1.8)	326 (2.1)
Surgical procedure			
Laparoscopic cholecystectomy	27 668 (89.9)	13 527 (91.0)	14 141 (89.0)
Open cholecystectomy	3097 (10.1)	1345 (9.0)	1752 (11.0)
<b>Bariatric surgery</b>	<b>18 553</b>	<b>9181</b>	<b>9372</b>
Main diagnosis			
Body mass index 40-50 kg/m <sup>2</sup>	9993 (53.9)	5155 (56.1)	4838 (51.6)
Body mass index 30-40 kg/m <sup>2</sup>	5135 (27.7)	2360 (25.7)	2775 (29.6)
Body mass index ≥50 kg/m <sup>2</sup>	2398 (12.9)	1209 (13.2)	1189 (12.7)
Other	1027 (5.5)	457 (5.0)	570 (6.1)
Surgical procedure			
Sleeve gastrectomy	10 211 (55.0)	5005 (54.5)	5206 (55.5)
Roux-en-Y gastric bypass	7211 (38.9)	3638 (39.6)	3573 (38.1)
Gastric banding	1131 (6.1)	538 (5.9)	593 (6.3)
<b>Appendectomy</b>	<b>17 572</b>	<b>9718</b>	<b>7854</b>
Main diagnosis			
Uncomplicated appendicitis	9086 (51.7)	5013 (51.6)	4073 (51.9)
Complicated appendicitis	7278 (41.4)	4071 (41.9)	3207 (40.8)
Other	1208 (6.9)	634 (6.5)	574 (7.3)
Surgical procedure			
Laparoscopic appendectomy	15 826 (90.1)	8867 (91.2)	6959 (88.6)
Open appendectomy	1746 (9.9)	851 (8.8)	895 (11.4)
<b>Hepatopancreatic surgery</b>	<b>10 648</b>	<b>4585</b>	<b>6063</b>
Main diagnosis			
Liver cancer/tumour	2804 (26.3)	1249 (27.2)	1555 (25.6)
Liver metastasis	2761 (25.9)	1142 (24.9)	1619 (26.7)

Pancreatic cancer/tumour	2733 (25.7)	1224 (26.7)	1509 (24.9)
Other cancer/tumour	1314 (12.3)	548 (12.0)	766 (12.6)
Other	1036 (9.7)	422 (9.2)	614 (10.1)
<b>Surgical procedure</b>			
Open hepatectomy	4948 (46.5)	2060 (44.9)	2888 (47.6)
Open pancreatectomy	3653 (34.3)	1618 (35.3)	2035 (33.6)
Laparoscopic hepatectomy	1595 (15.0)	688 (15.0)	907 (15.0)
Laparoscopic pancreatectomy	452 (4.2)	219 (4.8)	233 (3.8)
<b>Oesophageal and gastric surgery</b>	<b>8338</b>	<b>3244</b>	<b>5094</b>
<b>Main diagnosis</b>			
Cancer/tumour	3313 (39.7)	1498 (46.2)	1815 (35.6)
Other	2434 (29.2)	651 (20.1)	1783 (35.0)
Diaphragmatic hernia	1504 (18.0)	635 (19.6)	869 (17.1)
Gastric reflux	928 (11.1)	382 (11.8)	546 (10.7)
Inflammation/ulcer	159 (1.9)	78 (2.4)	81 (1.6)
<b>Surgical procedure</b>			
Gastrectomy	2900 (34.8)	1318 (40.6)	1582 (31.1)
Hiatal hernia repair	2035 (24.4)	561 (17.3)	1474 (28.9)
Oesophagectomy	1455 (17.5)	559 (17.2)	896 (17.6)
Fundoplication	1366 (16.4)	570 (17.6)	796 (15.6)
Gastrojejunostomy	582 (7.0)	236 (7.3)	346 (6.8)

Average numbers are shown in each group. Data relative to pre-implementation period (January 1, 2014 to December 31, 2015) and implementation period (January 1, 2017 to December 31, 2018) were pooled in intervention and control hospitals. Numbers may not sum to 100 because of rounding.



**Table S2. Hospital and Patient Characteristics by Study Group and Period**

Characteristics	Intervention Group		Control Group	
	Pre-implementation	Implementation	Pre-implementation	Implementation
<b>Hospitals</b>	<b>(n=20)</b>	<b>(n=20)</b>	<b>(n=20)</b>	<b>(n=20)</b>
Median (range) volume of digestive tract surgery	1768 (1143-2914)	1728 (1131-2937)	2051 (1161-3722)	1921 (931-3489)
Median (range) rate of ambulatory procedures	17.9 (7.2-49.7)	25.4 (9.7-52.6)	14.2 (5.6-37.6)	25.1 (8.8-40.6)
<b>Patients</b>	<b>(n=37 579)</b>	<b>(n=37 468)</b>	<b>(n=41 548)</b>	<b>(n=38 767)</b>
Mean (SD) age (years)	56.6 (18.6)	56.7 (18.5)	56.5 (18.2)	57.3 (18.2)
Women	19 480 (51.8)	19 373 (51.7)	22 202 (53.4)	20 202 (52.1)
Median household income quartiles (€):				
Very low (11 727-18 926)	7251 (19.3)	7268 (19.4)	12 196 (29.4)	11 609 (29.9)
Low (18 927-20 206)	7903 (21.0)	8043 (21.5)	12 398 (29.8)	11 214 (28.9)
High (20 209-22 332)	9833 (26.2)	9925 (26.5)	9722 (23.4)	9296 (24.0)
Very high (22 332-43 350)	12 592 (33.5)	12 232 (32.6)	7232 (17.4)	6648 (17.1)
Elixhauser comorbidities*				
0	18 794 (50.0)	18 025 (48.1)	20 349 (49.0)	19 484 (50.3)
1	8488 (22.6)	8579 (22.9)	9918 (23.9)	8612 (22.2)
2	4811 (12.8)	5072 (13.5)	5625 (13.5)	5176 (13.4)
≥3	5486 (14.6)	5792 (15.5)	5656 (13.6)	5495 (14.2)
Emergency admission	9780 (26.0)	9977 (26.6)	8325 (20.0)	8222 (21.2)
Surgical procedure during July/August	5245 (14.0)	5277 (14.1)	5819 (14.0)	5419 (14.0)
Operative procedure:				
Hernia repair	9300 (24.7)	8317 (22.2)	10 041 (24.2)	8909 (23.0)
Colorectal	7636 (20.3)	8194 (21.9)	8558 (20.6)	8531 (22.0)
Cholecystectomy	8002 (21.3)	6870 (18.3)	8773 (21.1)	7120 (18.4)
Bariatric	4008 (10.7)	5173 (13.8)	4755 (11.4)	4617 (11.9)
Appendectomy	4815 (12.8)	4903 (13.1)	3862 (9.3)	3992 (10.3)
Hepatopancreatic	2234 (5.9)	2351 (6.3)	2986 (7.2)	3077 (7.9)
Oesophageal and gastric	1584 (4.2)	1660 (4.4)	2573 (6.2)	2521 (6.5)

Values are numbers (percentages) unless stated otherwise. Numbers are shown in pre-implementation period (January 1, 2014 to December 31, 2015) and implementation period (January 1, 2017 to December 31, 2018), for each group (intervention and control hospitals). SD, standard deviation. Numbers may not sum to 100 because of rounding. Details regarding additional patient characteristics by operative procedure are provided in table S3.

\*Congestive heart failure, cardiac arrhythmias, valvular disease, pulmonary circulation disorders, peripheral vascular disorders, hypertension uncomplicated/complicated, paralysis, other neurological disorders, chronic pulmonary disease, diabetes uncomplicated/complicated, hypothyroidism, renal failure, liver disease, peptic ulcer disease excluding bleeding, AIDS/HIV, lymphoma, metastatic cancer, solid tumor without metastasis, rheumatoid arthritis/collagen vascular diseases, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, blood loss anemia, deficiency anemia, alcohol abuse, drug abuse, psychoses, and depression.

**Table S3. Patient Characteristics Across Operative Procedures by Study Group and Period**

Operative procedure	Intervention Group		Control Group	
	Pre-implementation (n=37 579)	Implementation (n=37 468)	Pre-implementation (n=41 548)	Implementation (n=38 767)
<b>Hernia repair</b>	<b>(n=9300)</b>	<b>(n=8317)</b>	<b>(n=10 041)</b>	<b>(n=8909)</b>
Main diagnosis				
Uncomplicated inguinal or incisional hernia	7596 (81.7)	6530 (78.5)	8053 (80.2)	6867 (77.1)
Complicated inguinal or incisional hernia	1192 (12.8)	1213 (14.6)	1248 (12.4)	1150 (12.9)
Other	512 (5.5)	574 (6.9)	740 (7.4)	892 (10.0)
Surgical procedure				
Open inguinal hernia repair	3012 (32.4)	2596 (31.2)	3423 (34.1)	2866 (32.2)
Open incisional hernia repair	2479 (26.7)	2475 (29.8)	3431 (34.2)	3219 (36.1)
Open direct hernia repair	1880 (20.2)	1503 (18.1)	1719 (17.1)	1529 (17.2)
Laparoscopic inguinal hernia repair	1505 (16.2)	1298 (15.6)	1103 (11.0)	834 (9.4)
Laparoscopic incisional hernia repair	424 (4.6)	445 (5.4)	365 (3.6)	461 (5.2)
<b>Colorectal surgery</b>	<b>(n=7636)</b>	<b>(n=8194)</b>	<b>(n=8558)</b>	<b>(n=8531)</b>
Main diagnosis				
Cancer	3896 (51.0)	4404 (53.7)	3786 (44.2)	3874 (45.4)
Other	1558 (20.4)	1639 (20.0)	2178 (25.4)	2062 (24.2)
Diverticulosis	1088 (14.2)	1015 (12.4)	1372 (16.0)	1274 (14.9)
Ostomy surveillance	466 (6.1)	568 (6.9)	701 (8.2)	713 (8.4)
Inflammatory bowel disease	402 (5.3)	358 (4.4)	363 (4.2)	429 (5.0)
Bowel occlusion	226 (3.0)	210 (2.6)	158 (1.8)	179 (2.1)
Surgical procedure				
Segmental colectomy	4364 (57.2)	4674 (57.0)	4401 (51.4)	4460 (52.3)
Rectal surgery	1692 (22.2)	1837 (22.4)	1766 (20.6)	1805 (21.2)
Rectopexy	583 (7.6)	630 (7.7)	1213 (14.2)	1048 (12.3)
Ostomy and Hartman procedure reversal	460 (6.0)	542 (6.6)	648 (7.6)	695 (8.1)
Total colectomy or coloproctectomy	537 (7.0)	511 (6.2)	530 (6.2)	523 (6.1)
<b>Cholecystectomy</b>	<b>(n=8002)</b>	<b>(n=6870)</b>	<b>(n=8773)</b>	<b>(n=7120)</b>
Main diagnosis				
Other cholecystitis	2961 (37.0)	2405 (35.0)	3174 (36.2)	3073 (43.2)
Acute cholecystitis	2585 (32.3)	2492 (36.3)	2462 (28.1)	1972 (27.7)
Gallstone without cholecystitis	1731 (21.6)	1190 (17.3)	2174 (24.8)	1204 (16.9)
Other	597 (7.5)	639 (9.3)	803 (9.2)	705 (9.9)
Gallbladder cancer	128 (1.6)	144 (2.1)	160 (1.8)	166 (2.3)
Surgical procedure				
Laparoscopic cholecystectomy	7296 (91.2)	6231 (90.7)	7763 (88.5)	6378 (89.6)
Open cholecystectomy	706 (8.8)	639 (9.3)	1010 (11.5)	742 (10.4)
<b>Bariatric surgery</b>	<b>(n=4008)</b>	<b>(n=5173)</b>	<b>(n=4755)</b>	<b>(n=4617)</b>
Main diagnosis				
Body mass index 40-50 kg/m <sup>2</sup>	2280 (56.9)	2875 (55.6)	2499 (52.6)	2339 (50.7)
Body mass index 30-40 kg/m <sup>2</sup>	950 (23.7)	1410 (27.3)	1272 (26.8)	1503 (32.6)
Body mass index ≥50 kg/m <sup>2</sup>	568 (14.2)	641 (12.4)	632 (13.3)	557 (12.1)
Other	210 (5.2)	247 (4.8)	352 (7.4)	218 (4.7)
Surgical procedure				
Sleeve gastrectomy	2105 (52.5)	2900 (56.1)	2518 (53.0)	2688 (58.2)
Roux-en-Y gastric bypass	1637 (40.8)	2001 (38.7)	1835 (38.6)	1738 (37.6)
Gastric banding	266 (6.6)	272 (5.3)	402 (8.5)	191 (4.1)
<b>Appendectomy</b>	<b>(n=4815)</b>	<b>(n=4903)</b>	<b>(n=3862)</b>	<b>(n=3992)</b>
Main diagnosis				
Uncomplicated appendicitis	2471 (51.3)	2542 (51.8)	1926 (49.9)	2147 (53.8)
Complicated appendicitis	2027 (42.1)	2044 (41.7)	1632 (42.3)	1575 (39.5)
Other	317 (6.6)	317 (6.5)	304 (7.9)	270 (6.8)
Surgical procedure				
Laparoscopic appendectomy	4329 (89.9)	4538 (92.6)	3376 (87.4)	3583 (89.8)
Open appendectomy	486 (10.1)	365 (7.4)	486 (12.6)	409 (10.2)
<b>Hepatopancreatic surgery</b>	<b>(n=2234)</b>	<b>(n=2351)</b>	<b>(n=2986)</b>	<b>(n=3077)</b>
Main diagnosis				
Liver cancer/tumour	599 (26.8)	650 (27.6)	776 (26.0)	779 (25.3)

Liver metastasis	526 (23.5)	616 (26.2)	798 (26.7)	821 (26.7)
Pancreatic cancer/tumour	621 (27.8)	603 (25.6)	747 (25.0)	762 (24.8)
Other cancer/tumour	271 (12.1)	277 (11.8)	350 (11.7)	416 (13.5)
Other	217 (9.7)	205 (8.7)	315 (10.5)	299 (9.7)
<b>Surgical procedure</b>				
Open hepatectomy	1010 (45.2)	1050 (44.7)	1483 (49.7)	1405 (45.7)
Open pancreatectomy	805 (36.0)	813 (34.6)	999 (33.5)	1036 (33.7)
Laparoscopic hepatectomy	316 (14.1)	372 (15.8)	415 (13.9)	492 (16.0)
Laparoscopic pancreatectomy	103 (4.6)	116 (4.9)	89 (3.0)	144 (4.7)
<b>Oesophageal and gastric surgery</b>	<b>(n=1584)</b>	<b>(n=1660)</b>	<b>(n=2573)</b>	<b>(n=2521)</b>
<b>Main diagnosis</b>				
Cancer/tumour	755 (47.7)	743 (44.8)	942 (36.6)	873 (34.6)
Other	266 (16.8)	385 (23.2)	879 (34.2)	904 (35.9)
Diaphragmatic hernia	301 (19.0)	334 (20.1)	413 (16.1)	456 (18.1)
Gastric reflux	214 (13.5)	168 (10.1)	294 (11.4)	252 (10.0)
Inflammation/ulcer	48 (3.0)	30 (1.8)	45 (1.7)	36 (1.4)
<b>Surgical procedure</b>				
Gastrectomy	631 (39.8)	687 (41.4)	839 (32.6)	743 (29.5)
Hiatal hernia repair	262 (16.5)	299 (18.0)	625 (24.3)	849 (33.7)
Oesophagectomy	301 (19.0)	258 (15.5)	474 (18.4)	422 (16.7)
Fundoplication	273 (17.2)	297 (17.9)	450 (17.5)	346 (13.7)
Gastrojejunostomy	117 (7.4)	119 (7.2)	185 (7.2)	161 (6.4)

Numbers are shown in pre-implementation period (January 1, 2014 to December 31, 2015) and implementation period (January 1, 2017 to December 31, 2018), for each group (intervention and control hospitals). Numbers may not sum to 100 because of rounding.

**Table S4. Comparison of Surgical Outcomes between Hospital Groups in Conventional and Ambulatory Surgery**

Surgical Outcomes	Intervention Hospitals			Control Hospitals			Intervention vs Control Hospitals		
	Pre-implementation (n=47 515)	Implementation (n=51 236)	Implementation vs Pre-implementation	Pre-implementation (n=50 503)	Implementation (n=51 941)	Implementation vs Pre-implementation	Adjusted Ratio of Odds Ratio (95% CI)	P Value	Intraclass correlation coefficient
	No. (%)	No. (%)	Adjusted Odds Ratio (95% CI)	No. (%)	No. (%)	Adjusted Odds Ratio (95% CI)			
<b>Major adverse event<sup>a</sup></b>	4136 (8.7)	4238 (8.3)	0.95 (0.90 to 1.00)	4641 (9.2)	4749 (9.1)	1.07 (1.02 to 1.12)	0.89 (0.82 to 0.95)	<0.001	0.032
<b>Death</b>	585 (1.2)	531 (1.0)	0.85 (0.75 to 0.96)	648 (1.3)	650 (1.3)	1.01 (0.90 to 1.13)	0.84 (0.71 to 0.99)	0.04	0.027
<b>Intensive care stay</b>	2158 (4.5)	2091 (4.1)	0.89 (0.82 to 0.95)	2326 (4.6)	2274 (4.4)	1.04 (0.97 to 1.12)	0.85 (0.77 to 0.94)	0.002	0.148
<b>Reoperation</b>	1632 (3.4)	1736 (3.4)	0.98 (0.91 to 1.05)	1864 (3.7)	2028 (3.9)	1.10 (1.03 to 1.17)	0.89 (0.81 to 0.98)	0.02	0.025
<b>Severe complication</b>	1479 (3.1)	1631 (3.2)	1.03 (0.96 to 1.11)	1702 (3.4)	1838 (3.5)	1.08 (1.00 to 1.15)	0.96 (0.86 to 1.06)	0.43	0.017

A total of 201 195 patients were included in the analysis. Odds ratios were estimated using mixed-effect logistic regression models to compare surgical outcomes between pre-implementation and implementation periods in intervention and control hospitals, respectively. Ratio of odds ratios (ROR) captured the control chart impact by comparing the change in outcomes from pre-implementation to implementation periods between the intervention and control hospitals, based on a difference-in-difference approach. A ROR value less than unity indicated improvement caused by control charts in intervention versus control hospitals. Estimates with corresponding 95% confidence interval (95% CI) considered clustering of patients at the hospital level. Outcomes were adjusted for a risk score that considered age, sex, presence of comorbidities, emergency admission, date and operative procedure, main diagnosis, surgical procedure complexity, median household income for patient-level covariates, and status for hospital-level covariates.

<sup>a</sup> Major adverse event was a composite of surgical complications occurring at any hospital within 30 days following the surgical procedure inspired by Clavien-Dindo classification, including patient death, intensive care stay (at least 2 nights in intensive care or 5 nights in critical care), reoperation (open or laparoscopic digestive tract procedure), or severe complication (cardiac arrest, pulmonary embolism, sepsis, or surgical site infection).

**Table S5. Comparison of Surgical Outcomes by Hospital Group including Patients with Missing Household Income**

Surgical Outcomes	No. (%) in Intervention Hospitals		No. (%) in Control Hospitals		Intervention vs Control Hospitals		
	Pre-implementation (n=37 783)	Implementation (n=37 665)	Pre-implementation (n=41 737)	Implementation (n=38 948)	Adjusted Ratio of Odds Ratio (95% CI)	P Value	Intraclass correlation coefficient
<b>Major adverse event<sup>a</sup></b>	4103 (10.9)	4186 (11.1)	4611 (11.0)	4675 (12.0)	0.89 (0.83 to 0.96)	0.002	0.033
<b>Death</b>	589 (1.6)	532 (1.4)	649 (1.6)	655 (1.7)	0.83 (0.70 to 0.99)	0.03	0.029
<b>Intensive care stay</b>	2159 (5.7)	2095 (5.6)	2336 (5.6)	2283 (5.9)	0.85 (0.77 to 0.94)	0.001	0.151
<b>Reoperation</b>	1592 (4.2)	1689 (4.5)	1830 (4.4)	1957 (5.0)	0.91 (0.82 to 1.00)	0.05	0.026
<b>Severe complication</b>	1477 (3.9)	1620 (4.3)	1700 (4.1)	1822 (4.7)	0.96 (0.87 to 1.07)	0.44	0.017

A total of 156 133 patients were included in the analysis. Missing household incomes for 771 patients were imputed by the mean household income of patients with available household income in the same hospital group (Intervention/Control) and period (Pre-implementation/Implementation). Using mixed-effect logistic regression models, ratio of odds ratios (ROR) captured the control chart impact by comparing the change in outcomes from pre-implementation to implementation periods between the intervention and control hospitals, based on a difference-in-differences approach. A ROR value less than unity indicated improvement caused by control charts in intervention versus control hospitals. Estimates with corresponding 95% confidence interval (95% CI) considered clustering of patients at the hospital level. Outcomes were adjusted for a risk score that considered age, sex, presence of comorbidities, emergency admission, date and operative procedure, main diagnosis, surgical procedure complexity, median household income for patient-level covariates, and status for hospital-level covariates.

<sup>a</sup> Major adverse event was a composite of surgical complications occurring at any hospital within 30 days following the surgical procedure inspired by Clavien-Dindo classification, including patient death, intensive care stay (at least 2 nights in intensive care or 5 nights in critical care), reoperation (open or laparoscopic digestive tract procedure), or severe complication (cardiac arrest, pulmonary embolism, sepsis, or surgical site infection).

**Table S6. Estimated Absolute Risk Differences and Number Needed to Treat**

	Intervention Hospitals	Control Hospitals	Intervention minus Control Hospitals	
	Implementation minus Pre-implementation			
Surgical Outcomes	Absolute Risk Difference, % (95% CI)		Difference of Absolute Risk Differences, % (95% CI)	
			Number Needed to Treat (95% CI) <sup>a</sup>	
Major adverse events <sup>b</sup>	-0.4 (-0.8 to 0.0)	0.5 (0.2 to 0.9)	-0.9 (-1.4 to -0.4)	114 (70 to 280)
Death	-0.2 (-0.4 to -0.1)	0.0 (-0.2 to 0.2)	-0.2 (-0.5 to 0.0)	435 (-895 to 2071)
Intensive care stay	-0.4 (-0.7 to -0.2)	0.2 (-0.1 to 0.4)	-0.6 (-1.0 to -0.3)	161 (102 to 371)
Reoperation	-0.0 (-0.3 to 0.3)	0.4 (0.1 to 0.6)	-0.4 (-0.8 to -0.0)	263 (104 to 1701)
Severe complications	0.1 (-0.2 to 0.4)	0.3 (0.0 to 0.5)	-0.2 (-0.5 to 0.2)	667 (-4421 to 8684)

CI, confidence interval

<sup>a</sup> The number needed to treat was calculated by dividing -1 by the difference of the absolute risk difference, which was derived from mixed-effect logistic regression models and marginal standardisation method comparing surgical outcomes between the pre-implementation and implementation periods in the intervention and control hospitals. Corresponding 95% CI were computed from non-parametric bootstrap based on 1000 replicates. Marginal standardised risks of outcomes in each hospital groups and periods are shown in Figure S3.

<sup>b</sup> Major adverse events was a composite of surgical complications occurring at any hospital within 30 days following the surgical procedure inspired by Clavien-Dindo classification, including patient death, intensive care stay (at least 2 nights in intensive care or 5 nights in critical care), reoperation (open or laparoscopic digestive tract procedure), or severe complication (cardiac arrest, pulmonary embolism, sepsis, or surgical site infection).

**Table S7. Estimated Relative Risk Differences and Major Adverse Events Avoided**

	Intervention Hospitals	Control Hospitals	Intervention minus Control Hospitals	20 Intervention Hospitals in 2017-2018 (Implementation Period)	134 French Eligible Hospitals in 2018		
	Implementation minus Pre-implementation						
Surgical Outcomes	Relative Risk Difference, % (95% CI)		Difference of Relative Risk Difference, % (95% CI)	No. of observed cases	No. of avoided cases (95% CI) <sup>a</sup>	No. of observed cases	No. of avoidable cases (95% CI) <sup>a</sup>
Major adverse events <sup>b</sup>	-3.3 (-6.9 to 0.2)	4.9 (1.5 to 8.4)	-8.1 (-13.2 to -3.2)	4163	362 (141 to 573)	12 264	981 (394 to 1515)
Death	-14.1 (-22.9 to -3.2)	0.8 (-8.9 to 11.9)	-14.9 (-28.8 to -0.4)	528	93 (2 to 183)	1705	256 (7 to 450)
Intensive care stay	-8.3 (-12.9 to -3.3)	3.8 (-1.0 to 9.1)	-12.0 (-19.1 to -5.3)	2080	284 (117 to 442)	5877	705 (309 to 1047)
Reoperation	-0.1 (-6.7 to 6.7)	9.1 (2.6 to 15.7)	-9.2 (-18.9 to -0.1)	1682	146 (1 to 328)	5057	405 (2 to 855)
Severe complications	3.4 (-3.7 to 10.9)	7.0 (0.1 to 13.5)	-3.6 (-12.7 to 6.5)	1610	67 (-99 to 201)	4807	192 (-303 to 548)

CI, confidence interval

<sup>a</sup> The number of avoided cases among patients operated in intervention hospitals during the implementation period and the number of avoidable cases in hospitals eligible for Shewhart study (Figure 2) were estimated from the difference of relative risks difference derived from mixed-effect logistic regression models and marginal standardisation method comparing surgical outcomes between the pre-implementation and implementation periods in the intervention and control hospitals. Corresponding 95% CI were computed from non-parametric bootstrap based on 1000 replicates. Marginal standardised risks of outcomes in each hospital groups and periods are shown in Figure S3.

<sup>b</sup> Major adverse events was a composite of surgical complications occurring at any hospital within 30 days following the surgical procedure inspired by Clavien-Dindo classification, including patient death, intensive care stay (at least 2 nights in intensive care or 5 nights in critical care), reoperation (open or laparoscopic digestive tract procedure), or severe complication (cardiac arrest, pulmonary embolism, sepsis, or surgical site infection).

Figure S1. Geographic Location of Participating Hospitals

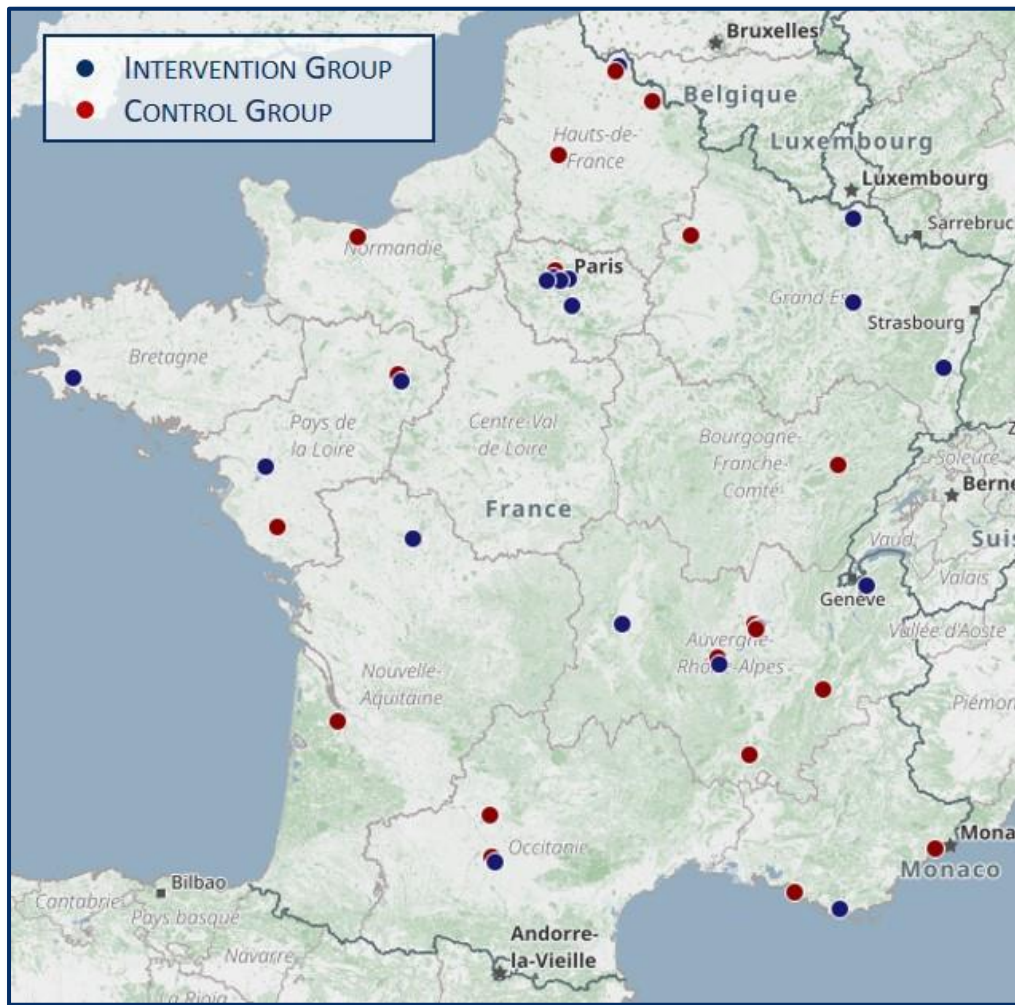
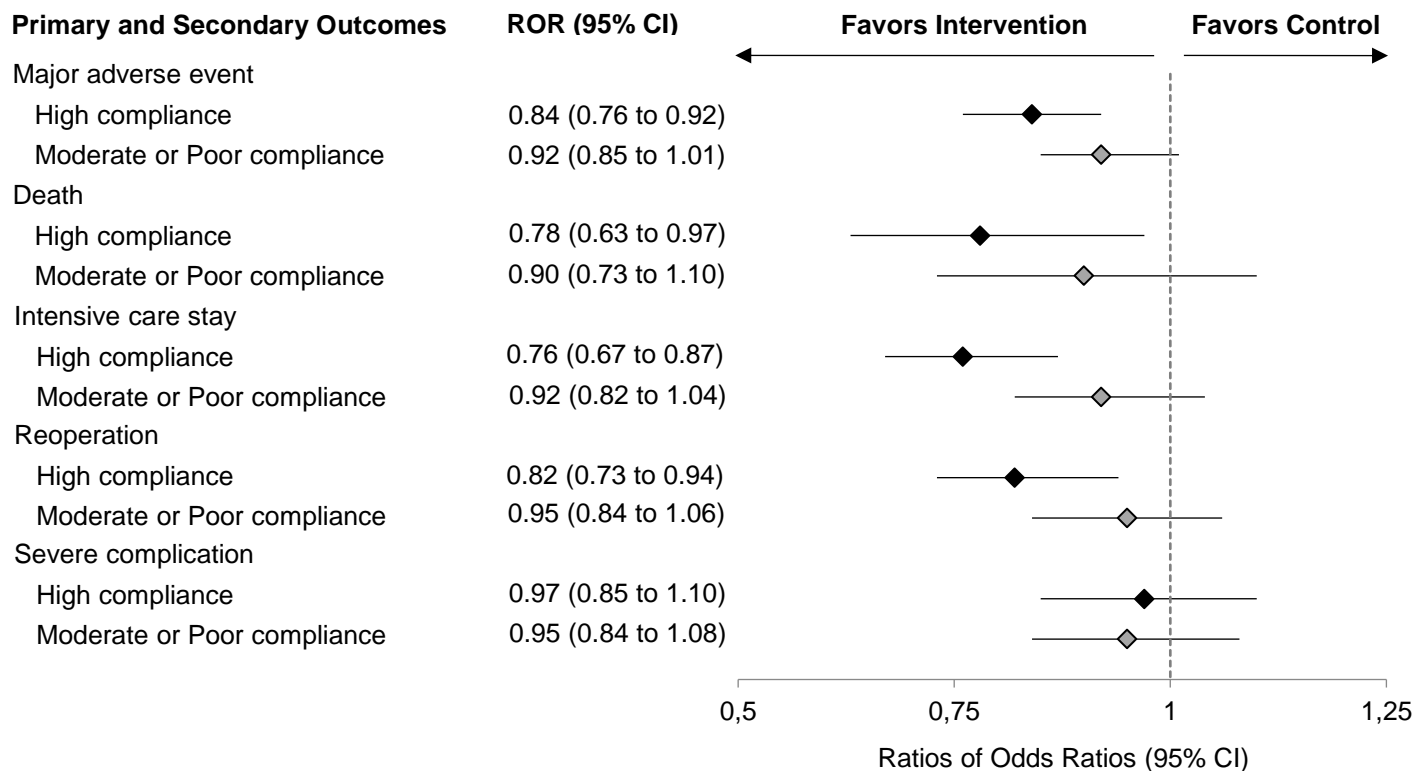


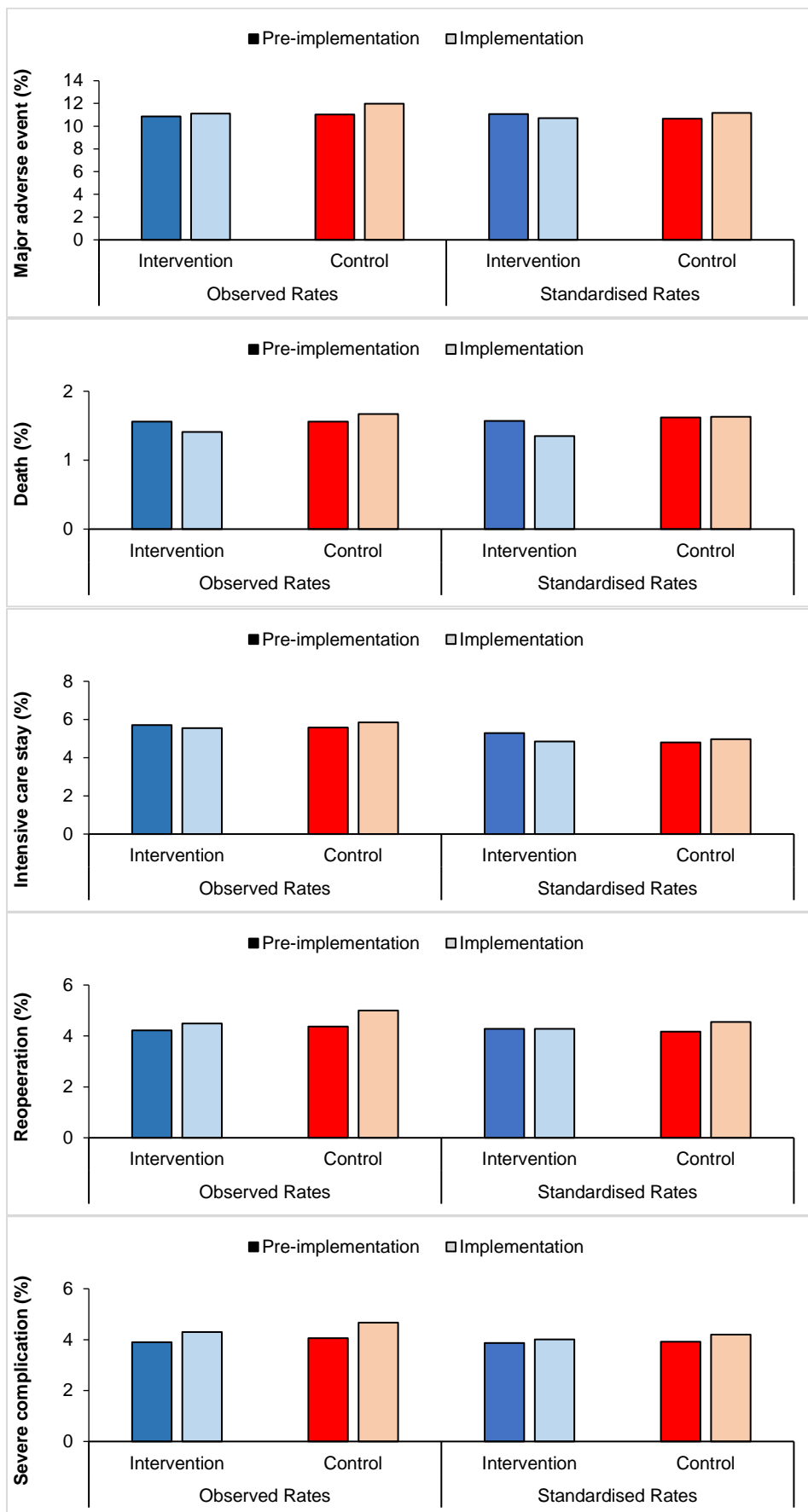
Figure S2. Surgical Outcomes by Control Chart Implementation in Conventional and Ambulatory Surgery



201 195 patients were included in the analysis. Hospitals were regarded as highly compliant for control chart utilization with an implementation score of 5 to 6, moderately compliant with a score of 3 to 4, and poorly compliant with a score of 2. Ratio of odds ratios (ROR) captured the control chart impact by comparing the change in outcomes from the pre-implementation to implementation period between the highly compliant intervention hospitals and the control hospitals (black diamonds), and between the moderate to poor compliance intervention hospitals and the control hospitals (grey diamonds). A ROR value less than unity indicated an improvement caused by control chart use in the intervention hospitals (high compliance or moderate-to-poor compliance) compared to control hospitals. Bars denote 95% confidence intervals (95% CI) that considered patient clustering at the hospital level. Outcomes were adjusted for a risk score that considered age, sex, presence of comorbidities, emergency admission, date and operative procedure, main diagnosis, surgical procedure complexity, median household income regarding patient-level covariates, and status for hospital-level covariates. Major adverse event was a composite of surgical complications occurring at any hospital within 30 days following surgical procedure inspired by Clavien-Dindo classification, including patient death, intensive care stay (at least 2 nights in intensive care or 5 nights in critical care), reoperation (open or laparoscopic digestive tract procedure) or severe complication (cardiac arrest, pulmonary embolism, sepsis, or surgical site infection).

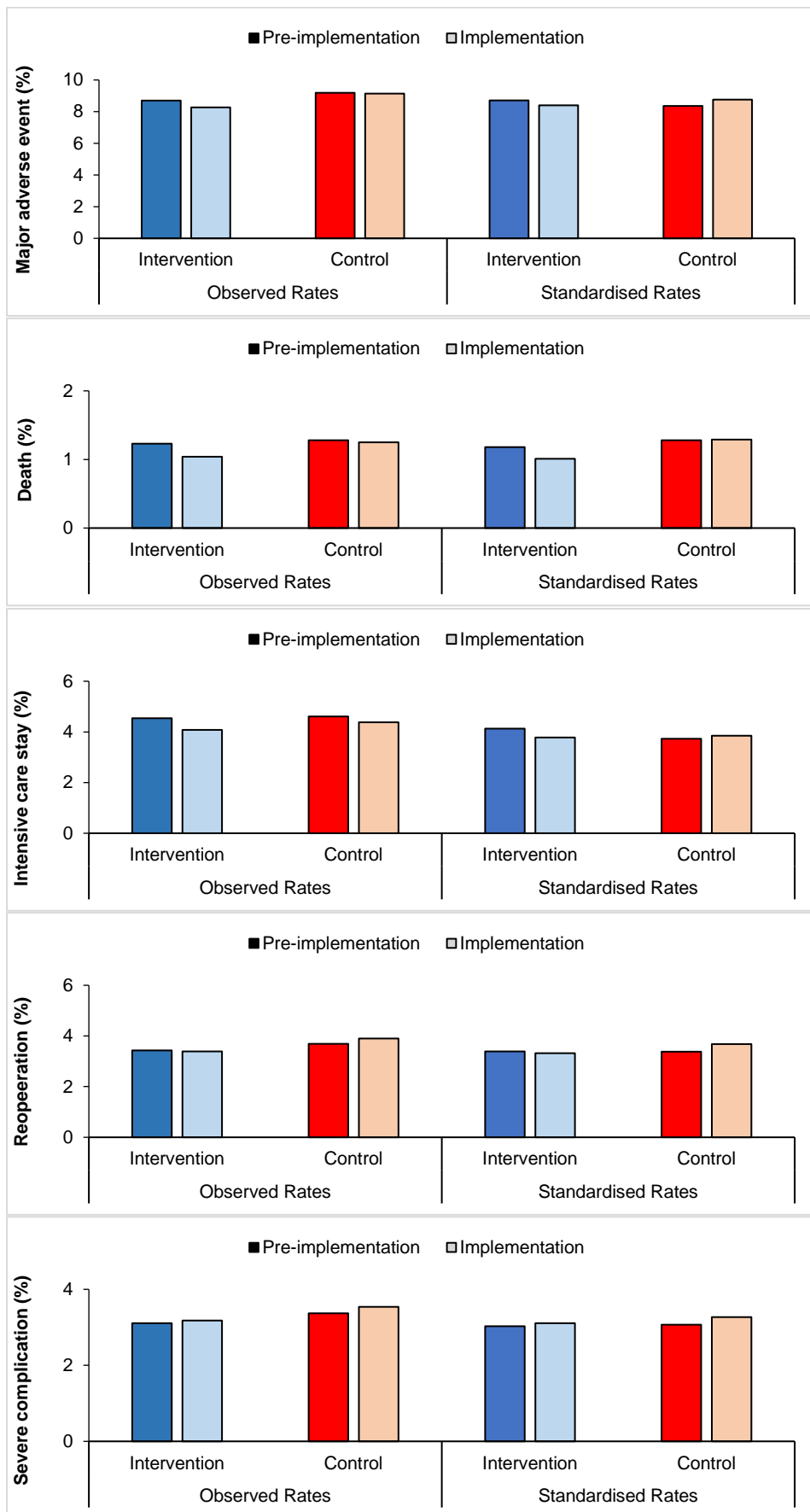


Figure S3. Surgical Outcomes Rates by Study Group and Period in Conventional Surgery



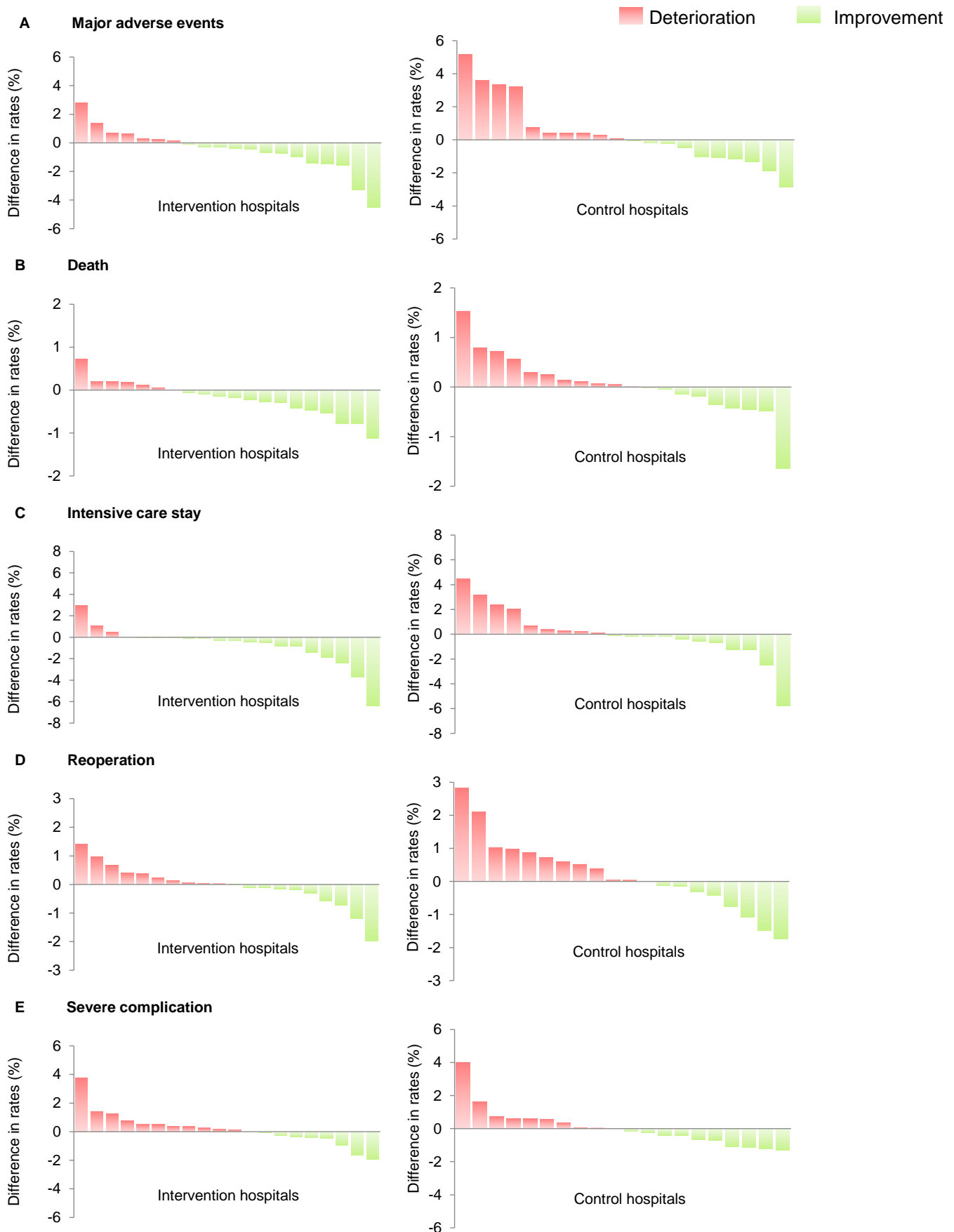
155 362 patients were included in the analysis. Using estimated parameters obtained from mixed-effect logistic regression models and marginal standardisation method, we determined marginal standardised risks of outcomes in each hospital groups and periods.

**Figure S4. Surgical Outcomes Rates by Study Group and Period in Conventional and Ambulatory Surgery**



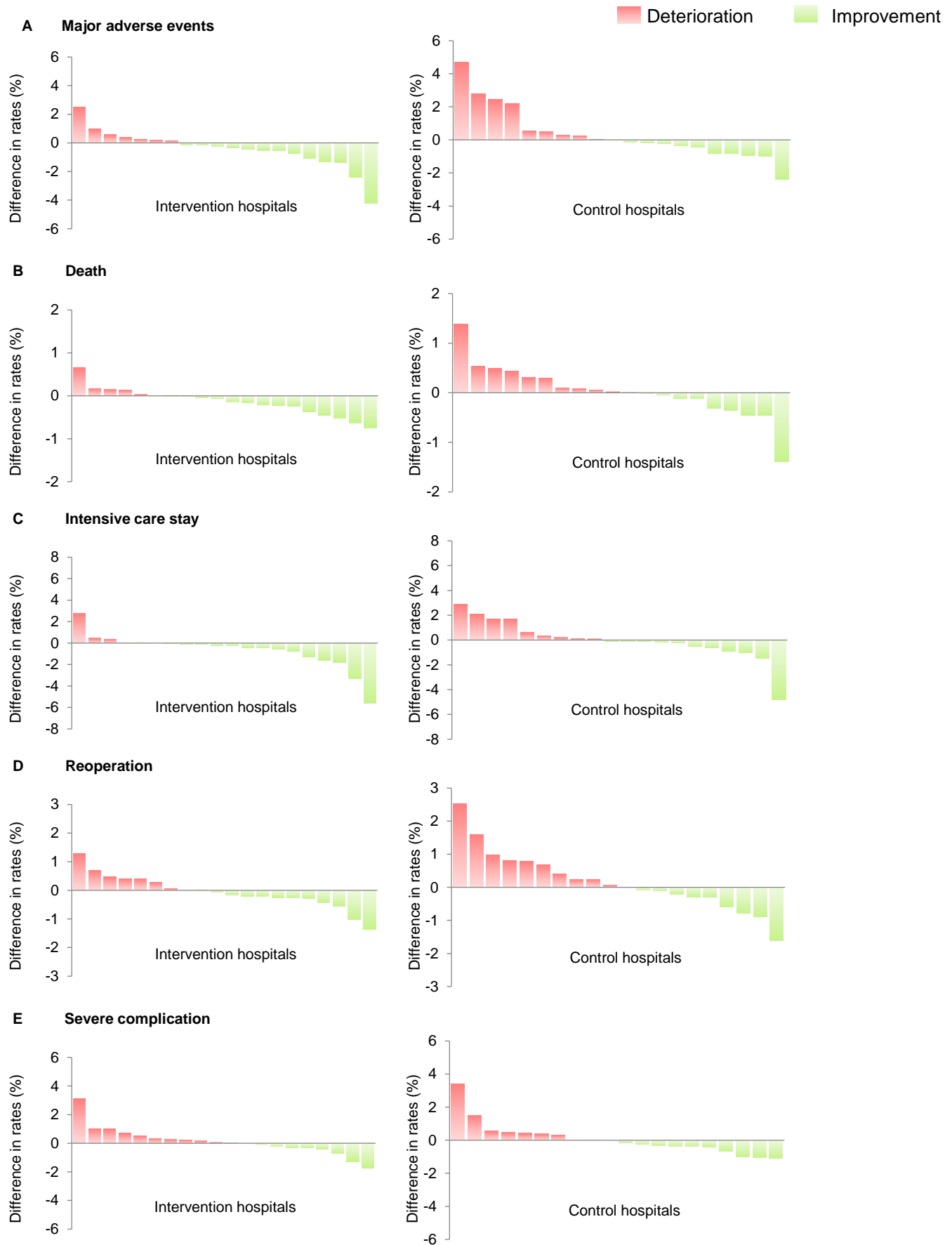
201 195 patients were included in the analysis. Using estimated parameters obtained from mixed-effect logistic regression models and marginal standardisation method, we determined marginal standardised risks of outcomes in each hospital groups and periods.

**Figure S5. Difference in Standardised Rates of Major Adverse Events from Pre-implementation Period to Implementation Period by Hospital in Conventional Surgery**



155 362 patients were included in the analysis. Standardised rates of primary and secondary outcomes per hospital were calculated for each hospital according to the formula = (observed hospital rates ÷ expected hospital rates) × average observed hospitals rates over pre-implementation and implementation periods. Expected hospital rates were calculated for each hospital, using the expected number of events corresponding to the sum of the patients' risk scores operated in the hospital.

**Figure S6. Difference in Standardised Rates of Major Adverse Events from Pre-implementation Period to Implementation Period by Hospital in Conventional and Ambulatory Surgery**



201 195 patients were included in the analysis. Standardised rates of primary and secondary outcomes per hospital were calculated for each hospital according to the formula = (observed hospital rates ÷ expected hospital rates) × average observed hospitals rates over pre-implementation and implementation periods. Expected hospital rates were calculated for each hospital, using the expected number of events corresponding to the sum of the patients' risk scores operated in the hospital.