Published in final edited form as:

Surgery. 2016 August ; 160(2): 359–365. doi:10.1016/j.surg.2016.04.035.

Colon Cancer Surgery at High and Low Mortality Hospitals

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Abstract

Introduction—There is wide variation in mortality across hospitals for cancer surgery. While higher rates of mortality are commonly ascribed to high-risk resections, the impact on more common operations is unclear. We sought to evaluate causes of mortality following colon cancer operations across hospitals.

Methods—49 American College of Surgeons Commission on Cancer (ACS-CoC) hospitals were selected for participation in a CoC special study. We ranked hospitals using a composite measure of mortality and performed onsite chart reviews. We examined patient characteristics and mortality following colon resections at very high mortality (HMH) and very low mortality (LMH) hospitals (2006–2007).

Results—We identified 3,025 patients who underwent surgery at 19 LMHs (n = 1,006) and 30 HMHs (n = 2,019). There were wide differences in risk-adjusted mortality between HMHs and LMHs (9.3% vs. 2.4%; $P < 0.001$). Compared to LMHs, HMHs had more patients who were black (11.2% vs. 6.5%; $P < 0.001$), had 2 comorbidities (22.7% vs. 18.9%; $P < 0.05$), ASA class 4–5 (11.9% vs. 5.3%; $P < 0.001$), and were functionally dependent (13.9% vs. 8.8%; $P < 0.001$). Rates of any complication were similar in HMH's vs. LMH's (OR 1.29, 95% CI: 0.85 – 1.95). But, for those experiencing complications, case fatality rates were statistically significantly higher in HMHs vs. LMHs (OR 3.74, 95% CI: 1.59 – 8.82).

Conclusions—There is significant variation in mortality across hospitals for colon cancer surgery, despite similar perioperative morbidity. This finding reflects a need for improved surgical decision-making to enhance outcomes and quality of care at these hospitals.

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DISCLOSURES: Dr. Birkmeyer is a founder and has equity interest in ArborMetrix Inc., a software and analytics company focused on assessing hospital quality and costs. All other authors report no financial conflicts of interest.

PREVIOUS PRESENTATION: This work was accepted as an oral presentation at the 11th Annual Academic Surgical Congress, Jacksonville, FL, USA, February 2–4, 2016.

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Keywords

Colorectal neoplasms; colorectal surgery; neoplasm metastasis; hospitals; clinical decision-making

Introduction

Major resections for complex and rare malignant neoplasms are associated with considerable risk for morbidity and mortality.^{1–3} There are many reasons for this. First, these are complex operations requiring advanced technical skills that are perhaps more consistently maintained by some surgeons with higher operative volume.³ Second, this may be related to better perioperative care resources in some hospitals.^{4,5} In other words, hospitals that are accustomed to caring for sick and complex cancer patients may be better equipped with resources for success.

While higher rates of mortality are commonly ascribed to these resections, causes for variation in colon cancer resections, which are much more common operations, is unclear. Specifically, in comparing hospitals with high mortality rates (HMH's) to those with low mortality rates (LMH's), it is possible that higher complication rates occur at HMH's with LMH's potentially being better at preventing complications. This would suggest that variation in complication rates drives differences in mortality. To remedy this, quality improvement efforts would need to be aimed at targeting compliance with evidence-based practices aimed at preventing complications or efforts at improving technical proficiency for surgeons at HMH's.⁶ Conversely, LMH's may be better at recognizing and treating complications once they occur, and thus these hospitals have lower rates of failure to rescue.⁷ If this is the case, then quality improvement efforts should focus on ways to effectively recognize and manage complications when they occur. Thus, a better understanding of the reasons for differences in mortality can help to guide surgical quality improvement efforts.

We sought to evaluate causes of mortality following colon cancer operations across high and low mortality hospitals. Through a deeper understanding of differences between hospitals and associations with morbidity and mortality, variation in hospital performance may be better understood. In this context, we examined perioperative care practices and outcomes in patients who underwent colon cancer resection at LMH's and HMH's.

Material and methods

Data Source and Study Population

The National Cancer Data Base (NCDB) Participant User File (PUF) is a joint project of the American College of Surgeons Commission on Cancer (CoC) and the American Cancer Society. Data represent nearly 70% of all newly diagnosed patients with cancer from greater than 1,500 CoC-accredited hospitals in the United States. Data are collected using standardized coding schemata and have been described previously.^{8,9}

We used hospital mortality and patient data to construct a composite measure of adjusted mortality and subsequently ranked all hospitals in our data set using this methodology. We

then subsequently selected those hospitals at the highest and lowest ends of predict mortality composite score for further analysis. Using this technique, we ranked the 1,279 hospitals that participated in the NCDB from January 1, 2005, through December 31, 2006. The composite measure used was derived from procedural volumes and mortality rates of major cancer resections according to previously described methods.^{10–15} In brief, we used an empirical Bayesian approach to calculate hospital-specific predictive mortality rates, which provide the best estimate of a hospital's mortality rate. Next, we enrolled hospitals as HMM's beginning with the institution with the highest predicted mortality rate and LMH's starting with the institution with the lowest predicted mortality rate until we reached the necessary sample size, based on pre hoc sample size calculations. Because low-mortality hospitals tend to be larger, higher volume hospitals, high-mortality hospitals were oversampled to achieve a roughly similar number of patients in both groups of hospitals. Of the 41 hospitals with the lowest mortality rates, 22 declined to participate. As a result, we included 19 LMH's in this study. Of the 77 hospitals identified as HMM's, we enrolled 30, all of which were included in this analysis. After data abstraction, 19 LMH's and 30 HMM's were included in the analysis. The study was approved by the University of Michigan Institutional Review Board.

On-site medical record reviews of patients at participating institutions from January 1, 2006, through December 31, 2007, were conducted by trained data abstractors. Of the hospitals with 150 or fewer patients, all records were abstracted. In hospitals with more than 150 patients, a random sample of up to 150 records were selected for review. After excluding patients with incomplete medical records for data abstraction, 3,025 patients with colon cancer were included in the study, with 1,006 patients treated in LMHs and 2,019 treated in HMMs.

Investigators were masked to the performance status of all centers. We collected information on perioperative complications using a previously validated data collection tool.¹⁶ The occurrence of distinct complication events were captured and categorized according to surgical (e.g., anastomotic leak or reoperation) and medical (e.g., cardiac or pulmonary) complications. Patient-level data were collected on eleven clinical practices that were related to perioperative processes of care. Seven of the eleven practices focused on processes related to the prevention of complications, including three related to venous thromboembolism (VTE), three related to surgical site infection, and one related to perioperative cardiac events. In addition, we collected four variables related to perioperative pain control (use of epidural catheter) and hemodynamic monitoring (arterial catheter, central venous catheter, and pulmonary artery catheter use).

Statistical Analysis

We compared complication rates, case fatality rates in patients who developed complications (failure to rescue rates), and perioperative practice patterns regarding processes of care between LMH's and HMM's. In determining complication rates, hierarchical logistic regression models were used to compare risk-adjusted complication rates between hospitals. The model included adjustment for age, sex, race, American Society of Anesthesiologists Physical Status classification, comorbid conditions, functional status, cancer stage, and

emergency surgery.¹⁷ Of note, functionally dependent patients in general were thought to have a higher preoperative risk of postoperative complications than functionally independent patients. Therefore, we adjusted for functional dependence in our models, as our goal was to attenuate differences in preoperative risk as much as possible. We used analogous methods to estimate failure to rescue rates between the two hospital groups.

To examine practice patterns, we report adherence rates of processes of care by hospital performance status (HMH's vs. LMH's) using Pearson's χ^2 test for categorical variables and Student's *t*-test for continuous variables. To examine the effect of various factors on complication rates, we calculated aORs using multi-level mixed effects logistic regression with random intercepts to account for hospital-level fixed effects. Analyses were conducted using SAS, version 9.1 (SAS Institute Inc., Cary, NC), and Stata, version 13 (StataCorp L.P., College Station, TX). All tests are 2-sided with significance set at a *P* value of less than 0.05.

Results

Patients who underwent colon cancer resection at HMH's presented with greater illness severity compared with those who were treated at LMH's (Table 1). Both hospital groups had patients with a similar mean (SD) age (HMH's, 69.8 [13.2] years vs. LMH's, 70.0 [12.8] years; *P*=0.772). However, a greater proportion of patients at HMH's had poorer functional status compared with patients at LMH's (280 [14.5%] vs. 89 [9.1%]; *P*<0.001). Patients who were treated at HMH's were more likely to have more than 2 comorbid conditions (459 [22.7%] vs. 190 [18.9%]; *P*<0.05). More specifically, there was a significantly higher proportion of patients with congestive heart failure (188 [9.4%] vs. 67 [7.0%]; *P*<0.05), mean (SD) BMI (28.1 [6.3] vs. 27.2 [5.4]; *P*<0.001), lower mean (SD) albumin level (3.45 [0.8] vs. 3.61 [0.8]; *P*<0.001), lower mean (SD) hematocrit percent (34.0 [6.9] vs. 34.7 [6.6]; *P*<0.01) and higher mean (SD) platelet counts (292.0 [2.4] vs. 283.8 [3.2]; *P*<0.05). Patients who were treated at HMH's had a similar distribution of cancer stage compared with those who underwent resection at LMH's (*P*=0.735). After risk adjustment, mortality rates were still considerably different (9.3% vs. 2.4%; *P*<0.001).

Across both hospital groups, we observed differences in operative approach (Table 2). Patients were more likely to undergo an open approach rather than a laparoscopic approach at an HMH vs. a LMH (1,535 [76.0%] vs. 679 [67.5%]; *P*<0.001).

Process adherence rates were higher for some measures in HMH's and higher for other measures in LMH's. Rates of neoadjuvant chemotherapy were low overall, but lower at HMH's vs. LMH's (15 [0.7%] vs. 20 [2.0%]; *P*=0.005). HMH's were less likely to use epidural catheters for postoperative pain (18 [0.9%] vs. 20 [2.0%]; *P*<0.05). When evaluating the use of central venous catheters, pulmonary artery catheters, and arterial catheters, HMH's were less likely to use these (476 [23.6%]) compared with LMH's (481 [47.8%]; *P*<0.001). With regard to receipt of antibiotics before incision, HMH's had higher compliance (1,859 [92.1%] vs. 911 [90.6%]; *P*<0.05). But, HMH's also had higher rates of antibiotics continuing greater than 24 hours after surgery (1,236 [61.2%] vs. 462 [45.9%]; *P*<0.001). HMH's had higher rates of recorded glucose on postoperative day 1 (1,770 [87.7%] vs. 847 [84.2%]; *P*<0.01) and use of hyperglycemia management protocols (576

[28.5%] vs. 279 [27.7%]; $P<0.001$). In terms of cardiovascular protective measures, HMH's were less likely to use perioperative β -blockers (417 [20.7%] vs. 278 [27.6%]; $P<0.001$). HMH's were much less likely to use VTE chemoprophylaxis or SCD's preoperatively (1,387 [68.7%] vs. 833 [82.8%]; $P<0.001$) and postoperatively (1,540 [76.3%] vs. 896 [89.1%]; $P<0.001$). Use of mechanical bowel preparation was higher in HMH's (1,334 [66.1%] vs. 626 [62.2%]; $P<0.001$).

As shown in Figure 1, overall complication rate was not statistically significantly different between HMH's and LMH's (20.8% vs. 13.3%; aOR for HMH's: 1.29; 95% CI, 0.85–1.95). However, despite similar adjusted odds of complication incidence, odds of fatality following complication (failure to rescue) were much higher in HMH's (31.2% vs. 15.7%; aOR for HMH's: 3.74; 95% CI, 1.59 – 8.82).

These results were stratified by complication type, and this is displayed in Table 3. There were no significant differences in the adjusted odds of experiencing surgical complications (aOR, 1.25; 95% CI, 0.73 – 2.15) when comparing HMH's and LMH's. For these complications, there was a higher rate of failure to rescue (22.7% vs. 10.2%) in HMH's, but this difference was not statistically significant (aOR, 3.22; 95% CI, 0.63 – 16.50). High-mortality hospitals also had a higher rate of medical complications (16.1% vs. 10.1%); however, this difference was not statistically significant (aOR, 1.26; 95% CI, 0.84 – 1.89) when comparing the two hospital groups. Rates of failure to rescue for medical complications were higher in HMH's (37.9% vs. 19.6%) and this difference was statistically significant (aOR, 4.49; 95% CI, 1.74 – 11.61).

Sensitivity Analyses

Due to high rates of pulmonary complications, we performed sensitivity analyses, adding preoperative dyspnea, a possible proxy for preoperative pulmonary status, to our models. Preoperative dyspnea was associated with higher adjusted odds of any complication (aOR 1.48, 95% CI: 1.13 – 1.94, $P=0.005$), but no difference in odds of death when a complication occurs (aOR 1.15, 95% CI: 0.63 – 2.09, $P=0.657$). It was also associated with increased odds of a medical complication (aOR, 1.45, 95% CI: 1.08 – 1.9, $P<0.05$) but not odds of death for those with medical complications (aOR, 1.11, 95% CI: 0.58 – 2.15). Finally, there was not a statistically significant association between preoperative dyspnea and postoperative surgical complications (aOR, 1.29, 95% CI: 0.87 – 1.90, $P=0.199$) or death in patients with surgical complications (aOR, 1.15, 95% CI: 0.34 – 3.88, $P=0.823$).

While we were unable to assess detailed systemic and structural factors around ICU's at these hospitals, we were able to perform an analysis of ICU utilization in these hospitals. We found that adjusted odds of ICU admission was actually higher in HMH's (aOR, 1.45, 95% CI: 1.05 – 2.02, $P<0.05$) controlling for patient factors and whether or not a complication occurred.

Discussion

This study examined variation in perioperative mortality rates following colon cancer resection in a sample of hospitals with very high and very low mortality rates. Our study

found no statistically significant differences in rates of overall, surgical or medical complications between HMH's and LMH's. However, we identified significant differences in case fatality rates with complications, or failure to rescue.

These findings have two main implications for surgical quality improvement. First, it appears that higher rates of mortality are not driven by variation in complication rates. Thus, it does not seem that efforts aimed at targeting compliance with evidence-based practices aimed at preventing complications would effectively attenuate this variation for colon cancer resections. Second, it instead appears that LMH's are better at recognizing and treating complications once they occur, and thus these hospitals have lower rates of failure to rescue. This suggests that quality improvement efforts should focus on ways to effectively recognize and manage complications when they occur.

The results of this study contribute to the growing body of literature demonstrating that failure to rescue is an important component of variation in surgical mortality.^{7,18,19} Additionally, a nationwide study in Denmark has previously demonstrated variation in mortality after colorectal cancer surgery that is related to the ability of hospitals to care for emergency patients and those with high ASA classification.²⁰ While there is substantial evidence regarding identification of failure to rescue, there is much less evidence regarding ways to improve recognition and treatment of complications once they occur. Previous work has identified several hospital characteristics that influence failure to rescue rates and quality, including nurse to patient ratios.²¹ It is now becoming more clear that increased attention to the role of organizational dynamics within hospitals can contribute to improved rates of rescue and patient safety.²² However, a better understanding of the factors related to perioperative complications and their subsequence management is still needed to optimize attenuation of variation in mortality across hospitals.

The current study has several limitations. First, this is a large observational study using registry-based patient-level data. Inherent in this is a lack of granularity as to decision-making and patient-level factors that may guide decisions beyond those that were measured in our data. Additionally, by going beyond just using secondary data in our analysis, we were limited to those hospitals that chose to participate in our study. The hospitals that did not participate may or may not have had the same trends in processes of care or failure to rescue. However for the hospitals that did choose to participate, the added granularity of on-site chart reviews makes these results more reliable. Second, this study occurred only in accredited American College of Surgeons Commission on Cancer (CoC) hospitals. Thus, this is not a random sample of hospitals performing colon cancer resections in the United States. However, over 1,500 accredited cancer care programs report data to the NCDB, representing over 70% of newly diagnosed cancer cases in the United States.⁸ Moreover, even in these hospitals, which may generally be more committed to participating in quality improvement initiatives, there is still wide variation in mortality following colon cancer resection, indicating opportunities for improvement. Third, not every postoperative mortality should necessarily be attributed to hospital of death. In fact, many patients with surgical emergencies who are at high risk are transferred to tertiary referral centers, and then they may potentially receive more aggressive care. Appropriate transferring and accepting of patients is another important aspect of surgical practice, with a need for further study

regarding what disincentives or incentives hospitals should have for accepting transfers of critically ill patients. Finally, we were unable to assess or disclose detailed characteristics of HMH's and LMH's aside from unadjusted and adjusted mortality rates and patient factors. However, we have shown that HMH's have a higher burden of patients with more comorbidities. Additionally, previous work has identified several hospital characteristics that contribute to failure to rescue, which we observed more in HMH's.²¹ These included non-teaching status, hospital size less than 200 beds, average daily census 50% capacity, decreased nurse-to-patient ratios and lack of high hospital technology.

An additional striking finding was that our results with regard to racial disparities were very pronounced. Black patients were much more likely to be treated at high mortality hospitals. Previous work has demonstrated the presence of both a higher proportion of black patients receiving care at different hospitals than white patients (segregation) and differences in treatments used (possibly due to implicit bias, differences in disease severity at presentation or patient preference).^{23,24} While we cannot entirely unpack the causes of this, our results do show a higher proportion of black patients receiving care at different hospitals than white patients, and that these hospitals in general are much higher mortality hospitals.

Conclusions

We have shown that, in colon cancer resections, variation in mortality across hospitals appears to be driven by a higher case fatality rate from complication in high mortality hospitals. This suggests that high mortality hospitals have higher rates of failure to rescue. High mortality hospitals should focus quality improvement efforts on ways to better recognize and treat complications once they occur.

Acknowledgments

Dr. Healy is supported by the National Institutes of Health (grant T32CA009672-25), Dr. Grenda was supported by Agency for Healthcare Research and Quality grant T32HS000053, and Dr. Wong was supported by the Association for Healthcare Research and Quality (grant AHRQ1K08 HS20937-01) and the American Cancer Society (grant RSG-12-269-01-CPHPS).

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Synopsis

We sought to evaluate causes of mortality following colon cancer operations across hospitals. There is significant variation in mortality across hospitals for colon cancer surgery despite similar rates of perioperative morbidity, suggesting a need for improved recognition and treatment of complications when they occur at high mortality hospitals.

Figure 1. Incidence of Complications and Subsequent case Fatality Rates for Colon Cancer Resections at LMH's and HMM's. Results control for age, sex, race, American Society of Anesthesiologists Physical Status classification, comorbidities, functional status, cancer stage and whether the case was an emergency case.

Table 1

Characteristics of patient who underwent colon cancer resection in LMH's and HMH's.

Characteristic	LMH's ^a	HMH's ^a	P Value [*]
Patients, No.	1,006	2,019	
Hospitals, No.	19	30	
Patient characteristics			
Age, mean (SD), y	69.8 (13.2)	70.0 (12.8)	0.772
Black race	65 (6.5)	227 (11.2)	<0.001
Female sex	532 (52.9)	1,016 (50.3)	0.184
2 Comorbid conditions	190 (18.9)	459 (22.7)	<0.05
ASA classification			<0.001
I	19 (2.0)	38 (1.9)	
II	411 (42.1)	654 (33.1)	
III	493 (50.5)	1,045 (52.9)	
IV	51 (5.2)	233 (11.8)	
V	2 (0.2)	7 (0.4)	
Independent functional status	892 (90.9)	1,650 (85.5)	<0.001
Partially dependent	81 (8.3)	242 (12.5)	
Totally dependent	8 (0.8)	38 (2.0)	
Ischemic heart disease	192 (19.5)	354 (17.7)	0.238
Congestive heart failure	67 (7.0)	188 (9.4)	<0.05
Diabetes mellitus	199 (19.9)	455 (22.7)	0.089
BMI, mean (SD)	27.2 (5.4)	28.1 (6.3)	<0.001
Albumin level, mean (SD), g/dL	3.61 (0.8)	3.45 (0.8)	<0.001
Creatinine level, mean (SD), mg/dL	1.08 (0.4)	1.10 (0.4)	0.274
Hematocrit level, mean (SD), %	34.7 (6.6)	34.0 (6.9)	<0.01
Platelet count, mean (SD), x103/ μ L	283.8 (3.2)	292.0 (2.4)	<0.05
Emergency surgery	79 (7.9)	159 (7.9)	0.983
Estimated blood loss, mean (SD), mL	212.1 (11.8)	198.7 (5.7)	0.248
Tumor stage			0.735
0/I	261 (28.7)	523 (26.8)	
II	277 (30.4)	617 (31.6)	
III	230 (25.3)	510 (26.1)	
IV	143 (15.7)	302 (15.5)	
Mortality rate, %			
Unadjusted	2.7	8.9	<0.001
Risk-adjusted overall	2.4	9.3	<0.001

^{*} Calculated using Student's t-test or Pearson's χ^2 analysis as appropriate;

SD=standard deviation. ASA=American Society of Anesthesiologists; BMI=body mass index; HMH's=high-mortality hospitals; LMHs=low-mortality hospitals.

^a HMHs indicate hospitals with high mortality rates; LMHs, hospitals with low mortality rates. Values are presented as number (percentage) unless otherwise indicated.

Table 2

Process of Health Care Adherence Rates and Complication Rates in LMHs and HMHs.

Characteristic	Percentage			<i>P</i> value*
	Overall	LMH's ^a	HMH's ^a	
Neoadjuvant treatment				
Chemotherapy	35 (1.2)	20 (2.0)	15 (0.7)	0.005
Radiation	11 (0.4)	5 (0.5)	6 (0.3)	0.420
Any	38 (1.3)	20 (2.0)	18 (0.9)	<0.05
Epidural catheter for pain management				
Any intraoperative monitoring ^b	957 (31.6)	481 (47.8)	476 (23.6)	<0.001
Prophylaxis against SSI				
Antibiotics 1 h before incision	2,770 (91.6)	911 (90.6)	1,859 (92.1)	<0.05
Antibiotics >24 h after surgery	1,698 (56.1)	462 (45.9)	1,236 (61.2)	<0.001
Avoidance of perioperative hyperglycemia				
Recorded glucose level on postoperative day 1	2,617 (86.5)	847 (84.2)	1,770 (87.7)	<0.01
Hyperglycemia management protocol	855 (28.3)	279 (27.7)	576 (28.5)	<0.001
Perioperative β -blocker use	695 (23.0)	278 (27.6)	417 (20.7)	<0.001
Venous thromboembolism prophylaxis				
Preoperative chemoprophylaxis or SCD use	2,220 (73.4)	833 (82.8)	1,387 (68.7)	<0.001
Postoperative chemoprophylaxis or SCD use	2,436 (80.5)	896 (89.1)	1,540 (76.3)	<0.001
Mechanical bowel preparation	1,960 (64.8)	626 (62.2)	1,334 (66.1)	<0.001
Colon resection				<0.001
Open	2,214 (73.2)	679 (67.5)	1,535 (76.0)	
Laparoscopic	762 (25.2)	308 (30.6)	454 (22.5)	

* Calculated using Student's *t*-test or Pearson's χ^2 analysis as appropriate; HMH's=high-mortality hospitals; LMHs=low-mortality hospitals; SSI=surgical site infection; SCD=sequential compression device;

^a HMHs indicate hospitals with high mortality rates; LMHs, hospitals with low mortality rates.

^b pulmonary artery catheter, central venous catheter or arterial catheter.

Table 3

Incidence of Complications and Case Fatality Rates at LMH's and HMH's, stratified by medical or surgical complication type. Results control for age, sex, race, American Society of Anesthesiologists Physical Status classification, comorbidities, functional status, cancer stage and whether the case was an emergency case.

Complication	Incidence of Complication			Case Fatality Rate		
	LMH, % ^a	HMH, % ^a	OR of Complication (95% CI)	LMH, % ^a	HMH, % ^a	OR of Mortality (95% CI)
Any surgical	5.9	8.5	1.25 (0.73 – 2.15)	10.2	22.7	3.22 (0.63 – 16.50)
Any medical ^b	10.1	16.1	1.26 (0.84 – 1.89)	19.6	37.9	4.49 (1.74 – 11.61)

HMH's=high-mortality hospitals; LMH's=low-mortality hospitals; NA=not applicable; OR=odds ratio;

^aHMH's indicate hospitals with high mortality rates; LMH's, hospitals with low mortality rates;

^bIncludes pulmonary, cardiac, thromboembolic, and other medical events;

^dIncludes venous thromboembolism