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Original Research Article

Abnormal vital signs after laparoscopic colorectal surgery: More common than you think

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ABSTRACT

Background: Anastomotic leak is a feared complication. The presence of abnormal vital signs is often cited as an important overlooked predictive clue in retrospective settings once the diagnosis of leak has already been established. We aimed to determine the prevalence of abnormal vital signs following colorectal resection and assess its predictive value.

Methods: We retrospectively studied patients undergoing colorectal resection. The performance of vital signs in predicting anastomotic leak was assessed using discrete-time survival analysis and receiver operator characteristic curve.

Results: 1662 patients (841 laparoscopic, 821 open) were included. Clinical anastomotic leak was diagnosed in 50 patients (3.1%). 96.8% of patients of the entire cohort had at least one abnormal vital sign during their postoperative course. No individual vital sign was a strong predictor of anastomotic leak in either laparoscopic or open cohorts.

Conclusion: Vital sign abnormalities are extremely common following open and laparoscopic colorectal surgery and alone are poor predictors of anastomotic leak.

Introduction

Anastomotic leak (AL) is perhaps the most dreaded complication following colorectal resection. AL is commonly responsible for major life changing morbidities, prolonged length of stay, need for reoperation, hospital readmission, and death.[1–6] Although a subset of patients with AL present in a "*classic manner*" with diffuse peritonitis and hemodynamic instability, the diagnosis in most patients is often quite challenging as no single or combination of tests can routinely secure the diagnosis. Abnormal vital signs are commonly claimed in retrospective settings such as morbidity conferences or malpractice suits to be highly suggestive indicators that anastomotic leak has occurred and that their presence should have prompted the clinician to order confirmatory tests or proceed with prompt reoperation.[7]

We have previously shown that abnormal vital signs are very common and actually ubiquitous after open colorectal resections[8]. The laparoscopic approach to colectomy significantly blunts the postoperative inflammatory response, and is widely believed to cause less inherent physiologic derangement postoperatively.[9] Minimally invasive surgery may therefore widen the diagnostic window between a normal and abnormal recovery. We hypothesized that abnormal vital signs would be much less frequent after laparoscopic colorectal resection with anastomosis as opposed to its open counterpart, and therefore more predictive of anastomotic leak.

Materials and methods

Study Population: Consecutive patients undergoing elective colon or rectal resection with anastomosis at the University of Chicago Medicine between November 1st, 2011 and September 30th, 2018 were identified from a central data repository and retrospectively studied. Patients were identified by Current Procedural

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Terminology (CPT) codes 44202, 44204, 42205, 44207, 44210, 44140, 44145, 44147, 44160, 45112, and 45114. Patients with a diverting ostomy were excluded. Clinical data including vital signs, patient demographics, body-mass index (BMI), date of procedure, complications, and readmissions were obtained either directly from the electronic medical record or abstracted from the Clinical Research Data Warehouse operated by the Center for Research Informatics at the University of Chicago. This study was approved by the Institutional Review Board of the University of Chicago (IRB# 18–1222).

Outcome and variables: The primary outcome of this study was anastomotic leak within 30 days of surgery. An anastomotic leak was defined as contrast extravasation on a radiologic study, a fluid collection adjacent to the anastomosis on CT scan, feculent or bilious output from a percutaneous or surgical drain, anastomotic fistula, or findings of anastomotic dehiscence at reoperation. To capture the primary outcome, all patients who underwent a CT scan, barium enema, interventional radiology drain placement, or reoperation within 30 days of surgery were flagged and their chart manually reviewed.

Abnormal vital signs were defined by the American College of Chest Physicians criteria for systemic inflammatory response syndrome (SIRS): temperature >38 °C, pulse >100 beats per minute, respiratory rate >20 breaths per minute, and a systolic blood pressure <80 mmHg or diastolic blood pressure <50 mmHg.[10] An abnormal white blood cell count (WBC) was <4000 cells/μL or >12,000 cells/μL.

Data Analysis: The association between anastomotic leak and abnormal vital signs was assessed in multiple ways. We first assessed the ability of abnormal vital signs to predict anastomotic leak using area under the receiver operator characteristic curve (AUC). In this analysis, the performance of each vital sign within the first four postoperative days was assessed to predict anastomotic leak during the following three days. For this analysis abnormal was defined as reaching the minimal or maximal threshold as defined by the SIRS criteria above. Using discrete-time survival analysis we next assessed the association of abnormal vital signs in the three days prior to diagnosis of anastomotic leak compared to patients that did not leak and matched by post-operative day. Because some patients were diagnosed with anastomotic leak after the initial hospitalization, patients were only included in the analysis if they were an inpatient during the first four postoperative days, or in day prior to diagnosis of anastomotic leak. Positive predictive value was calculated for those variables that showed an association with anastomotic leak.

All analyses were controlled for sex, age, race, American Society of Anesthesiologist (ASA) score, diagnosis, and procedure. To determine if abnormal vital signs are more or less predictive of anastomotic leak in minimally invasive surgery, analysis of patients undergoing open versus laparoscopic was performed separately. All analyses were performed using R version 3.3 (R Project for Statistical Computing).

Results

1662 patients underwent bowel resection with anastomosis during the study period and met inclusion criteria. Of these, 841 (50.6%) patients underwent laparoscopic bowel resection, while 821 (49.4%) patients underwent open bowel resection (Table 1). Laparoscopy was the preferred surgical approach at our institution during the study period with open surgery typically reserved for the large number of patients seen at our tertiary center for complex reoperative surgery. For the entire cohort, anastomotic leak was diagnosed in 50 patients (3.1%). The incidence of anastomotic leak was 3.8% for patients undergoing open surgery, and 2.3% for patients undergoing laparoscopic surgery (p = 0.07). Anastomotic leak occurred in 3.7% of patients with a colo-colonic reconstruction and 2.7% of patients with a entero-colonic reconstruction (p = 0.28). Daily vital signs were available in all patients totaling 328,324 discrete vital signs being included in the analysis. Daily WBC counts were drawn every postoperative day from the time of operation until discharge in 48% of patients, while WBC counts for the first 3 days postoperatively were available in 79% of the entire cohort. The median time from operation to diagnosis of leak was 11.5 days after open surgery and 11 days after laparoscopic surgery (range 3–21 days; p = 0.77).

Table 1
Cohort demographics.

Demographic	Lap (n = 841)	Open (n = 821)	p value
Age, mean, (SD)	47.2 (19.4)	54.7 (25.4)	<.001
Sex, n, (% female)	424 (50.5)	478 (58.2)	<.001
Race, n, (%)			
Black	174 (20.7)	262 (31.9)	<.001
White	587 (69.8)	502 (61.1)	
Other	80 (9.5)	57 (6.9)	
Current smoker, n, (%)	152 (18.1)	141 (17.2)	0.631
ASA Class, n %			
1	26 (3.1)	17 (2.1)	<.001
2	386 (46.9)	282 (34.3)	
3	352 (41.8)	423 (51.5)	
4	13 (1.5)	37 (4.5)	
N/A	63 (7.49)	59 (7.2	
Diagnosis, n (%)			
Malignancy	340 (40.4)	351 (42.7)	<.001
IBD	345 (41.1)	296 (36.1)	
Diverticulitis	74 (8.8)	98 (11.9)	
Other	82 (9.8)	76 (9.3)	
Anastomosis, n (%)			
Entero/colo-colo	547 (65.1)	543 (66.1)	0.672
Colo-rectal	294 (34.9)	278 (33.9)	

SD = standard deviation.
ASA = American Society of Anesthesiologists.
IBD = inflammatory bowel disease.

Incidence of abnormal vital signs. The frequency of abnormal vital signs across each patient's hospital course is displayed in Table 2. Of the entire cohort, 96.8% (n = 1610) of patients had at least one abnormal vital sign during their admission, 96.2% (n = 1599) had two episodes of abnormal vital signs, and 90.4% (n = 1502) had three or more abnormal vital signs episodes. Of the patients whom had multiple abnormal episodes of the same vital sign, 73% were from consecutive readings. 92.8% of patients had tachycardia and 65.8% had tachypnea; tachycardia and tachypnea were the two vital signs that were most frequently abnormal. Only 20.1% of patients developed a postoperative fever and was the vital sign least frequently abnormal. While the incidence of an abnormal vital sign was significantly more likely in patients undergoing open surgery compared to the laparoscopic cohort, the absolute difference was remarkably small in magnitude and was a very common

Table 2
Prevalence of abnormal vitals in entire cohort.

Vital Sign	Total (n = 1662)	Lap (n = 841)	Open (n = 821)	p value
Fever	20.1 (334)	16.9 (142)	23.3 (192)	<.001
Abnormal WBC	43.8 (729)	38.8 (326)	49.0 (403)	<.001
Hypotension	50.4 (837)	47.2 (397)	53.5 (440)	<.001
Tachypnea	65.8 (1094)	60.4 (508)	71.3 (586)	<.001
Tachycardia	92.8 (1543)	93.4 (786)	92.2 (757)	0.321
Any	96.8 (1610)	95.9 (788)	98.5 (829)	<.001

All values reported as % (n).
WBC = white blood cells.

finding in both groups (laparoscopic 98.5% versus open 95.9%; $p < 0.001$).

Association of abnormal vital signs with anastomotic leak. We next analyzed if patients whom were diagnosed with anastomotic leak had a higher frequency of abnormal vital signs during their admission (Table 3**)**. Surprisingly, temperature and abnormal WBC count were the only parameters that were significantly different in the leak vs no leak group in patients that underwent laparoscopic surgery; there was no significant difference in episodes of hypotension, tachypnea, and tachycardia between the leak vs no leak cohort; in fact, tachycardia was observed in 93.4% of patients in both groups. In patients that underwent open surgery, the incidence of hypotension was the only vital sign that differed between leak vs no leak patients (Table 3).

Prediction of anastomotic leak by abnormal vital signs. Because of the association of some vital signs with the development of anastomotic leak, we next sought to determine if the presence of abnormal vital signs during postoperative days 1–4 was predictive for anastomotic leak in the subsequent 3 days (Fig. 1). Using a cutoff of AUC >0.70 to be considered weakly predictive and >0.80 to be strongly predictive, we found that leukocytosis was marginally predictive of the development of anastomotic leak (AUC 0.72, 95% CI 0.57–0.88) in patients that underwent laparoscopic surgery. No other vital sign abnormalities in the laparoscopic cohort nor any vital sign in the open surgery cohort was found to be predictive of anastomotic leak.

Because vital sign abnormalities during the immediate postoperative period might be due to other etiologies such as such as pain, bleeding, or hypovolemia, we focused specifically on the three days prior to anastomotic leak in the leak cohort as compared to those that did not have a leak to limit confounding (Fig. 2). We found that for patients undergoing laparoscopic surgery, fever (OR 3.14, $p = 0.03$) and an abnormal WBC (OR 2.73, $p = 0.04$) were significantly associated with the diagnosis of anastomotic leak. Similarly, for patients undergoing open surgery, fever in the three days prior to diagnosis was significantly associated with the development of anastomotic leak (OR 2.39, p-value 0.04). The positive predictive value of these variables found to have significant associations were: leukocytosis following laparoscopic surgery 5.5% (95% CI 4.1–7.4), fever following laparoscopic surgery 9.1% (95% CI 6.1–13.6), and fever following open surgery 3.9% (95% CI 2.3–6.6). The presence of tachycardia, tachypnea, or hypotension was not associated with leak for open or laparoscopic surgery.

Discussion

Abnormal vital signs are often cited as an overlooked "*clue*" to the diagnosis of an anastomotic leak in peer review settings such as a morbidity conference, and even as representing negligence in the medicolegal setting. Specifically, the linkage of abnormal vital signs with anastomotic leak made in these retrospective settings, after the diagnosis of leak is established and known, is largely based on the assumption that vital sign abnormalities are unusual in a "*normal*" postoperative course after colectomy; our findings contradict this assumption as we demonstrate that abnormal vital signs are quite common after colorectal resection with anastomosis in both complicated and uncomplicated recoveries, and after both laparoscopic and open surgery.

In our cohort, 96.8% of the patients, including 95.9% of laparoscopic and 98.5% of open cases, had at least one abnormal vital sign as defined by SIRS criteria. 92.8% of patients had tachycardia and over half of patients were hypotensive and/or tachypneic at some point during their postoperative course. While an abnormal temperature was the least common abnormality, nearly 20% of patients had a fever postoperatively. These findings are similar to previous work describing the ubiquitous nature of abnormal vital signs even in an uncomplicated recovery in an open colectomy cohort.[8] However, we were surprised by the similarity in the frequency of abnormal vital signs in our laparoscopic cohort. Because laparoscopy significantly decreases the postoperative inflammatory response, we hypothesized that vital sign abnormalities would be relatively uncommon after minimally invasive surgery and would be a far more useful predictor of anastomotic leak.[9,11] Our analysis found that this was simply not the case, and that abnormal vital signs are routinely encountered in patients undergoing laparoscopic surgery. Although some of the vital signs were statistically less abnormal in the laparoscopic group, the differences were small in magnitude and unlikely to be clinically meaningful or useful.

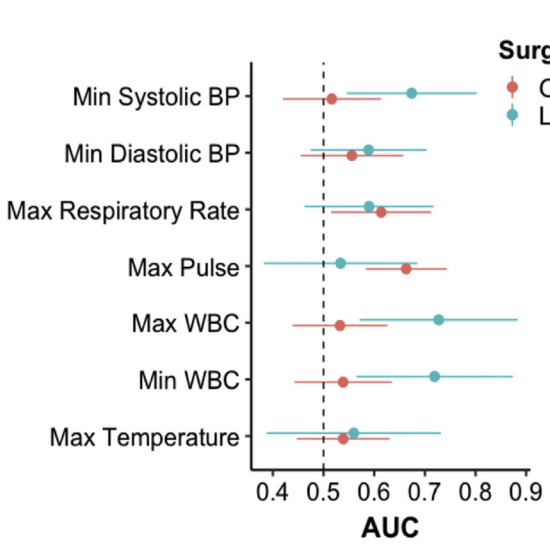
We performed multiple analyses to determine the predictive ability of abnormal vital signs for the development of anastomotic leak, investigating vital signs both in the early postoperative period and in the days immediately preceding the diagnosis of leak. Fever within the first four days following surgery showed the strongest association with development of anastomotic leak; to our surprise tachycardia, tachypnea, hypotension, and leukocytosis were poor predictors. Although early postoperative fever may justifiably raise suspicion for leak, many patients without a leak were febrile and an abnormal temperature alone is likely of limited clinical utility.

The armamentarium of diagnostic tools to assess for AL is extensive and obviously extends well beyond simple vital signs. We do not mean to imply that vital signs in isolation are typically used to definitively diagnose leaks, nor was it our aim to dismiss vital signs as one of the many elements that the clinician should consider. Rather, the specific impetus of this investigation is that abnormal vital signs are commonly cited in retrospective settings such as peer review analyses, morbidity conferences, or malpractice suits as an obvious trigger for the use of aggressive diagnostic modalities or even reoperation. This assertion is often made more strongly in laparoscopic resections, where it is suggested that with a minimally invasive approach, the patients' postoperative hemodynamics should be normal or minimally disturbed. The finding that abnormal vital signs are ubiquitous even in uncomplicated

Table 3
Prevalence of abnormal vitals stratified by anastomotic leak.

Vital Sign	Laparoscopic			Open		
	No Leak (n = 810)	Leak (n = 31)	P value	No Leak (n = 802)	Leak (n = 19)	p value
Fever	15.9 (129)	41.9 (13)	<.001	22.3 (184)	421.1 (8)	0.051
Abnormal WBC	38.0 (308)	58.1 (18)	0.025	47.7 (392)	57.8 (11)	0.437
Hypotension	46.7 (378)	61.3 (19)	0.109	51.7 (425)	78.9 (15)	0.024
Tachypnea	60.1 (487)	67.7 (21)	0.394	70.9 (569)	89.4 (17)	0.077
Tachycardia	93.4 (757)	93.4 (29)	0.984	92.0 (738)	100 (19)	0.626
Any	98.5 (798)	100 (31)	0.459	95.0 (762)	100 (19)	0.268

All values reported as % (n).
WBC = white blood cells.



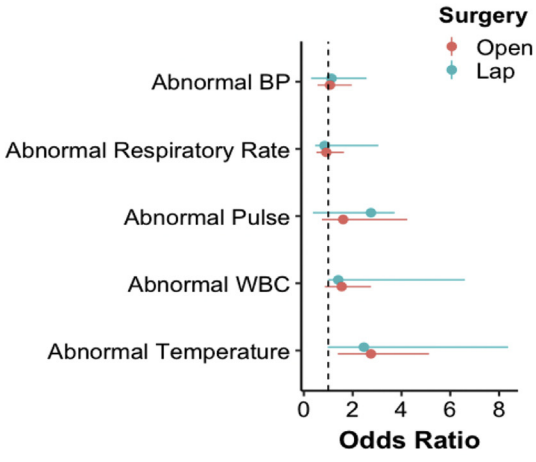
	Lap		Open	
	AUC	CI	AUC	CI
Min Systolic BP	0.68	0.55-0.80	0.52	0.44-0.62
Min Diastolic BP	0.59	0.48-0.70	0.56	0.46-0.66
Max Respiratory Rate	0.59	0.46-0.72	0.61	0.51-0.71
Max Pulse	0.53	0.38-0.68	0.66	0.58-0.74
Max WBC	0.72	0.57-0.88	0.53	0.44-0.63
Min WBC	0.71	0.56-0.87	0.54	0.45-0.64
Max Temperature	0.56	0.39-0.73	0.54	0.45-0.63

Fig. 1. Predictive value of the presence of abnormal vital signs and diagnosis of anastomotic leak. Area under the receiver operator characteristic curve (AUC) was performed to determine the predictive value of each vital sign within the first four days following surgery for the development of anastomotic leak in the following seven days. CI = 95% confidence interval. AUC >0.7 considered predictive.

recoveries in both laparoscopic and open surgery, indicates that abnormal vital signs alone, in the context of an otherwise satisfactory clinical course, do not represent a "stand alone" indication for further assessment.

Early diagnosis of anastomotic leakage minimizes the risk of septic complications and increases the patient's chance of survival.[12–14] It has previously been shown that a delay in administration of antibiotics from the onset of septic shock is associated with a decrease in survival of 7.6% per hour.[15] Patients who develop hemodynamic instability early in the postoperative period in the setting of diffuse peritonitis typically require return to the operating room without delay. However, most patients with anastomotic leak do not present in this classic fashion and instead experience confusion, respiratory compromise or failure to thrive. These signs and symptoms may be difficult to distinguish from other postoperative infectious complications or adverse medication reactions.[16] Recent studies highlight the potential utility of biochemical markers as early predictors of anastomotic leak. C-reactive protein has offered promising predictive data in a number of studies.[16–19] One particular study highlights the predictive value of CRP after both open (maximum AUC 0.806) and laparoscopic colorectal surgery (maximum AUC 0.766).[20] Other studies have suggested that serum procalcitonin may be a reliable predictor of leakage and combined CRP and serum calprotectin achieved an AUC of 0.93[16].[21–23] Similarly, contrast enemas and CT scanning are useful diagnostic modalities but no single or combination of clinical, biochemical or radiologic studies are reliable predictors of anastomotic leak after colorectal anastomosis.

Limitations of this study include the difference in the characteristics of the open vs laparoscopic cohort. Open cases were older, more likely to be African American, and had a higher ASA class. This reflects the institutional practice of utilizing a minimally invasive technique whenever appropriate and reserving open surgery for more complex cases (e.g. multiply reoperated patients) and likely



	Lap			Open		
	OR	CI	p-value	OR	CI	p-value
Abnormal BP	0.99	0.31-2.67	0.99	1.11	0.48-2.37	0.80
Abnormal Respiratory Rate	1.18	0.45-2.97	0.72	0.73	0.32-1.57	0.43
Abnormal Pulse	1.01	0.36-3.59	0.99	2.67	0.79-16.65	0.18
Abnormal WBC	2.73	1.05-7.01	0.04	1.50	0.68-3.15	0.29
Abnormal Temperature	3.14	0.99-8.45	0.03	2.39	0.98-5.26	0.04

Fig. 2. Association of anastomotic leak and the presence of abnormal vital signs in the three days prior to anastomotic dehiscence. OR = odds ratio, CI = 95% confidence interval.

accounts for the slightly higher leak rate in this cohort. Despite the obvious bias towards higher risk patients in the open cohort, we were surprised to find that the incidence of abnormal vital signs both cumulatively and individually was so similar in the two groups. Again, tachycardia and tachypnea are particularly common after laparoscopic colorectal surgery and must be interpreted with caution. Patients who had an AL were identified by reviewing the chart of patients who had an imaging study or intervention in the thirty days after surgery; as such, clinically occult leaks (those not requiring imaging or intervention) would have been missed. Finally, we did not document other infections that may have been the impetus for the abnormal vital signs. We designed this methodology to focus solely on the prediction of anastomotic leak, as at the time of abnormal vital signs diagnosis of other infections is often not known.

Conclusion

Vital signs abnormalities, as defined by the SIRS criteria, were common after both open and laparoscopic colorectal surgery and generally failed to distinguish an anastomotic leak from an uncomplicated recovery. While vital signs are clearly an important factor in the assessment of postoperative surgical patients, the diagnosis of anastomotic leak is typically quite difficult and nuanced, and vital signs appear to add little predictive value in isolation without clinical context. Surgeons make individualized assessments of their patient's recovery after colorectal resections and distinguishing what might be expected versus what should drive a more aggressive diagnostic workup or reoperation is often not straight forward, especially in light of the fallibility of the available diagnostic tools for anastomotic leak. Great caution should be exercised in drawing conclusions in retrospective settings, as many patients with similar hemodynamic profiles go on to an uncomplicated recovery.

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Declaration of competing interest

All authors report no conflicts of interest to disclose.

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