Is Appendicitis a Ticking Time Bomb?
Time to Treatment and Risk of Perforation after Patients Reach the Hospital

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Abstract

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Background

In the traditional model of appendicitis, time is the major driver of disease progression: luminal obstruction leads inexorably to perforation without timely intervention. This perceived association has guided clinical behavior related to timing of operation. Our objective was to evaluate whether there is an association between time and perforation after patients present to the hospital.

Methods

Using data from Washington's Surgical Care and Outcomes Assessment Program, we evaluated patterns of perforation among patients (≥18 years) who underwent appendectomy (2010-2011). Elapsed time was measured between presentation to the

Emergency Department (ED) and Operating Room (OR) start time. The relationship between in-hospital time and perforation was adjusted for potential confounding using multivariate logistic regression.

Results

9,408 adults underwent appendectomy (15.8% perforated). Mean time from ED to OR was the same (8.6 hours) for perforated and non-perforated appendicitis. In multivariate analysis, increasing time from ED to OR was not a predictor of perforation either as a continuous variable (OR 1.0 95%CI 0.99-1.01) or when considered as a categorical variable (patients ordered by elapsed time and divided into deciles). Factors associated with perforation were male sex, increasing age, 3+ co-morbid conditions, and lack of insurance.

Conclusions

There was no association between perforation and time in-hospital prior to surgery. These findings may reflect selection of patients for earlier intervention who are at higher risk for perforation or the effect of antibiotics begun at diagnosis, but they are also consistent with the theory that perforation is most often a pre-hospital occurrence and/or that perforation is not strictly a time-dependent phenomenon.

INTRODUCTION

Acute appendicitis is the most common indication for urgent intra-abdominal surgery.[1] The conventional pathophysiologic model of acute appendicitis is based on a relationship between time with disease and disease progression. This model suggests that risk of perforation increases as time elapses from symptom onset to treatment. Anywhere along the pathway from onset of symptoms, to presentation, to evaluation and treatment, delays can occur and many factors come into play, including aspects of the disease itself (such as symptoms), patient characteristics, access to medical care, and characteristics of the healthcare system in which care is delivered. Observational research has demonstrated an association between time and perforation,[2-12] and indirect evidence for an association between time and perforation has come from studies linking impaired healthcare access to increased risk of perforation.[13-15]

It is challenging to establish the precise time of symptom onset and to characterize patients' pre-hospital courses. While several of the previous studies have attempted this using chart review or by incorporating time-based questions into clinical history taking, most are hampered by small numbers of patients from a single institution, recall bias, and/or poor time discrimination. For example, studies have been based on "days" of symptoms rather than hours, which can lead to misclassification. The question of an association between time and perforation is important because it raises the possibility of an intervention (facilitating earlier treatment) that may reduce the incidence of perforation.

The Washington State Surgical Care and Outcomes Assessment Program (SCOAP), a physician-led quality surveillance program initiated in 2006, provides several benefits to evaluating the relationship between time-to-treatment and perforation, including a large number of diverse institutions, large numbers of patients, individualized chart review by trained abstractors, and specific data on emergency department (ED) arrival, time of diagnostic imaging, and operating room (OR) start time. The objective of this study was to evaluate the relationship between the amount of time patients "wait" for surgery and the risk of perforation.

METHODS

Study Population and Setting

Consecutive adult patients (18 years or older) were included in this prospective cohort if they underwent non-elective appendectomy in one of 52 SCOAP hospitals in Washington State between January 1, 2010 and December 31, 2011. Recent estimates derived from the state's abstract reporting system suggest that greater than 85% of non-elective appendectomies performed in Washington are captured by SCOAP. Participating hospitals submit data for all non-elective appendectomies. Unlike administrative datasets in which, for example, billing codes are used to identify diagnoses and interventions, SCOAP relies on direct review of clinical records by trained abstractors. SCOAP data are collected primarily for quality improvement, but the abstracting protocol is also developed in a prospective and evolving manner to answer new research questions. In 2010, the Agency for Healthcare Research and Quality funded the creation of a comparative effectiveness research platform using SCOAP data. That network—the Comparative Effectiveness Research Translation Network (CERTAIN)—developed this research study, and data pertaining to time of arrival and specific OR start time were added to the abstracting template in 2010. The University of Washington Human Subjects Division reviewed our study protocol and deemed it "not human-subjects research" since the analytic team did not have access to original SCOAP data, which was provided in a completely anonymous fashion for the purposes of this research project. The STROBE Statement Checklist was utilized in planning and reporting this research.[16]

Descriptive Variables

Demographic and socio-economic information, clinical characteristics, operative findings, and pathology results were abstracted from each patient's clinical record using standardized definitions. Abstracted data are audited for quality control and to verify that charts are being evaluated in a similar way across sites. A comorbidity score was calculated based on documentation of the following co-morbid conditions: coronary artery disease, asthma, diabetes, HIV/AIDS, diabetes, and/or elevated serum creatinine. White blood cell (WBC) count was based on the result obtained most proximal to surgery. Body mass index (BMI) was calculated from recorded height and weight at the time of the procedure.

Outcome and Predictor Variables

The outcome of interest was the presence or absence of perforation on the final pathologic report. The primary predictor of interest was time between ED arrival and initiation of surgery (OR time). In this large dataset, there were a small number of clear outliers, some with obviously misclassified time data. For this reason, we restricted the analytic cohort to the 99th percentile of all patients. This resulted in the exclusion of only 74 patients, all with ED to OR times longer than 2.5 days.

Statistical Analysis

Patients with negative appendectomy were excluded from analysis. The remaining patients were then divided into those diagnosed with perforated appendicitis and those with non-perforated appendicitis. Clinical and demographic characteristics of each group were compared. Continuous variables were compared using means (and Student's T-test) and/or medians. Differences between categorical variables were tested using Pearson's chi-square test. Statistical significance was set at $\alpha = 0.05$. Some demographic and socio-economic characteristics were not recorded for every patient, in particular race/ethnicity and insurance status. Those observations with missing race and/or ethnicity data were not discarded but are presented in the data tables as "unknown." To examine the influence of ethnicity on the outcome of interest, we generated a combination variable that combined the binary ethnic category (Hispanic/Latino or not) with race. Patients with unknown race were not included in the Hispanic or Latino designations except for those who were listed as Hispanic/Latino and did not have a race designated – these were included in the white, Hispanic category. For insurance status, unknown insurance status was included with the uninsured and self-pay categories.

In the next univariate analysis, we produced a mean, standard deviation (SD), and median ED to OR time for each of the different categories of the demographic, clinical, and socio-economic variables used in the initial analysis. A perforation rate for each of these categories was also generated. Statistical testing for differences in perforation was performed by univariate logistic regression and is presented in a separate table.

Time from ED to OR was compared for patients with and without perforation, using Student's T-test for significance testing. Additionally, we subdivided the time from ED to OR into two segments: arrival-to-imaging and imaging-to-OR. Not all patients had the exact time of imaging recorded, and some were imaged prior to ED arrival. These were excluded, reducing the number of observations for this sub-analysis. Analysis is based on the image immediately prior to the patient's appendectomy. For example, if a patient had an US followed by CT, only the CT time was included in the analysis by modality and the US was disregarded from this particular analysis.

To further analyze the relationship between time-to-treatment and risk of perforation, we ordered the patients by the length of their elapsed time from ED to OR and then divided the cohort into deciles. We calculated percent perforation and 95% CI for each decile. Percent perforation for each decile was compared to the first decile and a univariate logistic regression was performed with Decile 1 as the reference category. To better understand the differences between those patients with a short wait time and those patients with the longest wait times, we compared characteristics of patients in Decile 1 to those in Decile 10.

Finally, to adjust for potential confounding, we developed a multivariate logistic regression model. Covariates were initially considered for inclusion if they were known from clinical experience or the surgical literature to be associated with perforation. However, only variables with significant associations in univariate analysis were included in the final regression model. Using these *a priori* criteria, sex, age, comorbidity score, ethnicity, and certain hospital characteristics were included in the final multivariate logistic regression model. Though not significantly associated with perforation in univariate analysis, race has an important place in the recent literature on perforated appendicitis and, for this reason, was included it in the final multivariate model. In the fully adjusted model, ethnicity was included as a yes/no/unknown variable rather than the race + ethnicity categories used in univariate analysis, because the latter variable was co-linear with race in the model. STATA version 12 (College, TX) was used for this analysis.

RESULTS

Overall Cohort, Perforated Patients vs. Non-Perforated Patients:

9,408 patients had an appendectomy from January 1, 2010 to December 31, 2012 (52% male, mean age 39.8, SD 16.6). 4.1% underwent appendectomy that was negative for appendicitis or other pathology and were excluded from further analysis. 15.8% of the total cohort had a perforated appendix (Table 1).

Comparing patients with perforated appendicitis to patients with non-perforated appendicitis (Table 1) there were some notable differences. Patients with perforation were more likely to be male (55.3% vs. 52.1%, $p < 0.001$) and older (48.8 years vs. 38.2 years, $p < 0.001$) than those without perforation. Patients with perforation were more likely to have comorbid conditions. Race and ethnicity did not differ, but there were significantly fewer patients with private insurance (54.2% vs. 63.6%, $p < 0.001$) and more patients with Medicare (17.0% vs. 6.4%, $p < 0.001$) in the perforated group.

Elapsed Time in the Hospital:

7,505 patients had complete data for time of ED admission and OR start time. We compared the entire time elapsed from ED to OR and found that it was the same for patients with perforated and for those with non-perforated appendicitis (8.6 hours vs. 8.6 hours) (Table 2). We also compared time from ED to imaging (3.2 hours vs. 3.4 hours, p = NS) and time from imaging to the OR (7.8 vs. 8.2 hours, p = NS). When the patients were ordered into deciles based on ED-to-OR time (Figure 1) and compared using univariate logistic regression (with the first decile as reference), there were no differences in perforation based on time elapsed from ED to OR. With time as a continuous variable, the unadjusted OR of perforation for each incremental increase in ER to OR time was 1.00 (95% CI 0.99-1.01). When we adjusted for clinical and demographic factors, the OR of perforation for each incremental increase remained 1.00 (95% CI 0.99-1.01).

Wait Time, Perforation, and Patient Characteristics:

Mean and median wait times among the various clinical, demographic, and socio-economic strata were compared (Table 3). Though there was a higher percentage of perforation among male patients, they had shorter mean and median ED to OR times than women (mean 8.2 vs. 9.0 hours). Perforation increased with increasing age; the eldest group of patients had the highest rate of perforation and the longest mean ED-to-OR time (10.0 hours). Both perforation and wait time increased with increasing number of comorbid conditions.

In terms of race and ethnicity, African Americans had the longest mean wait time but the second lowest perforation rate. No race had significantly different odds of perforation from white patients in univariate analysis (Table 4), and, after adjustments, only Asian patients had significantly different risk of perforation compared to white patients (OR 0.68, p = 0.004). Interestingly, Asian patients also had the third-longest wait time (8.8 hours). In unadjusted analysis, minority race non-Hispanics had significantly reduced odds of perforation compared to white non-Hispanics (13.4% vs. 16.8%, p = 0.005), but no other category differed from white non-Hispanics (Table 3). Although minority race Hispanic patients had the highest percent perforation (22.2%), there were only 6 patients who met this definition in the cohort. In the fully adjusted model (Table 4), there was no difference in odds of perforation between non-Hispanics and Hispanics.

Among insurance categories, Medicare beneficiaries had the longest mean wait time (9.6 hours) and the highest percent perforation (Table 3), but after adjustments, there was no difference compared to privately insured patients (OR 0.98, p = 0.86) (Table 4). Uninsured patients and patients with government sponsored health care policies waited over an hour more, on average, than privately insured patients (Table 3). In both univariate and multivariate models, those patients in the uninsured, self-pay and unknown category had substantially increased odds of perforation (OR 1.43, p < 0.001) (Table 4).

Comparing Decile One to Decile Ten:

Perforation was similar among patients in Decile compared to Decile 1 (Table 5). Age was similar, as was mean white blood cell count. In Decile 10, there were fewer privately insured patients and more with Medicaid or no insurance. There were more women and more patients with multiple co-morbid medical conditions. There were slightly more African Americans in Decile 10 (5.0% vs. 1.3%, $p < 0.001$) and less Caucasians, though the latter difference was not statistically significant. Patients in Decile 10 were more likely to undergo advanced imaging, while those in Decile 1 were more likely to present to the ED with imaging from an outside facility (26.5% vs. 2.2%, $p < 0.001$).

Sensitivity Analyses:

We performed two sensitivity analyses to assess whether an association was being obscured. First, we performed an additional logistic regression of perforation vs. time using time coded as a categorical variable (hours). In this model, we selected ED to OR time between 1 and 2 hours as the reference category instead of those with times between 0 and 1 hour. There was a very small number of patients reported as going to the OR within one hour (n=37), and this group had a very high percent perforation (27%). These patients were included in the model, but not as the reference group. Within the first 24 hours there was no significant association between perforation and any of the hourly increments. For hourly increments between 25 and 63 hours, there was no pattern of increase in the odds of perforation, though some hours were individually different from hour 1-2. Secondly, we performed logistic regression with ER to OR time categorized into patient deciles (patients ordered as noted above). This choice was made in case the more granular hourly data was obscuring trends by categorizing time into groups where some had very few or no observations. In unadjusted logistic regression, no decile (compared to decile 1) had significantly different odds of perforation. This was repeated with those patients in the first hour excluded (i.e., reducing percent perforation of decile 1 and potentially enhancing a difference with later deciles). There were no differences in the odds of perforation. Finally, ED to OR time in deciles was included in the full multivariate model (i.e., instead of time as a continuous variable). Again, the results were unchanged.

DISCUSSION

After patients present to the ED, we found no relationship between time-to-treatment and perforation. Risk factors for perforation included male sex, advancing age, and 3-plus comorbid conditions. Among demographic and socio-economic characteristics, Asian-Americans had lower odds of perforation compared to whites, and the uninsured/self-pay group had a 43% increase in odds of perforation compared to the privately insured (after adjusting for in-hospital time). Hispanic ethnicity and African-American race were not risk factors for perforation. Hospital appendectomy volume and rural or urban setting were not associated with perforation.

Beginning with several classic papers published in the late-19th and early-20th centuries, surgeons have considered appendicitis a progressive disease.[17, 18] Based on observations in the OR and at autopsy, the pathophysiologic mechanism behind this progression is thought to begin with luminal obstruction and subsequent visceral distension, which leads to venous congestion, blood supply compromise, gangrenous changes in the appendiceal wall, and, ultimately, perforation. Although both Fitz and McBurney believed that some cases of appendicitis resolved without intervention,[17, 18] the treatment imperative became early operation in order to forestall progression to perforation. More recent observational studies have demonstrated an association between perforation and the amount of time elapsed from symptom onset to definitive care.[2-12] Several studies have specifically evaluated time-to-treatment once patients reach the hospital in both pediatric and adult populations, but divergent conclusions have been reached about the association between in-hospital time and risk of perforation.[8, 10, 12, 19-21] Three substantial strengths for the current study compared to these previous investigations are the large size of the study population (7,505 patients with complete time data), the multi-institutional design, and the level of discrimination with which we were able to define elapsed time—the dataset includes exact time of ED presentation and OR start. To illustrate this advantage, consider a study based on dates recorded in the medical record. A patient who presented at 11 PM on Monday and taken to the OR at 3 AM on Tuesday (4 hours) would be classified as having waited one day between ED and OR, whereas a patient who presented at 1 AM on Monday and taken to the OR at 11 PM that same evening (22 hours) would be classified as having waited less than a day. This can lead to substantial misclassification in studies based on dates recorded in medical records. Given that 97% of the patients in this series had surgery within 48 hours and lingering questions about the appropriate timing of appendectomy (related to whether procedures can be delayed by a few hours to accommodate work force or health system priorities), assessments using hourly intervals offer an advantage.

Multiple investigators have found an association between potential markers of limited access to healthcare and an increased risk for perforation, extrapolating that such healthcare barriers lead to delays in presentation and increased perforation. In adults, insurance status[13-15] and race and ethnicity[13, 15] have been associated with perforation. Similarly, among children, race and ethnicity have been implicated as risk factors for perforation,[22-25] as has insurance status.[24-26] However, these studies into impaired access and perforation have not produced consistent results. For instance, Pieracci *et al*, Boomer *et al*, and Lee *et al* all found that, compared to white adults, other racial and ethnic groups had lower or the same odds of perforation (similar to the findings of the current study).[14, 27, 28] Moreover, many of the studies in the pediatric literature contradict one another in terms of which races or ethnicities have higher or lower proportions of perforation. It is not clear whether these divergent findings stem from differences in study populations, data sources, study designs, characteristics of the healthcare settings where different studies are conducted, or other causes. In summary, most studies (including the current study) that evaluate perforated appendicitis have detected one or more potential access issues that appear to be risk factors for perforation, but the specifics have varied considerably from study to study.

Using a California billing claims database (ICD-9 diagnostic codes) and U.S. Census data, Luckmann and Davis calculated separate population-based incidences for perforating and non-perforating appendicitis. For all age groups, African American had a lower incidence of both perforating and non-perforating appendicitis than white patients, as did Asian Americans in all age groups except for those ≥60 years. The younger Hispanic population (age 0–29) had a slightly increased incidence of perforating appendicitis compared to whites of the same age, but rate ratios were otherwise not different or slightly reduced compared to the white population. Noting that "some cases of appendicitis [may] resolve spontaneously before an appendectomy is performed," Luckmann and Davis point out that differences in access to or utilization of healthcare services may drive some of the differences in the incidence of non-perforating appendicitis.[29] In another article, Luckmann illustrated how this might lead to inconsistencies in determining a denominator when calculating proportions of perforation.[30] These methodological concerns, as well as the divergence seen in the secular incidences of perforating compared to non-perforating appendicitis,[31] have lead some authors to dissent from the view that time-to-treatment is the predominant driver of perforation.[29, 30, 32, 33] Alternative theories to time-dependence have been proposed to explain perforation, including differences in microbiology[34] or differences in host inflammatory response.[29, 35, 36] By the time patients develop symptoms, a unique microbiology or host response profile already may have resulted in perforation. If true, this would further suggest that perforation may not be a particularly modifiable pre-hospital event.

This study has limitations. Initiation of antibiotics may be stopping the natural progression of appendicitis, muting the time-to-perforation effect. Unfortunately SCOAP does not collect data on the initiation of antibiotics. An alternative explanation for lack of association is that surgeons' clinical acumen may enable identification of those at highest risk for perforation, leading to a form of selection bias, in which those most near to perforation (but not yet perorated) are taken expeditiously to the OR. However, given the lack of objective measures to identify such patients, it seems unlikely that surgeons are able to "cherry pick" with such a level of discrimination. Furthermore, no evidence of greater perforation in the early hours is identified (beyond the small number of patients taken to the OR within one hour of presentation—a characteristic of the cohort also addressed in one of our sensitivity analyses). Finally, of course, patients present to the operating hospital at different stages in the progression of their disease, which means that time zero is not the same for every patient. However, if appendicitis were strictly time dependent and the interval for progression is less than 2.5 days, some relationship between time and perforation should be evident in our data, especially since our definition of perforation is based on pathologic review, allowing detection of small, early perforations. Additionally, patients with perforation and abscess or discrete fluid collection are frequently taken for IR drain and would not be captured in our data set, which would remove a number of late-stage presenters from analysis, potentially making disease stage of the remaining patients somewhat more similar at presentation.

In conclusion, perforation was not associated with elapsed time from ED to OR among adult patients admitted for appendectomy across a large number of diverse hospitals. These data are consistent with the hypothesis that perforation is more often a pre-hospital event. They may also suggest a more complex pathophysiology behind disease progression in appendicitis or, as some researchers have suggested, that perforated and non-perforated appendicitis are actually separate biological or host entities. Although observational data cannot prove that time does or does not impact disease progression, our findings are consistent with the hypothesis that perforation in appendicitis is not strictly a time-dependent phenomenon and that additional factors may need to be identified on which to focus quality improvement efforts aimed at reducing the incidence of perforated appendicitis.

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Table 1: Clinical and Demographic Characteristics of the Cohort

	All Appendectomy	Non-Perforated	Perforated	P – value (chi^2)
	N = 9,048	N=7,233*	N = 1,421	
% Male	52.0%	52.1%	55.3%	0.03
Mean Age (SD)	39.8 (16.6)	38.2 (15.8)	48.8 (17.6)	<0.001
Age Distribution:				
18 – 29	34.6%	37.5%	17.5%	<0.001
30 – 39	20.8%	22.0%	14.2%	<0.001
40 – 49	16.3%	16.6%	17.7%	NS
50 – 59	14.0%	12.8%	21.3%	<0.001
60 – 69	8.9%	7.4%	17.2%	<0.001
70+ (max = 97)	5.4%	4.2%	12.0%	<0.001
Mean WBC count (SD)	13.3 (4.8)	13.2 (4.3)	14.5 (4.8)	<0.001
Cigarette smoker	21.8%	21.5%	22.8%	NS
Comorbidity Index				
0	86.1%	87.1%	80.4%	<0.001
1	11.3%	10.7%	14.1%	<0.001
2	1.8%	1.6%	3.2%	<0.001
3+	0.9%	0.6%	2.3%	<0.001
Race				
White	71.7%	71.6%	72.4%	NS
African American	2.7%	2.7%	1.8%	NS (0.055)
Asian	5.3%	5.4%	4.3%	NS (0.078)
Amer. Indian / Alaska	0.9%	0.8%	1.1%	NS
Hawaiian / PI	0.6%	0.7%	0.4%	NS
(Unknown)	19.0%	18.8%	20.00%	NS
Ethnicity				
White, non-Hispanic	65.4%	65.2%	66.7%	NS
*White, Hispanic**	8.0%	8.1%	7.5%	NS
Minority, non-Hispanic	9.3%	9.5%	7.5%	0.015
Minority, Hispanic	0.1%	0.1%	0.1%	NS
*Unknown Race**	17.3%	17.2%	18.2%	NS
Insurance				
Private	61.8%	63.6%	54.2%	< 0.001
Medicare	8.1%	6.4%	17.0%	< 0.001
Medicaid	8.4%	8.2%	8.2%	NS
Uninsured, Self-pay, Unknown	18.1%	18.0%	18.0%	NS
Other Gov't Prog.	3.6%	3.9%	2.7%	0.03
Pre-op imaging	93.3%	93.9%	93.9%	NS
Negative Appendectomy	4.1%	--	--	--
Perforation	15.8%	--	--	--

TABLE 2: Pre-operative Wait Times

	All Appendectomy	Non-perforated	Perforated	p-value
ER to OR time	8.6 hours (6.5)	8.6 (6.4)	8.6 (7.2)	NS
Image to OR time	7.8 hours (7.0)	7.8 (6.9)	8.2 (7.8)	NS
CT to OR (n=7641)	7.9 h (7.2)	7.8 (7.0)	8.3 (7.9)	NS (0.053)
US to OR (n = 707)	9.4 h (7.2)	9.4 (7.2)	7.7 (7.7)	NS
MRI to OR (n = 45)	9.5 h (13.8)	10.3 (14.7)	5.1 (6.1)	NS
ER to Image time	3.2 h (5.9)	3.2 (5.5)	3.4 (7.4)	NS

Table 3: Percent Perforation and ED-to-OR Time by Clinical and Demographic Groups

	Perforation (%)	ER to OR time (Mean, SD)	Median	Obs.
Male	17.3%	8.2 (6.2)	6.5	3847
Female	15.5%	9.0 (6.8)	7.1	3479
Age Distribution:				
18 – 29	8.4%	9.0 (6.8)	7.2	2600
30 – 39	11.3%	8.3 (5.9)	6.7	1520
40 – 49	17.7%	7.9 (5.7)	6.4	1180
50 – 59	24.7%	8.3 (6.2)	6.5	1004
60 – 69	31.5%	8.4 (6.6)	6.3	625
70+ (max = 97)	36.1%	10.0 (8.8)	7.0	399
Cigarette smoker (no)	16.2%	8.5 (6.5)	6.7	5648
Cigarette smoker (yes)	17.3%	8.9 (6.7)	7.1	1648
Comorbidity Index				
0	15.4%	8.4 (6.2)	6.7	6308
1	20.5%	9.4 (7.9)	6.9	814
2	28.0%	9.9 (7.5)	7.6	143
3+	43.4%	11.1 (9.0)	8.1	63
Race				
White	16.6%	8.4 (6.4)	6.6	5202
African American	11.7%	11.2 (8.9)	8.3	198
Asian	13.4%	8.8 (5.8)	7.4	370
Amer. Indian / Alaska	21.6%	8.2 (6.7)	6.5	61
Hawaiian / PI	9.6%	10.9 (8.7)	7.8	47
(unknown)	17.3%	8.7 (6.3)	6.9	1450
Ethnicity				
White, non-Hispanic	16.8%	8.4 (6.5)	6.6	4720
*White, Hispanic**	15.4%	8.4 (5.9)	6.8	615
Minority, non-Hispanic	13.4%	9.6 (7.2)	7.6	670
Minority, Hispanic	22.2%	6.2 (2.4)	6.7	6
*Unknown Race**	17.2%	8.6 (6.3)	6.9	1317
Insurance				
Private	14.3%	8.1 (6.0)	6.5	4372
Medicare	34.4%	9.6 (8.3)	6.8	585
Medicaid	16.4%	9.4 (7.2)	7.2	648
Uninsured, Self-pay, Unknown	16.4%	9.0 (6.7)	7.0	1466
Other Gov't Prog.	12.0%	9.1 (5.9)	7.8	257

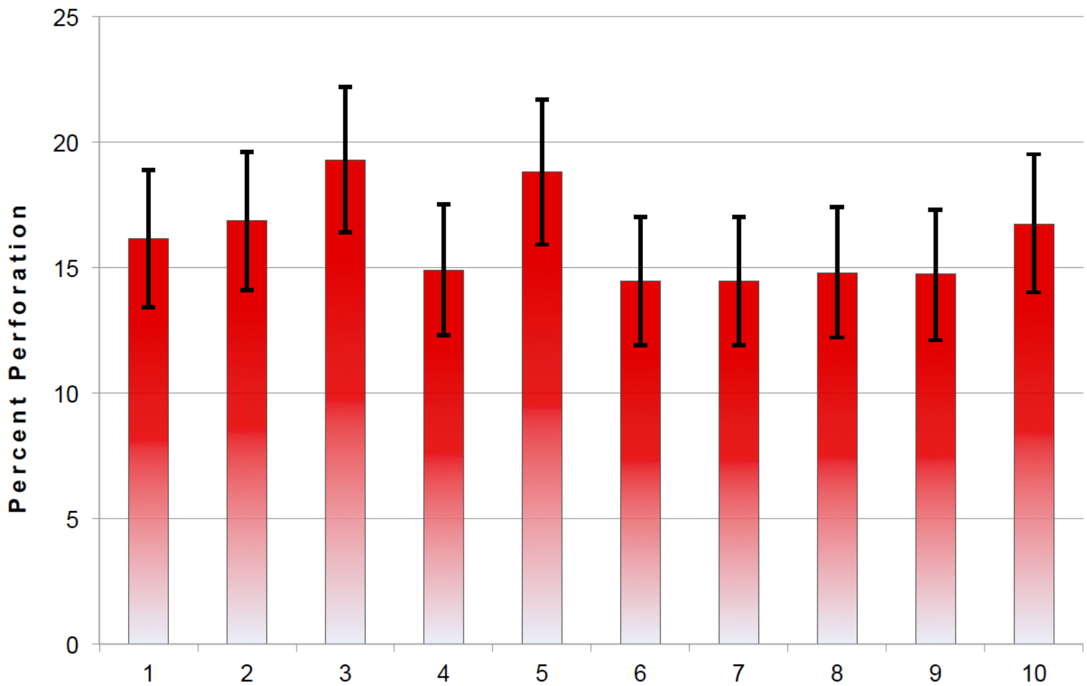
Table 4: Odds of Perforation, Unadjusted and Fully-Adjusted Regression Models

	Unadjusted OR	p-value	Fully Adjusted OR	P-value
ER to OR time (continuous variable)	1.00 (95%CI 0.99-1.01)	0.40	1.00 (95%CI 0.99-1.01)	0.91
Female	Reference	--	Reference	--
Male	1.17	< 0.001	1.24	0.003
Age (continuous)	1.04	< 0.001	1.04	< 0.001
Comorbidity Score				
0	Reference	--	Reference	--
1	1.40	0.001	0.99	0.925
2	2.44	< 0.001	1.32	0.064
3+	3.56	< 0.001	2.18	0.001
Race				
White	Reference	--	Reference	--
African American	0.68	0.094	0.65	0.064
Asian	0.73	0.054	0.68	0.004
Amer. Indian / Alaska	0.94	0.859	1.15	0.731
Hawaiian / PI	0.62	0.318	0.83	0.711
(unknown)	1.03	0.699	1.00	0.976
Ethnicity				
Not Hispanic	Reference	--	Reference	--
Hispanic	0.85	0.198	0.93	0.573
Unknown	1.09	0.211	1.08	0.476
Insurance				
Private	Reference	--	Reference	--
Medicare	3.05	< 0.001	0.98	0.867
Medicaid	1.1	0.424	1.24	0.099
Uninsured, Self-pay, Unknown	1.25	0.007	1.43	<0.001
Other Gov't Prog.	0.63	0.036	0.70	0.113
Hosp. Vol. (quartiles)				
First (lowest)	Reference	--	Reference	--
Second	0.81	0.301	0.87	0.407
Third	0.729	0.095	0.90	0.470
Fourth	0.69	0.045	0.84	0.288
Urban	Reference	--	Reference	--
Rural	1.3	0.018	1.15	0.183

Table 5: Clinical & Demographic Characteristics of the 1st and 10th Deciles of Patients

	Decile One	**Decile Ten**	P – value
N	707	706	--
Time Range	0.22 – 3.4 hours	15.3 – 63.1 hours	--
Mean Time (SD)	2.4 (0.8) hours	22.7 (9.4) hours	< 0.001
Median Time	2.6 hours	19.1 hours	--
Mean age	39.1 (15.2)	40.6 (18.2)	0.10
Median age	36	36	
% male	57.5%	42.4%	< 0.001
Mean WBC count	13.4 (4.5)	12.5 (4.5)	< 0.001
Comorbidity index:			
% 0	88.8%	81.7%	< 0.001
% 1	10.0%	13.3%	0.056
% 2	0.9%	2.8%	0.006
% 3+	0.3%	2.1%	0.002
% Caucasian	74.5%	70.3%	0.07
% African American	1.3%	5.0%	< 0.001
% Asian	4.0%	5.7%	0.13
% Other/not available	20.2%	19.1%	0.6
% Private Insurance	67.3%	52.7%	< 0.001
% Medicare	6.2%	10.8%	0.08
% Medicaid	6.4%	9.9%	0.01
% Other government	2.6%	3.4%	0.34
% Uninsured, Self-pay, & Unknown	17.5%	23.2%	0.008
Pre-op Imaging Use	86.1%	94.9%	<0.001
CT done at different facility	26.5%	2.2%	<0.001
% perforation (95%CI)	16.1 (13.4 – 18.9)	16.7 (14.0 – 19.5)	0.77

Figure 1: Percent Perforation, by Deciles of ED to OR Time



0.2 - 3.4 hours	**3.4 - 4.3**	**4.3 - 5.1**	**5.1 - 5.8**	**5.8 - 6.7**	**6.7 - 7.8**	**7.8 - 9.4**	**9.4 - 11.6**	**11.6 - 15.3**	**15.3 - 63.1**