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# Healthcare disparities in outcomes of patients with resectable pancreatic cancer

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ABSTRACT

*Background:* The aim of this study was to evaluate health disparities in the outcomes of patients with resectable pancreatic adenocarcinoma.
*Methods:* We retrospectively analyzed 280,935 patients from the National Cancer Data Base (NCDB), from 1998 to 2012 to compare the differences in patient characteristics, refusal of offered surgical treatment and overall survival after pancreatic adenocarcinoma resection between white vs. black patients.
*Results:* Black patients did not undergo and refused offered surgical treatment more frequently. Race and insurance were the most important factors independently associated with not receiving the offered resection. Having private insurance, Hispanic ethnic background, geographic location, higher income, residing in urban/metropolitan area and systemic treatment were independently associated with improved survival. Race was associated with overall worse survival in an unadjusted model but not in multivariable analysis. The association between race and survival was removed when adjusting for facility location, income, education, tumor size, tumor stage or systemic treatment.
*Conclusion:* Disparities exist at various levels in resectable pancreatic cancers. These findings help developing targeted interventions and quality improvement initiatives.


## Introduction

Pancreatic cancer is among the most lethal gastrointestinal cancers with the lowest 5-year survival of 8%.[1] As the epidemiologic landscape of cancer is evolving, mortality from pancreatic cancer is projected to have the fastest growth in the next two decades. By 2030, it is predicted to be the second leading cause of cancer related death in the United States.[2] The majority of patients are diagnosed with advanced stage disease, and effective systemic regimens remain elusive. Surgical resection is the only currently known treatment that offers a clinically meaningful increase in overall survival for early stage disease. Consequently, it is important to maximize the availability of surgical treatment for operative candidates with pancreatic cancer.

Disparities in outcomes and survival have been recognized and studied in a variety of cancers. Multiple studies have reported various disparities at the regional and national level with notable heterogeneity in the reported observations.[3–8] All-site cancer mortality rate is reported to be highest in non-Hispanic black patients. Although racial disparities have decreased in the past few decades, in 2014, cancer-related mortality was still 15% higher in black patients, compared to white patients.[9] A complex interplay of various factors including income, education, race and ethnicity as well as access to care and quality of provided care contributes to disparities in cancer outcomes.[10–12] The role of these factors warrants additional investigation and may motivate quality improvements on local, regional and national levels.

The purpose of this study was to evaluate racial disparities in the outcomes of patients with resectable pancreatic adenocarcinoma who undergo tumor resection. We used records from National Cancer Data Base (NCDB) of the American College of Surgeons (ACS) Commission on Cancer (CoC) to assess the impact of race/ethnicity, in association with various socioeconomic factors and clinicopathological features, on the short-term and long-term outcomes of these patients.

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## Materials and methods

*Study Population:* Data was obtained from the NCDB, a large retrospective national database which includes approximately 70% of all newly diagnosed cancer patients from 1500 Commission-accredited facilities including 74% of pancreatic cancer patients.[13] Among other variables, the NCDB pancreatic Participant User File includes information regarding American Joint Commission on Cancer (AJCC) tumor stage, the treatment modality delivered, and if pancreatic resection was not performed, a reason why it was not performed. We first selected all the patients with the diagnosis of pancreatic adenocarcinoma who were enrolled from 1998 to 2012. We initially focused on patients who did not undergo the offered surgical treatment. Next, we evaluated those patients who received surgical treatment and examined the disparities in survival after any form of pancreatic resection (pancreaticoduodenectomy, total, extended or distal pancreatectomy).

*Study variables:* The database includes a variety of demographic and socioeconomic factors including patient age, gender, race, median income, education level, insurance status, geographic location, residence location (rurality or urban influence), and distance between patient's residence and the treatment center. Median income is reported based on the median household income for the matching zip code of the patient's residence at the time of diagnosis, estimated by US Census data in 2000. Education level was reported as percentage of individuals who did not earn a high school degree in the residence area for the matching zip code as reported by US census data in 2000. This variable is distributed into four quartiles: 29% or more, 20–28.9%, 14–19.9% and less than 14% of the residents of that zip code without a high school degree. States were geographically categorized into 9 different groups: New England (CT, MA, ME, NH, RI, VT), Middle Atlantic (NJ, NY, PA), South Atlantic (DC, DE, FL, GA, MD, NC, SC, VA, WV) East North Central (IL, IN, MI, OH, WI), East South Central (AL, KY, MS, TN), West North Central (IA, KS, MN, MO, ND, NE, SD), West South Central (AR, LA, OK, TX), Mountain (AZ, CO, ID, MT, NM, NV, UT, WY) and Pacific (AK, CA, HI, OR, WA). A rural county is defined by a population <2500 or if the population <20,000 and not adjacent to a metropolitan area.

Patient outcomes were adjusted for clinicopathological features of the tumor including tumor size, grade, AJCC 7th edition stage (separately analyzed for T-category, N-category, and overall stage) as well as surgical factors including facility type, year of diagnosis and treatment, number of lymph nodes evaluated and margin status, and also systemic treatment. Studied outcomes included readmission rate, 30-day mortality, 90-day mortality and overall survival.

### *Statistical analysis*

Summary statistics were calculated for each variable as means and standard deviations for continuous variables and counts with proportions for categorical variables. T-tests and chi-square tests were used for bivariate comparisons. Logistic regression was used to model whether patients did not receive surgery with adjustment for covariates. Cox proportional hazards regression was used to test for unadjusted associations with survival outcomes. Initial survival models used generalized additive models to examine whether any associations were non-linear. Upon closer examination, while some nonlinear associations were found, the nonlinearities were not prominent and final models used Cox regression with linear covariates to simplify the presentation and interpretation. To examine which variables accounted for the unadjusted association between race and overall survival, we constructed a series of bivariate Cox models, each adjusting for race and an additional covariate to ascertain which variables resulted in race no longer being significant. All analyses were done in R.[14]

## Results

### *Patient population*

A total of 280,935 patients with pancreatic adenocarcinoma were identified. Of those, 84% were white, 11.6% were black, 3.0% had “other” racial background, and 1.4% were of unknown race. In this study we only included patients with white and black racial backgrounds; ethnicity is recorded as a separate, independent variable. While there was a slight male predominance in whites (51.5% vs. 48.5%), pancreatic cancer was reported in higher proportion of black females compared to males (54.7% vs. 45.3%). Black patients presented in more advanced stages with higher proportion of stage 3 (13.5% vs 12.6%) and stage 4 (59.8% vs. 57.9%) cancers, compared to white patients. The p-values for these racial distributions were statistically significant, with p values $< 0.001$ (Table 1).

### *Disparities in offering, and receiving the offered surgical treatment*

Surgical tumor resection was offered to 69,423 patients. Surgery was offered more frequently to white patients (62,250/225,842, 27.5%) compared to black patients (7173/31,272, 22.9%) ($p < 0.001$). In contrast, surgery was not performed (due to patient refusal or other reasons) on those who were offered surgical treatment, at a significantly higher proportion in black patients (1119/7,046, 15.8%) compared to white patients (7012/61,383, 11.4%). Black patients also more frequently refused offered surgical treatment (388/7,173, 5.4%) compared to white patients (2584/62,250, 4.1%). Multivariable analysis of factors associated with not receiving offered surgical treatment is presented in Table 2. In multivariable analysis, black race was an independent risk factor for not undergoing surgery (OR1.6, 95% CI 1.43–1.79). Other factors that are independently associated with not receiving surgical treatment include age, female gender, Hispanic ethnicity, lack of insurance, median income, comorbidities (Charlson/Deyo Score), and low income. Among factors studied, having insurance was strongly associated with lower probability of not undergoing surgical treatment (OR: 0.3, 95% CI 0.24–0.37 for private insurance and OR: 0.21, 95% CI 0.17–0.27 for any type of governmental insurance).

### *Disparities in outcomes of patients undergoing pancreatic tumor resection*

After selecting pancreatic cancer patients who underwent tumor resection, 62,858 patients were identified. Of those, 54,281 (86.4%) patients were white and 5927 (9.4%) were black. Again, there was a slight male predominance in whites (51.6% male vs 49.2% female) and a female predominance in blacks (56.2% females vs. 46.8% males). A higher proportion of whites were insured (97.7% vs. 94.5%), had private insurance (40.2% vs. 38%), or used Medicare (53.2% vs. 46.2%). A higher percentage of black patients were within the lowest quartile of median income (45.2% vs. 14.2%) and education (34.6% vs. 13.5%) compared to white patients. Table 3 shows comparisons of socioeconomic and clinicopathological features between black versus white patients with pancreatic cancer who underwent surgical resection.

*Unadjusted factors associated with overall survival:* The unadjusted hazard ratios between individual covariates and overall survival are shown in Table 4. Among sociodemographic factors, black race, non-Hispanic ethnic background, lack of insurance or Medicaid coverage, presence of comorbidities, lower quartile of median income and education, and residing in a rural area were

**Table 1**
Demographic features of white vs. black patients with pancreatic adenocarcinoma.

| Variable | Class | Total (%) | White (%) | Black (%) | p value |
|---|---|---|---|---|---|
| Sex | Male | 136025 (50.7) | 121279 (51.5%) | 14746 (45.3) | <0.001 |
| | Female | 132065 (49.3) | 114255 (48.5%) | 17810 (54.7) | |
| Insurance | No insurance | 7869 (2.9) | 6112 (2.6) | 1757 (5.4) | <0.001 |
| | Private insurance | 88367 (33.0) | 78400 (33.3) | 9967 (30.6) | |
| | Medicaid | 11534 (4.3) | 8365 (3.6) | 3169 (9.7) | |
| | Medicare | 149088 (55.6) | 132885 (56.4) | 16203 (49.8) | |
| | Other Government | 2236 (0.8) | 1901 (0.8) | 335 (1.0) | |
| Comorbidity | None | 135945 (68.1) | 120492 (68.9) | 15453 (62.5) | <0.001 |
| | Present | 63768 (31.9) | 54490 (31.1) | 9278 (37.5) | |
| Facility location | New England | 15075 (5.6) | 14344 (6.1) | 731 (2.2) | <0.001 |
| | Middle Atlantic | 43435 (16.2) | 38410 (16.3) | 5025 (15.4) | |
| | South Atlantic | 57114 (21.3) | 46001 (19.5) | 11113 (34.1) | |
| | East North Central | 49126 (18.3) | 43132 (18.3) | 5994 (18.4) | |
| | East South Central | 18007 (6.7) | 14892 (6.3) | 3115 (9.6) | |
| | West North Central | 22001 (8.2) | 20713 (8.8) | 1288 (4.0) | |
| | West South Central | 23257 (8.7) | 19773 (8.4) | 3484 (10.7) | |
| | Mountain | 12098 (4.5) | 11769 (5.0) | 329 (1.0) | |
| | Pacific | 27977 (10.4) | 26500 (11.3) | 1477 (4.5) | |
| Ethnicity | Non-Hispanic | 238096 (88.8) | 207783 (88.2) | 5520 (93.1) | <0.001 |
| | Hispanic | 12075 (4.5) | 11832 (5.0) | 58 (1.0) | |
| | Unknown | 17919 (6.7) | 15919 (6.8) | 349 (5.9) | |
| Median Income Quartile | <$38,000 | 49484 (19.1) | 34569 (15.2) | 14915 (47.4) | <0.001 |
| | $38,000-$48,000 | 62771 (23.5) | 55822 (24.6) | 6949 (22.1) | |
| | $48,000-$63,000 | 68322 (26.4) | 62866 (27.7) | 5456 (17.3) | |
| | >$63,000 | 77943 (30.1) | 73765 (32.5) | 4178 (13.3) | |
| Education (No High school degree) | >29% | 44888 (17.4) | 33289 (14.7) | 11599 (36.8) | <0.001 |
| | 20–29% | 67961 (26.3) | 56318 (24.8) | 11643 (36.9) | |
| | 14–20% | 84541 (32.7) | 78659 (34.6) | 5882 (18.7) | |
| | <14% | 61272 (23.7) | 58882 (25.9) | 2390 (7.6) | |
| Residence location | Urban | 242292 (95.1) | 211770 (94.8) | 30522 (97.7) | <0.001 |
| | Rural | 12411 (4.9) | 11693 (5.2) | 718 (2.3) | |
| Clinical Stage | 1 | 22631 (11.1) | 20097 (11.2) | 2534 (10.0) | <0.001 |
| | 2 | 36954 (18.1) | 32713 (18.3) | 4241 (16.7) | |
| | 3 | 25909 (12.7) | 22468 (12.6) | 3441 (13.5) | |
| | 4 | 118759 (58.1) | 103551 (57.9) | 15208 (59.8) | |

associated with lower overall survival. Compared to East North Central, hospitals in New England, Middle Atlantic, South Atlantic, Mountain, West North Central and Pacific had increased overall survival; this difference was not statistically significant with West Central and East South Central regions. Among the clinicopathological factors, grade of differentiation (poor or undifferentiated), positive margin, node involvement, higher stage of disease and lack of systemic treatment were associated with lower survival. Also, a lower number of examined nodes and lack of margin assessment were associated with lower overall survival.

*Multivariable analysis of factors associated with overall survival*: The adjusted model with multivariable analysis of the factors in association with overall survival is illustrated in Table 4. Having private insurance, Hispanic ethnic background, highest quartile of median income, residing in urban or metropolitan area and systemic treatment were significantly associated with improved survival. Presence of comorbidities (Charlson/Deyo score equal or greater than 1), higher stage of tumor, lower grade of differentiation of tumor, positive margin, no assessment of margin and node involvement were associated with lower overall survival. Geographic location was also independently associated with survival; compared to East North Central, other geographic locations (Middle Atlantic, Mountain, New England, Pacific, South Atlantic, West North Central) except East South Central and West South Central were independently associated with improved overall survival. Race was not independently associated with overall survival in the multivariable analysis.

*Factors accounting for the association between race and survival:* Table 5 shows the association between race and overall survival in a series of models each including race and one additional covariate.

**Table 2**
Multivariate analysis of factors associated with not receiving the offered surgery.

| Variable | Class | HR (95%CI) | p value |
|---|---|---|---|
| Race | Black (vs. white) | 1.6 (1.43–1.79) | <0.001 |
| Age | | 1.07 (1.07–1.08) | <0.001 |
| Sex | Female (vs. Male) | 1.15 (1.07–1.24) | <0.001 |
| Ethnicity | Hispanic (vs. non-Hispanic) | 1.06 (1.05–1.07) | <0.001 |
| Education level | | 0.97 (0.92–1.02) | 0.175 |
| Residence location | Rural (vs. urban) | 1.02 (1–1.05) | 0.047 |
| Distance[a] | | 1 (1–1) | <0.001 |
| Comorbidities | Charlson/Deyo Score | 0.91 (0.86–0.97) | 0.003 |
| Insurance | Private (vs. no insurance) | 0.3 (0.24–0.37) | <0.001 |
| | Governmental (vs. no insurance) | 0.21 (0.17–0.27) | <0.001 |
| Median income | >$63,000 (vs. <$63,000) | 0.85 (0.74–0.98) | 0.022 |

[a] Distance in miles between patient's residence and the hospital reporting the case.

**Table 3**
Demographic and clinicopathological features of patients with pancreatic cancers who underwent surgical resection of tumor.

| Variable | Class | Total (%) | White (%) | Black (%) | p value |
|---|---|---|---|---|---|
| Race | White | 54281 (86.4) | NA | NA | NA |
| | Black | 5927 (9.4) | NA | NA | |
| | Asian | 245 (0.4) | NA | NA | |
| | Others | 1018 (1.4) | NA | NA | |
| | Missing | 1387 (2.2) | NA | NA | |
| Sex | Male | 30596 (50.8) | 28002 (51.6) | 2594 (43.8) | <0.001 |
| | Female | 29612 (49.2) | 26279 (48.4) | 3333 (56.2) | |
| Insurance | No insurance | 1501 (2.6) | 1187 (2.3) | 314 (5.5) | <0.001 |
| | Private insurance | 23301 (40.0) | 21125 (40.2) | 2176 (38.0) | |
| | Medicaid | 2344 (4.0) | 1814 (3.5) | 530 (9.3) | |
| | Medicare | 30617 (52.5) | 27968 (53.2) | 2649 (46.2) | |
| | Other Government | 514 (0.9) | 453 (0.9) | 61 (1.1) | |
| Comorbidity | None | 30889 (67.6) | 28045 (68.2) | 2844 (62.6) | <0.001 |
| | Present | 14775 (32.4) | 13073 (31.8) | 1702 (37.4) | |
| Facility location | New England | 2827 (4.7) | 2706 (5.0) | 121 (2.0) | <0.001 |
| | Middle Atlantic | 10171 (16.9) | 9250 (17.0) | 921 (15.5) | |
| | South Atlantic | 13278 (22.0) | 11181 (20.6) | 2097 (35.4) | |
| | East North Central | 10994 (18.3) | 9898 (18.2) | 1096 (18.5) | |
| | East South Central | 4153 (6.9) | 3595 (6.6) | 558 (9.4) | |
| | West North Central | 4815 (8.0) | 4586 (8.5) | 229 (3.9) | |
| | West South Central | 5287 (8.8) | 4681 (8.6) | 606 (10.2) | |
| | Mountain | 2932 (4.9) | 2865 (5.3) | 67 (1.1) | |
| | Pacific | 5751 (9.5) | 5519 (10.2) | 232 (3.9) | |
| Ethnicity | Non-Hispanic | 53847 (89.4) | 48327 (89.0) | 5520 (93.1) | <0.001 |
| | Hispanic | 2644 (4.4) | 2586 (4.8) | 58 (1.0) | |
| | Unknown | 3717 (6.2) | 3368 (6.2) | 349 (5.9) | |
| Median Income Quartile | <$38,000 | 10177 (17.5) | 7579 (14.5) | 2598 (45.2) | <0.001 |
| | $38,000-$48,000 | 13693 (23.5) | 12414 (23.7) | 1279 (22.2) | |
| | $48,000-$63,000 | 15443 (26.5) | 14373 (27.4) | 1070 (18.6) | |
| | >$63,000 | 18889 (32.5) | 18083 (34.5) | 806 (14.0) | |
| Education (No High school degree) | >29% | 9087 (15.6) | 7094 (13.5) | 1993 (34.6) | <0.001 |
| | 20–29% | 15036 (25.8) | 12881 (24.6) | 2155 (27.5) | |
| | 14–20% | 19177 (32.9) | 18066 (34.4) | 1111 (19.3) | |
| | <14% | 14922 (25.6) | 14428 (27.5) | 494 (8.6) | |
| Residence location | Urban | 54490 (95.2) | 48942 (94.9) | 5548 (97.6) | <0.001 |
| | Rural | 2765 (4.8) | 2629 (5.1) | 136 (2.4) | |
| Tumor Grade | Well/Moderate | 32280 (62.1) | 28911 (61.7) | 3369 (65.8) | <0.001 |
| | Poor/Undifferentiated | 19688 (37.9) | 17941 (38.3) | 1747 (34.2) | |
| Margin | Negative | 41628 (73.7) | 37525 (73.8) | 4103 (73.2) | 0.826[a] |
| | Positive | 14025 (24.8) | 12633 (24.8) | 1392 (24.8) | |
| | Not assessed | 826 (1.5) | 712 (1.4) | 114 (2.0) | <0.001[b] |
| Pathological Stage | 1 | 8050 (15.4) | 7187 (15.3) | 863 (16.7) | <0.001 |
| | 2 | 32306 (61.6) | 29119 (61.8) | 3087 (59.9) | |
| | 3 | 7762 (14.9) | 7033 (14.9) | 729 (14.1) | |
| | 4 | 4233 (8.1) | 3759 (8.0) | 474 (9.2) | |
| Systemic treatment | None | 12880 (37.1) | 11526 (36.9) | 1354 (38.4) | 0.101 |
| | Received | 21848 (62.9) | 19673 (63.1) | 2175 (61.6) | |

[a] Positive vs. negative margin (excluding those not assessed).
[b] Positive vs. negative vs. not assessed.

The association between race and survival was no longer significant when adjusted for facility location, median income, education, number of examined nodes, tumor size, tumor stage or systemic treatment. In attempting to adjust the model for race and Table 4 covariates, the association between race and survival was preserved for the other parameters not listed in Table 5 (data not shown).

## Discussion

Currently, surgical resection is the only treatment option that can potentially provide long-term survival for patients with early stage pancreatic adenocarcinoma. Thus, we investigated healthcare disparities in the patients eligible for pancreatic resection; we evaluated a variety of demographic, socioeconomic and clinicopathologic factors with respect to overall survival. To our knowledge, this is the largest and most comprehensive study investigating survival disparities in patients with pancreatic cancer.

We observed a racial disparity in the receipt of surgical treatment for pancreatic cancer. Compared to white patients, resection was offered less frequently to black patients, and black patients were less likely to undergo resection even when offered. Previous studies examining resection rates in black patients are inconsistent with some showing lower rates of tumor resection,[3,6,15] and others not.[16,17] In a SEER database study, Murphy et al. reported that black and white patients were offered surgery at a same rate but black patients received surgical treatment less frequently.[18] Riall et al. reported that among the patients with resectable disease who underwent surgical evaluation, black patients had a lower resection rate.[15] Shah et al. demonstrated that black patients refuse surgery more frequently but emphasized the need for a large-scale study using a national database.[19] In contrast, Wray et al. showed equivalent rates of pancreatic cancer resection between the races[16] and Singal et al. showed slightly higher rate of tumor resection in African Americans.[17] Our study supports those published studies showing racial disparities in receiving surgery and strengthens the evidence by providing a larger study population and showing that racial disparity is independent from the

**Table 4**
Bivariate and multivariate analysis of sociodemographic and clinicopathologic variables on overall survival.

| Variable | Unadjusted model | | Multivariate Analysis | |
|---|---|---|---|---|
| | HR (95%CI) | p value | HR (95%CI) | p value |
| **Race black (vs. white)** | **1.04 (1.01–1.07)** | **0.020** | 0.98 (0.91–1.06) | 0.627 |
| **Sex Female (vs. Male)** | **0.94 (0.92–0.95)** | **<0.001** | 0.98 (0.94–1.03) | 0.442 |
| **Age** | **1.01 (1.01–1.02)** | **<0.001** | **1.01 (1.01–1.01)** | **<0.001** |
| **Insurance** (vs. None) | | | | |
| Private | **0.88 (0.83–0.94)** | **<0.001** | **0.85 (0.75–0.99)** | **0.035** |
| Medicaid | 1.00 (0.93–1.08) | 0.939 | 1.07 (0.91–1.27) | 0.418 |
| Medicare | **1.12 (1.06–1.19)** | **<0.001** | 0.95 (0.82–1.09) | 0.456 |
| Other Government | 0.88 (0.78–1.00) | 0.051 | 0.95 (0.74–1.21) | 0.683 |
| **Comorbidities** | **1.16 (1.13–1.19)** | **<0.001** | **1.15 (1.10–1.20)** | **<0.001** |
| **Geographic location** (vs. East North Central) | | | | |
| East South Central | **1.08 (1.04–1.13)** | **<0.001** | 1.03 (0.94–1.12) | 0.579 |
| Middle Atlantic | **0.91 (0.88–0.94)** | **<0.001** | **0.86 (0.80–0.93)** | **<0.001** |
| Mountain | **1.05 (1.00–1.10)** | **0.038** | **0.83 (0.74–0.94)** | **0.002** |
| New England | **0.92 (0.87–0.96)** | **<0.001** | **0.82 (0.73–0.92)** | **<0.001** |
| Pacific | **0.90 (0.87–0.94)** | **<0.001** | **0.85 (0.78–0.93)** | **<0.001** |
| South Atlantic | 0.99 (0.96–1.02) | 0.494 | **0.92 (0.86–0.98)** | **0.015** |
| West North Central | **0.91 (0.88–0.95)** | **<0.001** | **0.91 (0.84–0.99)** | **0.035** |
| West South Central | 1.02 (0.99–1.06) | 0.230 | 0.94 (0.86–1.02) | 0.154 |
| **Ethnicity** (vs. non-Hispanic) | | | | |
| Hispanic | **0.90 (0.86–0.95)** | **<0.001** | **0.83 (0.74–0.93)** | **0.001** |
| **Median income** (vs. <$38000) | | | | |
| $38,000-$48,000 | **0.94 (0.91–0.97)** | **<0.001** | 0.97 (0.91–1.05) | 0.146 |
| $48,000-$63,000 | **0.89 (0.86–0.91)** | **<0.001** | 0.94 (0.87–1.02) | 0.456 |
| >$63,000 | **0.81 (0.78–0.83)** | **<0.001** | **0.91 (0.83–0.99)** | **0.031** |
| **Education*** (Vs. >29%) | | | | |
| 20–29% | 0.97 (0.94–1.00) | 0.077 | 1.07 (0.99–1.15) | 0.056 |
| 14–20% | **0.92 (0.89–0.94)** | **<0.001** | 1.03 (0.95–1.11) | 0.483 |
| <14% | **0.84 (0.82–0.87)** | **<0.001** | 0.99 (0.91–1.09) | 0.906 |
| **Rural** residence (vs. urban) | **1.13 (1.08–1.18)** | **<0.001** | **1.12 (1.02–1.23)** | 0.021 |
| **Tumor grade poor/Undifferentiated** (vs. well/moderate) | **1.41 (1.38–1.44)** | **<0.001** | **1.42 (1.36–1.48)** | |
| **Margin Positive** | **1.71 (1.67–1.74)** | **<0.001** | **1.53 (1.46–1.61)** | **<0.001** |
| **Margin assessment** (Not assessed vs. assessed) | **2.20 (2.04–2.38)** | **<0.001** | **1.45 (1.08–1.94)** | **<0.001** |
| **Number of examined nodes** | **0.99 (0.99–0.99)** | **<0.001** | 0.99 (0.99–1.00) | **0.012** |
| **Node involvement** | **1.05 (1.05–1.05)** | **<0.001** | **1.11 (1.09–1.13)** | **<0.001** |
| **Pathologic stage** (vs. I) | | | | |
| II | **1.34 (1.30–1.39)** | **<0.001** | **1.21 (1.16–1.27)** | **0.021** |
| III | **1.80 (1.70–1.89)** | **<0.001** | **1.58 (1.42–1.76)** | **<0.001** |
| IV | **3.05 (2.90–3.20)** | **<0.001** | **2.09 (1.88–2.33)** | **<0.001** |
| **Systemic treatment** | **0.78 (0.76–0.80)** | **<0.001** | **0.62 (1.60-0.65)** | **<0.001** |

comorbidity parameters included in the NCDB. In addition, we identified that, independent of the socioeconomic factors we studied, black patients do not undergo offered surgical resection of pancreatic cancer as frequent as white patients do. Within the limitations of the NCDB, we were not able to identify some of the important underlying reasons such as physician factors and physician-patient dynamics that could be associated with higher rate of not receiving the offered surgical treatment and refusing surgery and this should be addressed in future studies. Nonetheless, these findings should raise awareness that when approaching patients with resectable pancreatic cancer, the surgical team should actively assess a patient's health literacy. Black patients may be particularly vulnerable to an incomplete discussion of the risks and benefits of surgical resection. Developing cultural awareness is a crucial step to improve dynamics of doctor-patient relationship and provide optimal care to the patients with diverse background and minimize health care disparities.[20]

We also observed that insurance status was the most important factor associated with undergoing the offered surgical treatment option. The role of insurance status with respect to surgical treatment and overall survival has been previously reported.[21,22] In a study on California Cancer Registry, Abraham et al. reported that compared to patients with Medicare/Medicaid, those who had other insurance products were more likely to undergo tumor resection.[3] Loehrer et al. studied the impact of health care expansion on disparities in pancreatic cancer in Massachusetts and showed that the state's 2006 health care reform was associated with a significant increase in pancreatic cancer resection.[23] Our findings reinforce the crucial role of insurance status in the receipt

**Table 5**
Impact of sociodemographic and clinicopathological factors on association between race and overall survival in pancreatic cancer patients who underwent tumor resection.

| Covariate | p value for race after adjustment[a] |
|---|---|
| Facility location | 0.122 |
| Insurance | 0.012 |
| Sex | 0.007 |
| Ethnicity | 0.024 |
| Median income | **0.322** |
| Education | **0.835** |
| Residence location | 0.006 |
| Comorbidities | **0.075** |
| Tumor grade | 0.002 |
| Margin status | 0.019 |
| Number of examined nodes | **0.053** |
| Positive nodes | 0.015 |
| Year of diagnosis | 0.011 |
| Age | <0.001 |
| Tumor size | **0.199** |
| AJCC pathologic stage | **0.708** |
| Distance travelled | 0.029 |
| Systemic treatment | **0.106** |

[a] p value for association between race on survival, after adding the variable to the multivariate model.

of cancer therapy. Other factors that had impact on refusing surgery were increased age, female gender, Hispanic ethnic background, presence of comorbidity, and median income. The impact of socioeconomic factors on pancreatic cancer outcomes remains an area of investigation.[24] Our findings support the hypothesis that low socioeconomic status is a barrier for receiving pancreatic cancer resection, which in turn can impact outcome.

Socioeconomic factors were also independently associated with survival of patients who underwent pancreatic cancer resection. While having any type of insurance was associated with better outcomes in the unadjusted model, only having private insurance was linked to improved outcomes in the multivariable analysis. The highest quartile of median income was also associated with better outcomes while education did not have a significant independent impact on patient outcome. On the other hand, living in a rural area was an independent factor associated with decreased survival. The evidence pertaining to the impact of socioeconomic factors on outcomes of pancreatic cancer is inconsistent.[8,25,26] Shapiro et al. reported that socioeconomic factors were not associated with survival of pancreatic cancer patients in a SEER-based study.[24] However, median income was not included in that study and when the impact of insurance was investigated, the comparison was made between insured versus uninsured patients. In the current study, we investigated various types of insurance and demonstrated that only private insurance was associated with better outcomes in multivariable analysis. We also included residence location (rural versus urban/metropolitan), which was not studied in previous reports and showed that rural patients have worse outcome.

Geographic location of patients and treatment facility was another independent factor associated with survival. Shapiro et al. showed that patients who received care in the Southeast had worse outcomes compared to those in the Northeast, Pacific and Midwest.[24] We further explored the impact of geographic location and showed that patients in the Middle Atlantic, Mountain, New England, Pacific, South Atlantic, and West North Central had improved survival compared to the East North Central while there was no survival advantage for patients in the East South Central and the West South Central areas. The impact of geographic location was independent of the studied socioeconomic factors and one explanation could be availability of specialized care in specific areas. Pancreatic cancer resection is complex and growing evidence supports centralization of care in specialized, high volume centers.[27] Some of the areas with lower survival mentioned above may suffer from the lack of adequate surgical care compared to those with better outcomes.[28] Various strategies have been proposed which may ultimately improve regionalization of cancer care to improve access to care, especially in underserved areas.[29,30]

Several clinicopathological factors were also independently associated with decreased survival, including presence of comorbidities, advanced tumor stage, poor tumor differentiation, positive margin status and nodal involvement. Our findings also corroborate the significance of systemic treatment as an independent factor for improved survival. It is notable that the impact of the above socioeconomic factors that were discussed above were independent from these clinicopathological factors.

We observed that race was associated with overall survival in an unadjusted model; however, this association was not significant in a multivariable analysis. The association between black race and lower overall survival was rendered non-significant by both socioeconomic and clinicopathological including facility location, median income, education, number of examined nodes, tumor size, tumor stage, presence of comorbidities and receipt of systemic. Several studies have previously investigated racial disparities in pancreatic cancer. Shapiro et al. studied the SEER database and showed no association between race and overall survival in patients with AJCC stage I and II disease.[24] In another SEER-based study, Riall et al. included resectable pancreatic cancer patients who were Medicare-enrolled and showed no racial disparity in patients who underwent resection of tumor.[15] Murphy et al. reported their investigation on a similar patient population without the above exclusions and demonstrated that while overall survival was decreased in all black patients, there was no racial disparity in those who underwent tumor resection.[18] In contrast, Singal et al. reported decreased survival in black patients, even after adjustment for treatment although they did not find any disparity in receipt of surgery.[17] NCDB is the largest national cancer database and registers about 70% of cancer patients. This is the first study published on NCDB focused on disparities in pancreatic cancers. Our findings help explain the differences observed in survival of patients with pancreatic cancer across the races. We have illustrated the factors that are associated with racial disparities and pancreatic cancer resection outcome. Eliminating disparities is an important step to improve outcomes in cancer care. Our findings provide a basis for future research and opportunities to impact health policy designed to eliminate disparities and improve the quality of cancer care.

Important studies previously published on disparities of pancreatic cancer outcome have used the SEER database.[15,17,18,24] Using the NCDB, the current study addresses several limitations of previous reports including broader inclusion and diversity, more comprehensive inclusion of socioeconomic factors, data regarding chemotherapy and other systemic treatments, accounting patients' comorbidities, margin assessment and margin status. The limitations of this study include the administrative nature of the NCDB and potential coding errors, as well as the retrospective nature the database. Nonetheless, the data in NCDB is quality controlled and standardized to enhance its validity. Moreover, there is substantial missing data regarding follow up and survival of patients who did not receive surgery, thus, we confined our survival analysis to resected patients. Especially in a large, overpowered dataset like the NCDB, not all comparisons that demonstrate statistical significance are clinically relevant. Consequently the relationships identified in this study merit additional study. Comorbidities in the NCDB are limited to Charlson/Deyo scores. Various important risk factors for pancreatic cancer such as molecular epidemiology and genetic factors, social habits such as smoking, alcohol consumption and nutritional status are not included in NCDB, and thus could not be addressed in this study. Another inherent limitation of our study is the use of zip code-based socioeconomic factors as opposed to individual-level information. Nevertheless, area-based assessment of socioeconomic factors has been shown to be a reliable surrogate in epidemiologic studies.[31–33] A patient's decision to proceed with pancreatic resection is complex, and reflects the perceptions and goals of each individual patient, shaped by the medical risks and benefits communicated by the surgeon. Since the NCDB database lacks important variables that contribute to a patient's decision for declining offered surgical treatment, one approach to eliminating this disparity is to identify and address these physician and patient related factors.

## Conclusion

Our results demonstrate that disparities exist at various levels in patients with resectable pancreatic adenocarcinoma. Racial disparities exist in the offer and receipt of resection and race is an independent risk factor in not undergoing offered surgical treatment. Lack of insurance is another important risk factor that contributes to refusal of tumor resection. Healthcare disparities also exist in the outcomes of patients who undergo surgical resection of

pancreatic cancer. Observed racial disparities in survival can be explained by socioeconomic factors and clinicopathological characteristics, and race is not an independent factor associated with outcomes of patients with pancreatic cancer who undergo surgical treatment. We have identified important socioeconomic factors that are associated with overall survival of patients with pancreatic cancer after tumor resection. We also demonstrate that geographic location plays an important role in the outcomes of patients who undergo tumor resection. Addressing these pancreatic cancer disparities may improve cancer outcomes and therefore should be the basis for additional study and quality improvement initiatives.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2018.12.007.

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