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SIGNATURE PAGE

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CARROLL COLLEGE

Colorectal Cancer

Analysis of cancer stage at diagnosis compared to insurance status, age, ethnicity, and year

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ABSTRACT

Colorectal cancer is the third most common type of cancer in the U.S., with about 138,000 diagnoses annually. Early diagnosis through screening dramatically increases patient survival rates. Insured individuals may have better access to cancer screening, and as a result, better health outcomes. The purpose of this study was to determine if insurance status affects the probability of a late stage colorectal cancer diagnosis. We analyzed 3006 cases of colorectal cancer from 2002 to 2011 gathered from the Montana Central Tumor Registry (MCTR) and used Chi-square tests to compare stage of cancer diagnosis to insurance status, ethnicity, age, and year. Results suggested that patient insurance status is an important indicator of the stage at which patients are diagnosed with colorectal cancer ($F=17.0515$, p-value=0.0002, critical value=9.210, alpha=0.01). These results support public health policy that extends health insurance coverage to a greater proportion of the population in order to decrease the probability of late stage colorectal cancer diagnoses and better community health outcomes.

BACKGROUND

The burden of colorectal cancer in the U.S.

An estimated 1,650,000 people in the U.S. were diagnosed with cancer in 2012.[1] Of those, about 136,717 were diagnosed with colorectal cancer. Furthermore, it is estimated that 5.6% of the U.S. population will be diagnosed with colorectal cancer in their lifetime.[2] Annual colorectal cancer diagnoses in the United States included around 70,000 men and 60,000 women and are the third and fourth leading cause of cancer in men and women respectively.[3] Mortality rates from colorectal cancer are estimated at 16.7 deaths per 100,000 in the U.S. each year.[3] However, colorectal cancer screenings have been found to be highly effective, and may prevent as many as 18,800 deaths from colorectal cancer annually. [4] Those diagnosed early are three times more likely to survive for five years than those diagnosed at later cancer stages.[5] Although effective colorectal cancer screening and diagnostic tools are readily available, incidence rates of disease remain relatively high nationwide.[6]

Colorectal cancer in MT

Colorectal cancer is a nationally notifiable disease monitored by the Centers for Disease Control and Prevention (CDC).[7] Cancer diagnoses are reported to CDC from local and state health departments, including from Montana, where reporting by health facilities is required under state law. Because cancer is a “reportable disease” in the state of Montana, all cases are reported to the Montana Department of Public Health and Human Services (DPHHS) and directed to the Montana Central Tumor Registry (MCTR).[8] Each case report submitted to the MTCR includes diagnosis type, cancer stage, treatments, patient follow-up, and cancer outcomes.[9] Data from the MTCR are used to analyze incidence, mortality, morbidity, survival, and changing population frequencies of cancer in Montana.[10] These data include those for colorectal cancer. Currently, Montana is ranked 26th in the nation for invasive colorectal cancer diagnoses, with annual incidence rates of 50 cases per 100,000 population.[11]

The stages of colorectal cancer

The National Cancer Institute (NCI) categorizes cancer diagnoses as stage 0, I, II, III, or IV. Each stage is associated with descriptive terms. “In-situ” refers to stage 0, which is a carcinoma that has not spread from the original site. “Localized” refers to developing cancer that is limited to the organ in which it began. Cancer of this type falls into stages I, II, and III. Stage IV, the final stage, includes regional and distant cancers. “Regional” refers to cancer that has spread beyond the primary site and into neighboring organs, lymph nodes, or tissues. “Distant” has spread to distant organs or lymph nodes. In this study, late stage colorectal cancer is referred to stage IV cancer while early stage colorectal cancer refers to stages 0-III.[12]

Conjectures associated with colorectal cancer screening

In has been proposed that screening for colorectal cancer decreases the likelihood of late stage cancer diagnoses and increases the chances of diagnosis before symptoms occur.[13] Insurance type may also dictate whether or not colorectal cancer screening is covered by an insurance plan, thereby influencing the likelihood of screening.

Insurance types and eligibility

Several types of insurance are available in the U.S. These include: 1) “Private” insurance, any insurance that is supplied by an employer, or is paid out-of-pocket by the individual. 2) “Government” insurance, or insurance paid for by the federal government, including Medicaid, Medicare, and Veteran’s Health Insurance. Despite insurance availability, many individuals are “uninsured”, or do not have membership with any insurance company.

A U.S. citizen may be eligible for one of the three government insurance programs if certain criteria are met. Eligibility for Medicaid is granted to low-income children or families, or a citizen with a disability. To be eligible for Medicare, a citizen must be 65 or older, or younger than 65 living with

certain disabilities.[14] Eligibility for Veterans' Administration for Veteran Health Insurance is granted to citizens with veteran status.[15]

Objectives:

The goals of this analysis were two fold. First we set out to determine if type of patient insurance coverage correlated with colorectal cancer stage at the time of diagnosis in Montanans between the years of 2002 and 2011, and second, to determine whether demographic characteristics of insured and uninsured individuals correlated with cancer stage at diagnosis in the same population. The null hypothesis of the study was that the probability of late stage diagnosis was the same in each category of insurance status and demographic characteristics. The alternative hypotheses were then defined. H1: The probability of colorectal cancer stage diagnosis correlates with insurance status. H2: The probability of colorectal cancer stage diagnosis correlates with ethnicity. H3: The probability of colorectal cancer stage diagnosis correlates with age. H4: The probability of colorectal cancer stage diagnosis correlates with time frame of diagnosis. If "p" represents the probability of late stage diagnosis, the hypotheses were:

Null hypothesis:

$$H_O: p_1=p_2=p_3\ldots p_i$$

Alternative hypotheses:

Not all p_i are equal (if i=1,2,3)

The broader impacts of this study were to determine if uninsured or underinsured individuals with subsequently limited access to colorectal screenings were disproportionally diagnosed with later stages of colorectal cancer. If citizens are more likely to be diagnosed earlier with colorectal cancer because of having insurance, then this would validate political efforts to try to extend coverage. Since early diagnosis also increases curability of the disease, economic burden would be greatly decreased by extending coverage.

METHODS

A secondary analysis was performed to test the hypotheses above. The data set was provided by the Montana DPHHS, Cancer Control Programs of the Chronic Disease Control and Health Promotion Bureau (CDCHP), through the Montana Central Tumor Registry (MCTR). MCTR data were generated from case reports received from institutions throughout Montana, including: "60 hospitals, two radiation centers, one Veterans' Administration Hospital, three pathology laboratories, and many out-of-state cancer registries".[16] All data were de-identified prior to use by the MT DPHHS to protect patient identity. No private health information was used in this analysis and HIPPA guidelines were strictly observed.

The SAS software was used to retrieve pertinent data from the MCTR.[17] Inclusion criteria for data consisted of any colorectal cancer diagnoses [coded according to the International Classification for Diseases of Oncology, 3rd Edition (ICD-0-3): C180-189; C260; C199-209] between the years of 2002 and 2011, in 50-75 year-olds. Ten years of data were included to ensure adequate sample size, with data from 2011 representing the most recently completed year of data collection. Individuals aged 50-75 years were included, because this age group meets the CDC's recommendations for undergoing colorectal cancer screening.[18] The time frame included was split in half, to compare two time periods of diagnoses. The initial age group was split into those aged 50-64 years and 65-75 years. This maintained a large enough sample size in each population, while representing potential insurance transitions between age eligible groups for Medicare (persons 65 years and older). All data outside of these parameters were excluded.

The stage of colorectal cancer at the time of the diagnosis was split into three categories: early stage; late stage; and unreported stage as follows: (0) Early stage including all coding for in-situ and localized tumors (stages 0-III); (1) Late stage including all coding for regional and distant tumors (stage

IV); (2) unknown stage of diagnosis. These data were compared to insurance status at time of diagnosis. A total of 3006 cases were included in the study.

Demographic variables assigned for each case consisted of ethnicity, and income level. Ethnicity was split into two groups: (1) "American Indian" and (2) "Other", because American Indians make up the largest minority group in the MCTR. Income level was split into sub-categories by assigning poverty levels based on a data from the US Census Bureau.[19] The categories were split as follows: (1) less than 10% of the households in the county living in poverty; (2) 10-14% of households in poverty; (3) 14-20% of households in poverty; and (4) greater than 20% of households in poverty. Each variable (including insurance status, cancer stage at diagnosis, age, poverty level, and ethnicity) for each case was assigned a value of 0-6 as indicated by the codes in Table A.

Table A. Data dictionary.

Variable Name	Values
Insurance Status	0=Not insured 1=Private Insurance 2=Government insurance (Medicaid, Medicare, VA) 6=Unknown
Stage	0=Early stage (in-situ, localized) 1= Late stage (regional, distant) 2=Unknown stage
Age group	1= 50-64 years 2= 65-75 years
Poverty level	1= 10% or less households in poverty 2= 10% -14% households in poverty 3= 14%-20% households in poverty 4= greater than 20% households in poverty
Year	0= 2002-2006 1= 2007-2011
Ethnicity	1=American Indian 0=Other

The counts represent the total number of individuals in each category. Missing data were present in age, poverty level, and insurance status categories yielding total samples sizes of 3004, 3003, and 2985 respectively (Table B).

Table B. Counts and percent of cases falling into each of the categories assigned to the study variables.

Counts and Percent of Individuals Per Category						
Assigned value	Insurance Status	Cancer Stage	Age	Poverty level	Time period	Ethnicity
0	153 (5.1%)	1267 (42.1%)	0	0	1455 (48.4%)	2870 (95.5%)
1	1030 (34.5%)	1630 (54.2%)	1425 (47.4%)	506 (16.8%)	1551 (51.6%)	136 (4.5%)
2	1673 (56.0%)	109 (3.6%)	1579 (52.6%)	1253 (41.7%)	0	0
3	0	0	0	986 (32.8%)	0	0
4	0	0	0	258 (8.6%)	0	0
6	129 (4.3%)	0	0	0	0	0

Insurance status, age group, poverty level, time period of diagnosis, and ethnicity were treated as independent variables and each was then compared to the stage of diagnosis (y) using a correlation analysis with pivot tables.

To test for statistical significance of correlations, chi-squared tests using contingency tables were conducted.[20] Unknown or missing data were removed before compiling contingency tables of the data (Table C).

Table C. Contingency table of insurance status compared to stage of diagnosis.

	Insurance Status			
Stage	**Uninsured**	**Private Insurance**	**Government Insurance**	**Total**
Late	109	557	906	1623
Early	41	448	726	1257
Total	150	1005	1632	2880

Proportions of late stage diagnoses compared to total diagnoses were used to create expected frequencies of insurance status compared to stage of diagnosis. These expected frequencies were calculated based on the null hypothesis that proportions of each should be the same (Table D).

Table D. Contingency table of expected outcomes of insurance status compared to stage of diagnosis based on the null hypothesis.

	Expected Outcomes (Insurance Status)			
Stage	**Uninsured**	**Private Insurance**	**Government Insurance**	**Total**
Late	84.53	566.36	919.7	1623
Early	65.47	438.64	712.3	1257
Total	150	1005	1632	2880

Finally, the test statistic was computed using the data in the previous two tables. The test statistic is as follows (Table E):

Table E. Chi-square test statistic.

$$\chi^2 = \sum \frac{(f_o - f_c)^2}{f_c}$$

f_o	f_c	$(f_o - f_c)$	$(f_o - f_c)^2$	$\frac{(f_o - f_c)^2}{f_c}$
109	84.53	24.47	598.7809	7.0836
557	566.4	-9.36	87.6096	0.1547
906	919.7	-13.7	187.69	0.2041
41	65.47	-24.47	598.7809	9.1459
448	438.6	9.36	87.6096	0.1997
726	712.3	13.7	187.69	0.2635

The test statistic was then compared to the critical value, found in the chi-squared distribution, based on the number of degrees of freedom (three for poverty level, two for insurance status, and one for age and time frame). Additional Chi square tests were performed for ethnicity, age, and time frame of diagnosis. Because multiple comparisons for proportions were performed in the overall chi-square test, the Marascuillo Procedure[21] was used to test which specific proportions were different from each other after rejection the null hypothesis. The probabilities for the insurance groups are shown below with subscript numbers correlating to values in the data dictionary (Table A):

p_0= 0.7267

p_1= 0.5542

p_2= 0.5551

The following equation was used to calculate the critical range, where the chi-squared value corresponds to an alpha value of α=0.01, and two degrees of freedom:

$$r_{j,i} = \sqrt{\mathcal{X}^2{}_{1-\propto,k-1}} * \sqrt{\frac{p_i * (1-p_i)}{n_i}} + \sqrt{\frac{p_j * (1-p_j)}{n_j}}$$

The test statistics were then compared to the critical ranges found for each analysis to determine if there was a statistically significant difference in probabilities.

RESULTS

The purpose of this study was to determine whether the probability of being diagnosed with late stage colorectal cancer was equal among all categories of insurance status, ethnicity, age, or time frame of diagnosis on multiple demographic variables. Correlation analysis revealed differences between uninsured and insured individuals, and stage of colorectal cancer at the time of diagnosis (Table F). Approximately 71% of people without insurance were diagnosed with a late stage cancer, while only 54% of those with private or government insurance were diagnosed with late stage cancer. Individuals without insurance were diagnosed with late stage cancer 1.5 times more frequently.

Table F. Stage versus insurance status counts and percents.

INSURANCE STATUS vs STAGE OF DIAGNOSIS							
	Stage of Diagnosis						
Insurance	**Early**		**Late**		**Unknown**		**Grand Total**
Uninsured	41	26.8%	109	71.2%	3	2.0%	153
Private	448	43.5%	557	54.0%	26	2.5%	1031
Government	726	43.4%	906	54.2%	41	2.5%	1673
Unknown Status	42	32.6%	51	39.5%	36	27.9%	129
Grand Total	**1257**	**42.1%**	**1623**	**54.4%**	**106**	**3.5%**	**2986**

Furthermore, chi-squared tests revealed that the null hypothesis, that the probability of diagnosis of late stage cancer in all categories of insurance status could be rejected. This means at least one of the test groups was statistically different from the others (F=17.0515, p-value=0.0001983, critical value=9.210, alpha=0.01). Poverty and ethnicity did not yield statistically significant results (F=0.8137, p-value=0.6657, critical value=11.345 and F=2.022, p-value=0.36385, critical value =6.635 respectively). The age had a test statistic of 11.0947 and a critical value of 6.635. This is statistically significant and may warrant further study.

When comparing poverty level to cancer stage (Figure 8), no differences were seen, with 52.27%, 54.99%, 53.95%, and 55.43% of late stage diagnoses corresponding to categories 1 – 4 respectively (Table G).

Table G. Poverty versus stage counts and percents.

POVERTY vs STAGE OF DIAGNOSIS							
	Stage of Diagnosis						
% of Households in Poverty	Early		Late		Unknown		Grand Total
≤10%	219	43.2%	265	52.3%	23	4.5%	507
10-14%	529	42.2%	689	55.0%	35	2.8%	1253
14-20%	413	41.8%	533	53.9%	42	4.3%	988
≥20%	106	41.1%	143	55.4%	9	3.5%	258
Grand Total	**1267**	**42.1%**	**1630**	**54.2%**	**109**	**3.6%**	**3006**

Similarly, when comparing ethnicity to cancer stage at diagnosis, American Indians were diagnosed 53.97% of the time with late stage cancer, compared to 59.56% for other ethnicities, or around 1.1 times more frequently (Table H).

Table H. Ethnicity versus stage counts and percents.

ETHNICITY vs STAGE OF DIAGNOSIS							
	STAGE						
Ethnicity	Early		Late		Unknown		Grand Total
Other	1218	42.4%	1549	54.0%	103	3.6%	2870
American Indian	49	36.0%	81	59.6%	6	4.4%	136
Grand Total	**1267**	**42.1%**	**1630**	**54.2%**	**109**	**3.6%**	**3006**

Results were similar when age was compared to cancer stage (Table I). Around 58 % of those in the 50-64 year age group were diagnosed with late stage cancer, while 51.14% of 65-75 year olds were diagnosed at late stage. The younger group was diagnosed just 1.1 times more frequently than the older

group. Our results indicated that of the variables tested, insurance status may have the largest influence on stage of colorectal cancer diagnosis.

Table I. Age versus stage counts and percents.

AGE vs STAGE OF DIAGNOSIS							
	Stage of Diagnosis						
Age	**Early**		**Late**		**Unknown**		**Grand Total**
50-64 years old	560	39.3%	822	57.6%	44	3.1%	1426
65-75 years old	707	44.7%	808	51.1%	65	4.1%	1580
Grand Total	**1267**	**42.1%**	**1630**	**54.2%**	**109**	**3.6%**	**3006**

The Marascuillo Procedure was used to determine which insurance group was causing the rejection of the null hypothesis. Results indicated that the non-insured group was significantly different than the insured groups in regard to colorectal cancer stage at diagnosis (Table J).

Table J. Summary of Marascuillo Procedure results.

Contrast	Value	Critical Range	Significant
$\lvert p_0 - p_1 \rvert$	0.1725	0.12024	yes
$\lvert p_0 - p_2 \rvert$	0.1716	0.11657	yes
$\lvert p_1 - p_2 \rvert$	-9.00E-04	0.06048	no

DISCUSSION

Based on this analysis, insurance status correlates with later stage of colorectal cancer at time of diagnosis. Around 1.5 times more uninsured individuals were diagnosed with a late stage of cancer compared to insured individuals, which was determined to be a significant increase. This could be for a number of reasons. Uninsured individuals may receive less frequent primary or preventative care and be less likely to seek medical attention when sick or symptomatic if cost is a burden. Lack of preventative care has been used recently to drive policy changes in the United States, which aim to extend universal health coverage to all Americans. The Affordable Care Act[22] provides an example of how changes in health policy will eventually expand health coverage to 32 million uninsured Americans.[23] The results of this study demonstrate that insurance coverage correlates with earlier detection of colorectal cancer, corresponding to stages 0, I, II, or III. Based on our results, policies aimed at expanding health coverage to more uninsured Americans could be considered an effective method for lowering colorectal cancer prevalence rates and corresponding patient prognoses. With this in mind, the recommendation from this study would be to support the expansion of healthcare to the uninsured in the hopes of decreasing rates of late stage diagnoses of colorectal cancer.

The results herein demonstrated that private and government insurance are equally as effective in reducing rates of late-stage diagnoses compared to those without insurance. Neither private nor government insurances were significantly different from the expected outcomes.

Further analysis is recommended to determine the level of correlation between age statistics and stage of diagnosis. If the latter age group is more likely to be diagnosed with late stages of cancer, then it is possible that the CDC recommendations of when to get screened may not be yielding adequate preventative measures based on age. For example, the rate of late-stage diagnosis could go down if the older population was screened more often. Screening for colorectal cancer is not only helpful for early detection, but also prevention if polyps are found and removed before cancer develops.[24]

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