
Lung and Bronchus Cancer Disparities in South Carolina: Epidemiology and Strategies for Prevention

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Cancers of the lung and bronchus are by far the leading cause of cancer death in the United States (U.S.). According to 2006 estimates, the number of deaths from lung cancer will soon surpass the combined total of the next four leading causes of cancer death.¹ The projected number of new cases of lung and bronchus cancer in 2006 is 162,460 nationally, with 2,830 of these occurring in South Carolina.¹ These 2,830 lung cancer deaths make lung cancer by itself the third leading cause of death in South Carolina, after heart disease and deaths from all other malignancies.³ In the U.S. in 2006, cancers of the lung and bronchus are expected to account for an estimated 29% of all deaths from cancer: 31% among men and 26% among women.² The proportionate mortality from lung cancer in South Carolina was slightly higher, 31% of overall cancer deaths, 36% in men and 25% in women.²

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The substantial contribution of lung cancer to the overall mortality burden is due to the combined effects of a disease that has a high incidence rate and a poor overall five-year relative survival rate of 16%.⁵ The five-year relative survival rate varies markedly depending on the stage at diagnosis, from 49% to 16% to 2% for local, regional, and distant disease, respectively.⁵ Stage at diagnosis accounts for the most marked variation in prognosis, but patient characteristics associated with poorer survival also include being older, male, and African American (AA).⁵ Of South Carolina lung cancer patients who were staged in 2002, approximately 30% were diagnosed with regional disease and 50% were diagnosed with distant disease.² The distribution of lung cancer by stage at diagnosis does not show marked variation across gender-race subgroups.² Due to the fact that most lung cancers are diagnosed in late stages and the survival rate for late-stage disease is so poor, lung cancer incidence rates closely parallel mortality rates.

Nationally, lung cancer incidence and mortality rates are currently much higher in men than women, but the gap is narrowing as the rates in men have decreased during the past 15 years, whereas the rates in women rose steadily during the past five decades.⁶ Nationally, the age-adjusted lung cancer incidence rates are 61% higher in men than women (86.4 versus 53.7 per 100,000/year), but this differential is even more pronounced in South Carolina, where the rates in males exceed those in females by 106% (103.1 versus 50.2 per 100,000/year).^{2,7} Men in South Carolina have the ninth highest lung cancer incidence rates in the U.S., whereas SC females rank 35th.¹

A troubling aspect of the occurrence of lung cancer in South Carolina is that the favorable downward trend in men seen nationally during the past 15 years is not yet discernable. In South Carolina men, there is no evidence of a monotonic downward trend from 1997 through 2002, with the age-adjusted incidence rates (per 100,000) during this period of 107.0, 108.5, 115.6, 107.8, 110.5, and 103.1, respectively.² Based on historical smoking patterns, the downward trend in nationwide data in men can be expected to continue for approximately another 20 years. Conversely, the epidemic of lung cancer in women has only recently crested, with a decline in lung cancer incidence rates in women anticipated in the coming decades.

Lung cancer is the leading cause of cancer death across gender and racial groups, both nationally and in South Carolina (SC). However, the rates vary markedly between population subgroups (Figure 1). In South Carolina in 2002, the highest age-adjusted lung cancer incidence rates were in AA men (107.9 per 100,000/year), with rates in European-American (EA) men, EA women, and AA women that were 6%, 51%, and 63% lower, respectively. The 6% higher age-adjusted lung cancer incidence rates in SC AA than SC EA men (107.9 versus 101.8 per 100,000 per year)² is narrower than the 24% differential seen nationally (105.7 AA versus 85.6 EA per 100,000 per year in 2002).⁷ However, while the racial/ethnic disparity among men in South Carolina is less, this is due to higher rates in SC EA than US EA men (not lower rates in SC AA men than US AA men). Nationwide in 2002, the age-

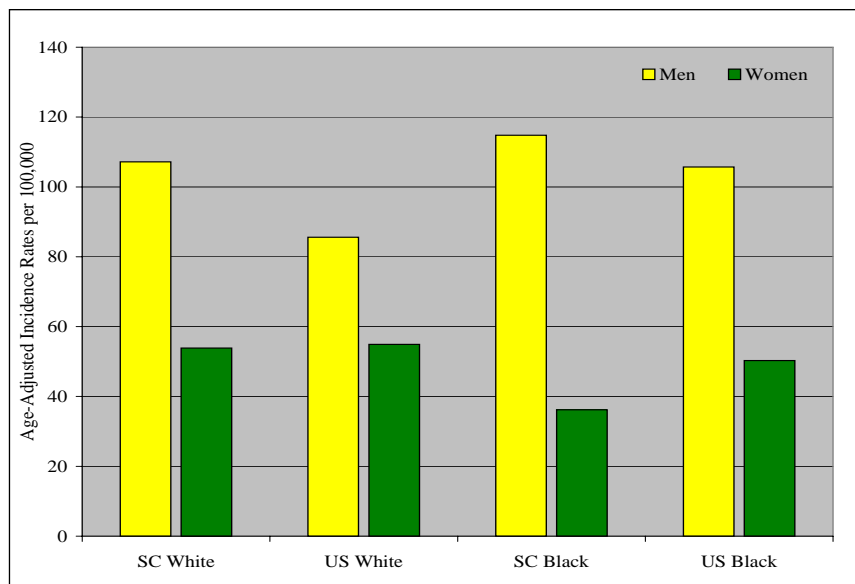


Figure 1. Lung and Bronchus Cancer Age-Adjusted Incidence Rates (1998-2002) per 100,000 by Race and Gender in SC, US (2002)

adjusted lung cancer incidence rates in AA women were 8% less than in EA women (50.3 versus 54.9 per 100,000 persons/year).⁷ A greater difference exists in South Carolina, where AA women had rates 24% lower than EA women (40.3 versus 53.0 per 100,000/year);² the wider gap in SC was a consequence of markedly lower lung cancer incidence rates in SC AA women compared to US AA women.

A comparison of age-adjusted lung cancer mortality rates during 2000-2004 in South Carolina yields patterns very similar to the incidence patterns noted above, with a mortality rate 10% higher in AA men than in EA men, whereas the mortality rate in AA women was 30% lower than in EA women. As noted above, mortality rates are a function of both the incidence rates and survival from lung cancer. Nationally during 1995-2001, the five-year relative survival rate was lower in AA compared to EA; 11% lower in men and 15% less in women, and this racial gap persisted across diagnostic stage.⁵

Comparing the county-specific age-adjusted lung cancer rates for SC AA males to the state EA rate revealed a statistically significantly greater AA incidence rate in

9% of counties and greater AA mortality rates in 17% of counties (Figure 2 and Figure 3). Among women, compared to state rates for EA women, AA women had significantly lower incidence and mortality rates of lung cancer in approximately 40% of SC counties.

In summary, a comparison of the patterns of occurrence of lung cancer in South Carolina to the U.S. as a whole reveals three notable features of the SC rates among males: 1) the rates in SC are much higher than the overall national rate; 2) the absence of the downward trend in rates over time, which has been clear and pronounced for over 15 years in the U.S.; and 3) the rates in African Americans are as high as national rates, but the racial disparity in male lung cancer rates in South Carolina (6%) is less pronounced than nationally (24%) due to the very high rates in SC EA men. Among women, in South Carolina the incidence rate in AA women was 24% lower than EA women, considerably less than the 8% difference in rates seen nationally.

Cigarette Smoking: The Predominant Cause

The predominant cause of lung cancer is cigarette smoking, which accounts for ap-

proximately 85% of the lung cancer burden.⁸ On average, a patient's individual risk of lung cancer is largely determined by smoking history and age. The smoking-associated risk of lung cancer is extremely strong and follows clear-cut dose-response gradients, increasing with the number of cigarettes smoked per day and the number of years of smoking.⁸ A current smoker benefits from quitting smoking at any age. Compared to persistent smokers, the risk of lung cancer decreases after smoking cessation and continues to decrease further with longer duration of sustained cessation.⁹ However, compared to never smokers, the residual risk of lung cancer in quitters lasts many decades,¹⁰ indicating the powerful carcinogenic effects of cigarette smoke are exerted broadly across the multi-step pathway of lung carcinogenesis.

The link between cigarette smoking and lung cancer is so strong that population patterns in the historical prevalence of cigarette smoking can be used to predict the future occurrence of lung cancer.¹¹ The epidemic rise in lung cancer rates is closely linked with a two- to three-decade lag in the population prevalence of cigarette smoking.¹¹ Thus, assessing race- and sex-specific smoking prevalence can assist in developing strategies to reduce the burden of disease and can deepen our understanding of racial disparities in lung cancer incidence and mortality.

Active cigarette smoking accounts for most of the lung cancer burden, but secondhand smoke exposure is estimated to cause an additional 3,000 lung cancer deaths nationally per year.¹² Cigar smoking also is an established cause of lung cancer.¹³ The lung cancer risks associated with cigar smoking are substantial, but less than the risks observed for cigarette smoking due to differences in smoking frequency and depth of inhalation. The same pattern holds true for pipe smoking.¹⁴

Epidemiology of Cigarette Smoking

In 2004,¹⁵ nationwide prevalence of cigarette smoking was 24% in AA males,

24% in EA males, 20% in EA females, and 17% in AA females. National Health Interview Survey data show that among males, AA and EA were equally likely to be daily smokers (21%) but AA males smoked one-third fewer cigarettes per day than EA (14 versus 21 cigarettes per day).¹⁶ A similar pattern is evident among women, as only 16% of AA were daily smokers compared to 19% of EA. As in men, AA women who smoked daily smoked fewer cigarettes than their EA counterparts: 12.3 versus 17.0 cigarettes smoked per day, respectively.¹⁶

In South Carolina, as in the nation as a whole, it is not understood why the incidence of lung cancer in AA men is higher than in EA men given that the overall daily number of cigarettes smoked is actually lower in AAs. The rates in AA men are higher than would be expected if one were to predict cancer outcomes based on cigarette smoking prevalence and intensity of smoking alone. Results from the Multi-Ethnic Cohort Study provide strong evidence that AA smokers are more susceptible to smoking-induced lung carcinogenesis.¹⁷ The reasons underlying this enhanced susceptibility are not known, but research has focused on two different lines of inquiry: 1) the type of cigarettes smoked and 2) intrinsic host factors affecting inter-individual susceptibility to carcinogens in cigarette smoke.

With respect to the type of cigarettes smoked, the prevalence of smoking mentholated cigarettes is 69% among African Americans compared to 22% among EA smokers.¹⁸ The hypothesis has been proposed that menthol cigarettes may increase the risk of lung cancer even more than non-menthol cigarettes; if so, the greater prevalence of menthol cigarette use in AAs compared to EAs may contribute to the racial disparity in lung cancer incidence rates.^{18,19} Menthol cigarettes could be associated with greater risk, for example, if smokers of menthol cigarettes inhaled more deeply than smokers of non-menthol cigarettes because of the local anesthetic effects of menthol.²⁰ Another

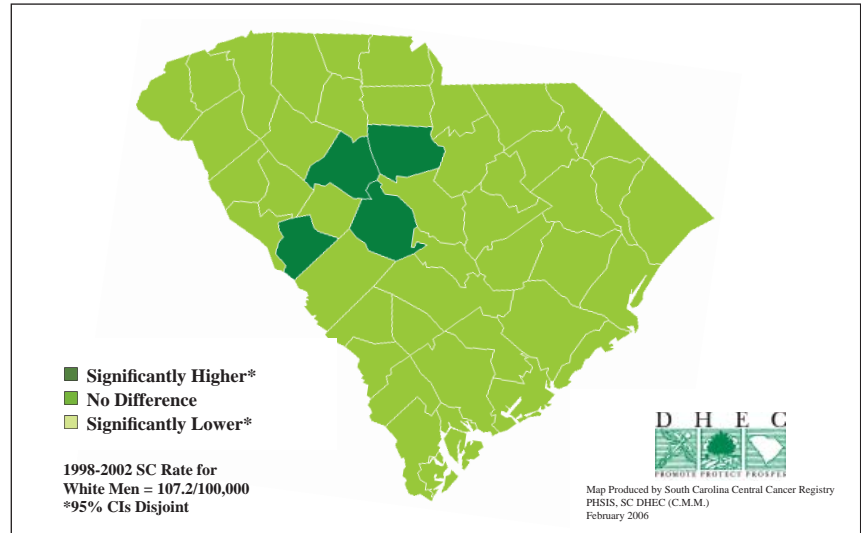


Figure 2. South Carolina Lung Cancer: Comparison of the Age-Adjusted, County-Specific Incidence Rate for Black Males vs. the Age-Adjusted, State-Specific Incidence Rate for White Males (1998-2002)

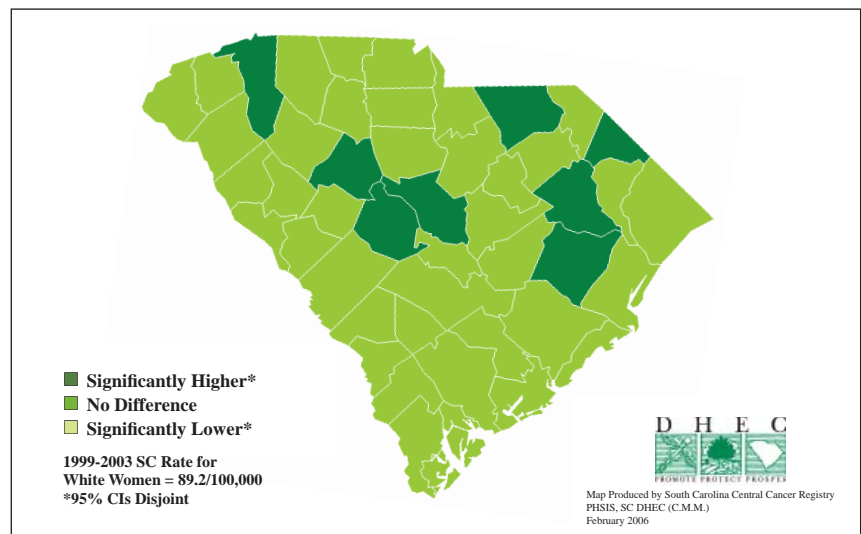


Figure 3. South Carolina Lung Cancer: Comparison of the Age-Adjusted, County-Specific Mortality Rate for Black Males vs. the Age-Adjusted, State-Specific Mortality Rate for White Males (1999-2003)

mechanistic pathway may be by menthol stimulating an increase in membrane permeability to carcinogens.²¹ Furthermore, menthol cigarette smokers may have a greater potential for nicotine dependence that undermines successful quitting.^{19,20} AA smokers are less likely than EA smokers to successfully quit smoking.²² This is despite several lines of evidence showing that AA smokers are more motivated to quit than are EA smokers.^{16,22} However, the evidence to date suggests that menthol

cigarette smokers do not have a greater risk of lung cancer than non-menthol smokers,²³⁻²⁶ regardless of racial/ethnic group.^{23,24} Gaps in the evidence have been identified, including that evidence is lacking on this topic from studies conducted in the rural south, where the majority of AAs reside.²⁷

With respect to inter-individual differences in susceptibility, few studies have been designed specifically to make comparisons

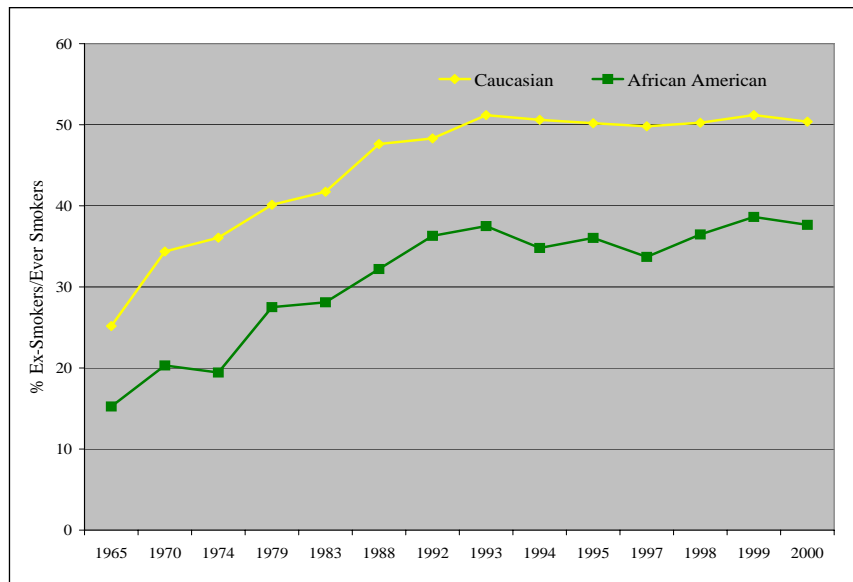


Figure 4. Quit Ratio by Race. Source: www.cdc.gov/tobacco. Note: Years reflect NHIS survey years.

between AA and EA. Biomarkers of tobacco carcinogens have been observed to be present in higher concentrations in AA male smokers compared to EA male smokers per unit exposure.²⁸ In a case-control study, stronger risks of lung cancer in AA than EA have been observed for phenotypic markers such as mutagen sensitivity and cell cycle arrest.^{29,30} Despite intensive study of lung cancer risk in relation to polymorphisms in genes, which encode proteins involved in DNA repair and carcinogen metabolism and detoxification,^{31,33} few studies have made comparisons of these associations in AA compared to EA.

In comparison to EA, AA smokers report greater motivation to quit as demonstrated through both self-report and behavioral data. AA smokers are more likely to want to quit smoking and are more likely to make a quit attempt.^{16,22} Results from the National Health Interview Survey¹⁶ show that 45% of AA male smokers vs. 40% of EA male smokers made a quit attempt in the past 12 months. For women, the equivalent rates were 47% vs. 43%. However, although motivation to quit appears to be higher among AAs, this does not translate to successful quitting. In fact, the quit ratio (proportion of ever smokers who have

quit) has been consistently lower among AA smokers (Figure 4). The most recent data indicate that 37% of AA smokers have quit, compared to 49% of EAs. Thus, it appears AA smokers may be more motivated to attempt to quit, but less likely to successfully do so.

Results of some case-control studies have suggested a potentially higher risk of smoking-associated lung cancer in women compared to men.³⁴ However, the evidence from prospective cohort studies fails to support the notion of a sex-differential in susceptibility to lung cancer from smoking.³⁵ Equal rates of lung cancer mortality exists between younger U.S. men and women, and these rates correspond to a time of equal smoking prevalence. This provides evidence against an important gender difference in susceptibility to smoking-induced lung cancer.³⁶ Current evidence against the gender difference hypothesis outweighs the evidence in favor. This evidence primarily comes from studies demonstrating similar associations between relative risk estimates for men and women for a specific degree of smoking history.³⁵

Additional Risk Factors

In addition to tobacco smoke exposure,

many other factors are established causes of lung cancer. A number of agents have been identified as lung carcinogens based on evidence obtained from workers exposed to these substances at relatively high concentrations. These include chromium, nickel, arsenic, asbestos, and radon.³⁷⁻³⁹ The relative contribution of occupational exposures to the lung cancer burden, though substantial at approximately 10%,⁶ is diminishing over time. This recent trend is due to steps being taken to minimize workplace exposures as agents are identified as lung cancer risk factors.³⁷

Radon is an inert gas produced naturally from radium in the decay series of uranium. Because it enters buildings in soil gas, it is a common indoor air pollutant. The U.S. Environmental Protection Agency estimates approximately 15,000 to 20,000 lung cancer deaths per year in the United States are caused by radon.⁴⁰ Studies of radon exposures in residential settings indicate a level of lung cancer risk associated with indoor radon exposure is consistent with this prediction.⁴¹

In addition to the known, established causes of lung cancer, many other factors have been studied in relation to risk. The evidence is solidifying that outdoor air pollution contributes to lung cancer risk, and may be responsible for 1-2% of the overall lung cancer burden.⁴²

The identification of lifestyle factors other than cigarette smoking that affect lung cancer risk could expand the menu of options for the primary prevention of lung cancer. Diet and physical activity are examples of factors that have been studied in this regard. The results of case-control and prospective cohort studies have tended to show that individuals with high dietary intake of fruits or vegetables have a lower risk of lung cancer than those with low fruit or vegetable intake.⁴³ Behavioral Risk Factor Surveillance System (BRFSS) survey data reveal that in South Carolina in 2003, the prevalence of eating five or more fruits and vegetables per day was 13% lower in

Table 1. South Carolina 2000 BRFSS data by race and gender: How old were you when you first started smoking cigarettes regularly?*

	Never Smoked (%)	Ever Smoked (%)			
		< 14 years	15-16 years	17-18 years	>19 years
Total	48	12.8	20.8	25.5	36.2
Gender					
Male	55	14.7	22.4	25.5	31.9
Female	39	10.8	19.1	25.4	40.8
Race					
White	46	13.4	22.4	25.8	33.8
Black	58	6.3	13.0	22.3	52.6
Others	51	28.9	20.4	28.0	17.6

*This question was asked of all respondents who reported smoking 100+ cigarettes in his/her lifetime.

AA than EA,⁴⁴ documenting a difference between racial/ethnic groups with respect to this potentially protective health behavior. Although protective associations have been observed with increased fruit and vegetable consumption, the specific constituents of fruits and vegetables that might confer protection are unknown. For example, the results of large-scale randomized primary prevention trials now clearly indicate that regular use of dietary supplements containing beta-carotene⁴⁵⁻⁴⁷ or vitamin E^{48,49} does not protect against lung cancer. In fact, in high-intensity smokers, beta-carotene supplements increased lung cancer risk.^{45,47}

Several studies have reported that more physically active individuals have a lower risk of lung cancer than those who are more sedentary,⁵⁰ even after adjustment for cigarette smoking. Physical activity has yet to be studied in relation to lung cancer risk in an AA population. To the extent physical activity is relevant to lung cancer, it is worth noting BRFSS survey data indicate that among adults in South Carolina in 2003, the prevalence of getting 20 minutes or more of physical activity on three or more days per week was 18% less in AA than EA.⁴⁴ As with the assessment of any lifestyle factor other than smoking with lung cancer risk, potential

residual confounding by cigarette smoking must be considered a viable explanation until proven otherwise.

Screening for Lung Cancer

Screening for lung cancer has been controversial for over three decades. Early large randomized controlled trials (RCTs) of screening sponsored by the National Cancer Institute (NCI) as well as a Czechoslovakian study tested chest roentgenograms and sputum cytopathologic examination in various combinations. None demonstrated a decrease in lung cancer-related mortality,⁵¹⁻⁵⁵ the ultimate goal of any lung cancer screening program. It follows from this finding that increased detection of early-stage, resectable lung cancer does not prolong life. Factors such as inadequate statistical power and choice of a control arm are cited as limitations of these trials. Consequently, no cancer-related organization recommends screening for lung cancer. In general, the effectiveness of a lung cancer screening program is enhanced by minimizing the number of invasive tests for confirming a lung cancer diagnosis and by targeting a high-risk population. These steps decrease the unnecessary testing on those without cancer and increasing the yield of the screening program.

Advancements in imaging technology

have spurred a renewed interest in lung cancer screening. Low-radiation-dose CT (LDCT) imaging techniques use low levels of ionizing radiation to generate a low-resolution image. This technique is faster and less costly than standard helical CT scanning, but it is approximately four times more sensitive than a standard chest roentgenogram. The hypothesis is that LDCT will detect a lung malignancy at an earlier, and therefore more treatable, stage than the standard chest radiograph. Two observational studies evaluated LDCT in persons who were at high risk of lung cancer due to significant smoking histories. Of all suspicious nodules detected by LDCT, 10-13% were biopsy-confirmed as cancer, and most (53-81%) were stage I.⁵⁶⁻⁵⁹ The detection of a significant number of stage I cancers is a promising finding, but the mortality benefit is currently unknown.⁶⁰ An important consideration regarding LDCT as a screening tool is that its high sensitivity will result in many false positive test results, leading to the downstream effects of unnecessary invasive testing and surgical procedures. Furthermore, some detected cancers would never have progressed to clinical disease (i.e. overdiagnosis). Whether or not the aggregate morbidity and mortality associated with detecting lung cancers at an early stage with LDCT will be outweighed by reduced lung cancer mortality rates remains to be seen. These questions will be resolved by the NCI-sponsored National Lung Screening Trial (NLST), in which more than 50,000 persons were randomized to either chest radiograph or LDCT for three annual screens. Preliminary results are expected in 2009. The Medical University of South Carolina is a participating site in this study.⁶¹

Other screening modalities for lung cancer are under investigation. In one study, lesions over 7mm in size were evaluated with positron-emission tomography (PET) scanning plus LDCT; this combination successfully identified 90% of cancers, but also resulted in biopsies of 50% of false-positive tests.⁶² Screening with molecular markers, such as volatile

organic acids and microsatellite DNA alterations detected in exhaled condensate, has recently been tested.⁶³⁻⁶⁵ The application of proteomics could potentially generate a specific blood and tissue-specific antibody profile that mirrors the natural history of lung cancer at a molecular level.^{66,67} The expression pattern of specific microRNAs have been observed to be able to distinguish lung tumors from adjacent normal tissue; if these findings are replicated, this could potentially provide a new strategy for the early detection of lung cancer.⁶⁸

Conclusions

The optimal strategy to bring South Carolina's epidemic of lung cancer under control is an effective cigarette smoking control program. Because approximately 85% of all lung cancer is attributable to cigarette smoking, lung cancer prevention strategies need to focus on preventing initiation of cigarette smoking among youths and young adults and assisting cessation efforts among current smokers. As seen in Table 1, a substantial proportion (36%) of all smokers and especially African American smokers (53%) in South Carolina began smoking after they turned 19 years old. This indicates a need to target smoking prevention intervention toward young adults.

Smoking cessation guidelines outlined by the U.S. Public Health Service identify several tools for quitting.⁶⁹ Pharmacotherapy, in the form of nicotine replacement therapy (NRT) or non-nicotine products (e.g., bupropion) have been observed to double a smoker's chance of quitting successfully. The use of NRT is based on the rationale that it reduces withdrawal by supplying nicotine via a less toxic delivery system. NRT products include nicotine patch, gum, lozenge (all available over-the-counter), inhaler, and nasal spray (available through prescription only). Behavior therapy, with or without pharmacotherapy, is also effective for smoking cessation.⁶⁹ However, use of these cessation aids remains low. Data from the 2000 NHIS indicate that

78% of smokers who tried to quit in the previous year did not use any of these cessation methods,⁷⁰ a finding that has been replicated by others.^{71,72} It is unclear if there is differential use or knowledge of effective cessation aids between AA and EA smokers. Moreover, there is a paucity of studies among AA smokers testing intervention strategies that reflect current state-of-the-art techniques.⁷³

For all smokers, quitting results in considerable health benefits in addition to the reduced risk of lung cancer.⁹ Clinicians must be willing to assist patients with quitting and be actively engaged in preventing young patients from starting to smoke. Unfortunately, evidence suggests that AA smokers are less likely than other racial/ethnic groups to be advised to quit smoking by a physician.⁷⁴ This is particularly disconcerting because AAs have a more difficult time quitting once they are dependent smokers, and also have a higher risk of cancer for a given exposure to tobacco.¹⁷

The potential role of socioeconomic status cannot be overlooked in considering racial/ethnic disparities in the lung cancer burden. Lung cancer is more likely to occur in the poor and less educated, a pattern that has been observed in diverse geographic locations.⁷⁵⁻⁷⁷ Lower socioeconomic status has also been observed to be associated with later stage at diagnosis.⁷⁸ Socioeconomic status is associated with a constellation of interacting determinants of lung cancer risk, such as smoking, diet, and exposures to inhaled carcinogens in the workplace and general environment. Lower socioeconomic status is associated with an unfavorable profile for all of these factors. Advancing our understanding of the complex linkages between components of socioeconomic status and lung cancer risk is essential to effectively addressing this social class disparity, and reducing lung cancer rates in the poorer segments of society.

The central role of cigarette smoking prevention and control efforts to lung cancer

prevention is clear. The evidence to date on the role of other lifestyle factors such as diet and physical activity suggests these may also play a role in affecting lung cancer risk, but the magnitude of the impact is not only less compared to cigarette smoking but it is presently much less well-defined. Achieving a more precise understanding of the role of diet and physical activity in the etiology of lung cancer should be a priority, as these would open up new avenues for prevention. For example, dietary modification could potentially be used to help prevent lung cancer in nonsmokers and help former smokers to further reduce their lung cancer risk. Healthy lifestyle behaviors tend to be correlated, so healthful dietary modifications in smokers could even have downstream effects by increasing the likelihood of smoking cessation attempts.

In contrast with other regions in the U.S., in the Southeast, AAs constitute a very high proportion of rural residents. South Carolina is a relatively rural state; over 40% of rural residents are AA. It also is a relatively poor state, with the average personal income only approximately four-fifths of the national average.⁷⁹ These factors converge to create racial and geographic disparities in health care, which may at least partly explain the disproportionately high cancer rates of AAs, who represent 31% of South Carolina's total population.⁸⁰ Tobacco control strategies must be developed for South Carolina's substantial rural population. Compared to the urban population, South Carolina's rural population tends to be older, less educated, poorer, receive less preventive care, and have fewer physician visits.^{81,82} Rural residents tend to adopt a more fatalistic outlook toward developing cancer than their urban counterparts.^{83,84} Racial disparities in prognosis and late stage at diagnosis of lung cancer may be magnified by these characteristics associated with residing in rural areas. Rural and urban populations in the Southeast have been observed to differ with regard to higher smoking rates and their knowledge as well as attitudes about the dangers of sec-

ondhand smoke.⁸⁵ Also, rural populations are less likely to participate in smoking cessation programs because of the lack of community-based health resources and programs.⁸⁵

Establishing culturally sensitive tobacco control interventions within minority communities in general, and specifically in rural minority communities, will be pivotal to effective control of cigarette smoking in South Carolina. Examples of strategies are those designed to develop a minority lay health educator network, church-based cessation programs, and culturally appropriate self-help materials. Lung cancer accounts for such a large proportion of the overall burden of cancer mortality in South Carolina that lung cancer control efforts need to be the centerpiece of South Carolina's overall cancer control strategy. Among males, lung cancer rates in AAs exceed those in EAs, and the reasons for this disparity are not understood. Research is needed to test new hypotheses to help better understand the persistent excess in lung cancer rates in AAs compared to other racial/ethnic groups so that this disparity can be eliminated. Substantially reducing the high rates of lung cancer in South Carolina will require preventing youths from starting to smoke cigarettes and effectively promoting smoking cessation among dependent smokers.

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References

1. American Cancer Society. Cancer Facts and Figures 2006. American Cancer Society: Atlanta; 2006.
2. South Carolina Central Cancer Registry. Thoracic cancer data request. In: Daguise V, ed. Columbia, SC: DHEC, Department of Biostatistics; 2005.
3. Leading causes of death in South Carolina, 2003.
4. South Carolina Central Cancer Registry. Office of Public Health Statistics and Information Services, Department of Health and Environmental Control. South Carolina Central Cancer Registry Incidence (final-mast2005-staffile) and Mortality (cancer-mortality9404-staffile); January, 2006.
5. Ries LAG, Eisner MP, Kosary CL, et al (Eds.). Cancer statistics review, 1975-2002, National Cancer Institute, Bethesda, MD. http://seer.cancer.gov/1975_2002/, based on November 2004 SEER data submission, posted on the SEER website 2005.
6. Alberg AJ, Samet JM. Epidemiology of lung cancer. *Chest* 2003;123(1 Suppl):21S-49S.
7. U.S. Cancer Statistics Working Group. United States Cancer Statistics: 1999-2002 Incidence and mortality web-based report. Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention and National Cancer Institute 2005. (www.cdc.gov/cancer/npcr/uscs)
8. U.S. Department of Health and Human Services. The Health Consequences of Smoking. A Report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, 2004.
9. U.S. Department of Health and Human Services. The health benefits of smoking cessation. A report of the Surgeon General. Centers for Disease Control, Office on Smoking and Health. DHHS Publication No.(CDC) 90-8416; 1990.
10. Hrubec Z, McLaughlin JK. Former cigarette smoking and mortality among U.S. veterans: A 26-year follow-up, 1954-1980. In: Burns DM, Garfinkel L, Samet JM, editors. Changes in Cigarette-Related Disease Risks and Their Implication for Prevention and Control. Bethesda, Maryland: U.S. Government Printing Office, 1997: 501-530.
11. Shibuya K, Inoue M, Lopez AD. Statistical modeling and projections of lung cancer mortality in 4 industrialized countries. *Int J Cancer* 2005; 117: 476-485.

12. National Institutes of Health (NIH), National Cancer Institute. Smoking and Tobacco Control Monograph 9. Cigars: health effects and trends. NIH Publication No. 98-4302. 1998. Bethesda, MD, U.S. Department of Health and Human Services.
13. Boffetta P, Pershagen G, Jockel KH et al. Cigar and pipe smoking and lung cancer risk: a multicenter study from Europe. *J Natl Cancer Inst* 1999; 91:697-701.
14. US Environmental Protection Agency. Respiratory Health Effects of Passive Smoking: Lung Cancer and Other Disorders. EPA: Washington (DC); 1992 December.
15. MMWR. Cigarette smoking among adults-United States, 2004. *MMWR* 54: 1121-1124.
16. Schoenborn CA, Adams PF, Barnes PM, Vickerie JL, Schiller JS. Health behaviors of adults: United States, 1999-2001. *Vital Health Stat* 10 2004(219):1-79.
17. Haiman CA, Stram DO, Wilkens LR, et al. Ethnic and racial differences in the smoking-related risk of lung cancer. *N Engl J Med* 2006; 354: 333-342.
18. Giovino GA, Sidney S, Gfroerer JC, O'Malley PM, Allen JA, Richter PA, Cummings KM. Epidemiology of menthol cigarette use. *Nicotine Tob Res* 6 Suppl 1:S67-S81, 2004.
19. McCarthy WJ, Caskey NH, Jarvik ME, Gross TM, Rosenblatt MR, Carpenter C. Menthol versus nonmenthol cigarettes: effects on smoking behavior. *Am J Public Health* 1995;85(1):67-72.
20. Ahijevych K, Garrett BE. Menthol pharmacology and its potential impact on cigarette smoking behavior. *Nicotine Tob Res* 6 Suppl 1:S17-S28, 2004.
21. Azzi C, Zhang J, Purdon CH, et al. Permeation and reservoir formation of 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK) and benzo[a]pyrene (BAP) across porcine esophageal tissue in the presence of ethanol and menthol. *Carcinogenesis* 2006; 27: 137-145.
22. US Department of Health and Human Services. Tobacco use among U.S. racial/ethnic minority groups-African American, American Indians and Alaskan Natives, Asian Americans and Pacific Islanders, and Hispanics: A report of the surgeon general. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.; 1998.
23. Brooks DR, Palmer JR, Strom BL, Rosenberg L. Menthol cigarettes and risk of lung cancer. *Am J Epidemiol* 158:609-616, 2003.
24. Carpenter CL, Jarvik ME, Morgenstern H, McCarthy WJ, London SJ. Mentholated cigarette smoking and lung-cancer risk. *Ann Epidemiol* 9:114-120, 1999
25. Sidney S, Tekawa IS, Friedman GD, Sadler MC, Tashkin DP. Mentholated cigarette use and lung cancer. *Arch Intern Med* 155:727-732, 1995
26. Kabat GC, Hebert JR: Use of mentholated

- cigarettes and lung cancer risk. *Cancer Res* 51:6510-6513, 1991.
27. Hebert JR. Invited commentary: Menthol cigarettes and risk of lung cancer. *Am J Epidemiol* 2003; 158: 617-620.
 28. Muscat JE, Djordjevic MV, Colosimo S, Stellman SD, Richie JP. Racial differences in exposure and glucuronidation of the tobacco-specific carcinogen 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK). *Cancer* 2005; 103: 1420-6.
 29. Zheng YL, Loffredo CA, Alberg AJ, et al. Less efficient g2-m checkpoint is associated with an increased risk of lung cancer in African Americans. *Cancer Res.* 2005; 65:9566-73.
 30. Zheng YL, Loffredo CA, Yu Z, et al. Bleomycin-induced chromosome breaks as a risk marker for lung cancer: a case-control study with population and hospital controls. *Carcinogenesis* 2003;24:269-74.
 31. Hung RJ, Boffetta P, Brockmoller J, et al. CYP1A1 and GSTM1 genetic polymorphisms and lung cancer risk in Caucasian non-smokers: a pooled analysis. *Carcinogenesis* 2003; 24: 875-882.
 32. Hung RJ, Hall J, Brennan P, Boffetta P. Genetic polymorphisms in the base excision repair pathway and cancer risk: a HuGE review. *Am J Epidemiol* 2005; 162: 925-942.
 33. Benhamou S, Sarasin A. ERCC2/XPD gene polymorphisms and lung cancer: a HuGE review. *Am J Epidemiol* 2005; 161: 1-14.
 34. Patel JD. Lung cancer in women. *J Clin Oncol* 2005; 23: 3212-3218.
 35. Bain C, Feskanich D, Speizer FE, et al. Lung cancer rates in men and women with comparable histories of smoking. *J Natl Cancer Inst* 2004; 96(11):826-34.
 36. Jemal A, Travis WD, Tarone RE, Travis L, Devesa SS. Lung cancer rates convergence in young men and women in the United States: analysis by birth cohort and histologic type. *Int J Cancer* 2003; 105(1):101-7.
 37. Alberg AJ, Yung R, Strickland PT, et al. Respiratory cancer and exposure to arsenic, chromium, nickel, and polycyclic aromatic hydrocarbons. *Clin Occup Environ Med* 2002;2: 779-801.
 38. Doll R. Mortality from lung cancer in asbestos workers. *Br J Ind Med* 1955; 12:81-86.
 39. National Research Council (NRC), Committee on the Biological Effects of Ionizing Radiation. *Health Risks of Radon and Other Internally Deposited Alpha-Emitters: BEIR IV.* 1988. Washington, D.C., National Academy Press.
 40. US Environmental Protection Agency (EPA). Technical Support Document for the 1992 Citizen's Guide to Radon. Washington, D.C.: U.S. Government Printing Office, 1992.
 41. Pavia M, Bianco A, Pileggi C, Angelillo IF. Meta-analysis of residential exposure to radon gas and lung cancer. *Bull WHO* 2003; 81: 732-738.
 42. Vineis P, Forastiere F, Hoek G, Lipsett M. Outdoor air pollution and lung cancer: recent epidemiologic evidence. *Int J Cancer* 2004; 111:647-652.
 43. Alberg AJ, Samet JM. Epidemiology of lung cancer. In: Sadler MJ, Caballero B, Strain JJ (Eds.) *Encyclopedia of Human Nutrition.* London: Academic Press, 2005.
 44. Behavioral Risk Factor Surveillance System, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention. <http://apps.nccd.cdc.gov/brfss/>, accessed April 8, 2006.
 45. The Alpha Tocopherol Beta Carotene Cancer Prevention Group. The effect of vitamin E and beta carotene on the incidence of lung cancer and other cancers in male smokers. *N Engl J Med* 1994;330:1029-35.
 46. Hennekens CH, Buring JE, Manson JE et al. Lack of effect of long-term supplementation with beta-carotene on the incidence of malignant neoplasms and cardiovascular disease. *N Engl J Med* 1996; 334:1145-1149.
 47. Omenn GS, Goodman GE, Thornquist MD et al. Effects of a combination of beta-carotene and vitamin A on lung cancer and cardiovascular disease. *N Engl J Med* 1996; 334:1150-1155.
 48. Lee IM, Cook NR, Gaziano JM, et al.: Vitamin E in the primary prevention of cardiovascular disease and cancer: the Women's Health Study: a randomized controlled trial. *JAMA* 2005; 294: 56-65.
 49. Lonn E, Bosch J, Yusuf S, et al.: Effects of long-term vitamin E supplementation on cardiovascular events and cancer: a randomized controlled trial. *JAMA* 2005; 293: 1338-47.
 50. Tardon A, Lee WJ, Delgado-Rodriguez M, Dosemici M, Albanes D, Hoover R, Blair A. Leisure-time physical activity and lung cancer: a meta-analysis. *Cancer Causes Control* 2005; 16: 389-397.
 51. Flehinger BJ, Melamed MR, Zaman MB, et al. Early lung cancer detection: results of the initial (prevalence) radiologic and cytologic screening in the memorial Sloan-Kettering Study. *Am Rev Resp Dis* 1984; 130:555-60
 52. Melamed MR, Flehinger BJ, Zaman MB. Screening for early lung cancer: results of the Memorial Sloan-Kettering study in New York. *Chest* 1984; 86:44-53
 53. Frost JK, Ball WC, Levin MT, et al. Early lung cancer detection: results from the initial (prevalence) radiologic cytologic screening in the Johns Hopkins Study. *Am Rev Resp Dis* 1984;130: 549-54.
 54. Fonatana RS, Sanderson DR, Taylor WF, et al. Early lung cancer detection: results from the initial (prevalence) radiologic cytologic screening in the Mayo Clinic Study. *Am Rev Resp Dis* 1984; 130: 561-65.
 55. Kubik A, Polak J. Lung cancer detection. Results of a randomized prospective study in Czechoslovakia. *Cancer* 1986; 57:2427-37.
 56. Henschke CI, McCauley DI, Yankelevitz DF, et al. Early lung cancer action project: overall design and findings from baseline screening. *Lancet* 1999; 354: 99-105
 57. Henschke CI, Naidich DP, Yankelevitz DF, et al. Early lung cancer action project. Initial findings on repeat screening. *Cancer* 2001; 92: 153-159.
 58. Swensen SJ, Jett JR, Hartman TE, et al. Lung cancer screening with CT: Mayo Clinic experience. *Radiology* 2003; 226:756-761.
 59. Swensen SJ, Jett JR, Hartman TE, et al. CT screening for lung cancer: five-year prospective experience. *Radiology* 2005; 235:259-265.
 60. Bach PB, Kelley MJ, Tate RC, McCrory DC. Screening for lung cancer: a review of the current literature. *Chest* 2003; 123(1 Suppl): 72S-82S.
 61. Church T, National Lung Screening Trial Executive Committee. Chest radiography as the comparison intervention for spiral CT in the National Lung Screening Trial. *Acad Radiol* 2003; 10:713-715.
 62. Pastorino U, Bellomi M, Landoni C, et al. Early lung-cancer detection with spiral CT and positron emission tomography in heavy smokers: 2-year results. *Lancet* 2003; 362:593-597.
 63. Phillips M, Cataneo RN, Cummin AR, et al. Detection of lung cancer with volatile markers in the breath. *Chest* 2003; 123:2115-2123.
 64. Carpagnano GE, Foschino-Barbaro MP, Mule G, et al. 3p microsatellite alterations in exhaled breath condensate from patients with non-small cell lung cancer. *Am J Respir Crit Care Med* 2005; 172:738-744.
 65. Machado RF, Laskowski D, Deffenderfer O, et al. Detection of lung cancer by sensor array analyses of exhaled breath. *Am J Respir Crit Care Med* 2005; 171:1286-1291.
 66. Petricoin EF, Liotta LA. Clinical applications of proteomics. *J Nutr* 2003; 133(Suppl): 2476S-2484S.
 67. Jamsheer Rahman SM, Shyr Y, Yildiz PB, et al. Proteomic patterns of preinvasive bronchial lesions. *Am J Respir Crit Care Med* 2005; 172:1556-1562.
 68. Yanaihara N, Caplen N, Bowman E, et al. Unique microRNA molecular profiles in lung cancer diagnosis and prognosis. *Cancer Cell* 2006; 9: 189-198.
 69. Fiore M, Bailey W, Cohen S. Treating tobacco use and dependence: Clinical practice guideline. Rockville, MD: US Public Health Service, 2000.
 70. Cokkinides V, Ward E, Jemal A, Thun M. Under-use of smoking-cessation treatments: Results from the National Health Interview Survey, 2000. *Am J Prev Med* 2005;28:119-122.
 71. Zhu S-H, Melcer T, Sun J, Rosbrook B, Pierce J. Smoking cessation with and without assistance: A population-based analysis. *Am J Prev Med* 2000;18:305-311.
 72. Solberg L, Boyle R, Davidson G, Magnan S, Carlson C, Alesci N. Aids to quitting tobacco use: How important are they outside controlled trials? *Prev Med* 2001;33:53-58.
 73. Lawrence D, Graber J, Mills S, Meissner H, Warnecke R. Smoking cessation interventions in U.S. racial/ethnic minority populations: An assessment of the literature. *Prev Med* 2003;36:204-216.
 74. Doescher M, Saver B. Physician's advice to

- quit smoking: The glass remains half empty. *J Family Pract* 2000;49:543-547
75. Mao Y, Hu J, Ugnat AM, Semenciw R, Fincham S. Canadian Cancer Registries Epidemiology Research Group. Socioeconomic status and lung cancer risk in Canada. *Int J Epidemiol* 2001; 30(4):809-817.
76. Li K, Yu S. Economic status, smoking, occupational exposure to rubber, and lung cancer: a case-cohort study. *Environ Sci Health Environ Carcinog Ecotoxicol Rev* 2002; 20:21-8.
77. van Loon AJ, Goldbohm RA, Kant IJ, et al. Socioeconomic status and lung cancer incidence in men in The Netherlands: is there a role for occupational exposure? *J Epidemiol Community Health* 1997; 51(1):24-9.
78. Schwartz KL, Crossley-May H, Vigneau FD, et al. Race, socioeconomic status and stage at diagnosis for five common malignancies. *Cancer Causes Control* 2003; 14:761-6.
79. US Department of Commerce. Personal Income By State. Washington, DC: Bureau of Economic Analysis; 2003.
80. US Cancer Statistics Working Group. United States Cancer Statistics: 2001 Incidence. Atlanta (GA): DHHS/CDC/NIH-NCI; 2004.
81. Hueston WJ, Hubbard ET. Preventive services for rural and urban African American adults. *Arch Fam Med* 2000; 9:263-6.
82. Probst JC, Moore CG, Glover SH, Samuels ME. Person and place: the compounding effects of race/ethnicity and rurality on health. *Am J Public Health* 2004; 94:1695-703.
83. Powe BD. Cancer fatalism among African Americans: a review of the literature. *Nurs Outlook* 1996; 44:18-21.
84. Powe BD, Weinrich S. An intervention to decrease cancer fatalism among rural elders. *Oncol Nurs Forum* 1999; 26:583-8.
85. McMillen R, Breen J, Cosby AG. Rural-urban differences in the social climate surrounding environmental tobacco smoke: a report from the 2002 Social Climate Survey of Tobacco Control. *J Rural Health* 2004; 20:7-16. ■
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