

CHAPTER 1

INTRODUCTION, OVERVIEW, AND SUMMARY AND CONCLUSIONS

CONTENTS

Introduction

Development and Organization of the 1986 Report

Overview

Environmental Tobacco Smoke Constituents

Extent of Exposure

Lung Cancer

Respiratory Disease

Cardiovascular Disease

Irritation

Determinants of Exposure

Policies Restricting Smoking

Summary and Conclusions of the 1986 Report

Health Effects of Environmental Tobacco Smoke

Exposure

Environmental Tobacco Smoke Chemistry and

Exposures of Nonsmokers

Deposition and Absorption of Tobacco Smoke Constituents

Toxicity, Acute Irritant Effects, and Carcinogenicity of Environmental Tobacco Smoke

Policies Restricting Smoking in Public Places and the Workplace

Introduction

Development and Organization of the 1986 Report

The 1986 Report was developed by the Office on Smoking and Health of the U.S. Department of Health and Human Services as part of the Department's responsibility, under Public Law 91-222, to report new and current information on smoking and health to the United States Congress.

The scientific content of this Report reflects the contributions of more than 60 scientists representing a variety of disciplines. Individual manuscripts were written by experts known for their understanding of and work in specific content areas. These manuscripts were refined through a series of meetings attended by the authors, Office on Smoking Health staff and consultants, and the Surgeon General.

Upon receipt of the final manuscripts from the authors, the Office and its consultants edited and consolidated the individual manuscripts into appropriate chapters. These draft chapters were subjected to an extensive outside peer review (see Acknowledgments for individuals and their affiliations) whereby each was reviewed by up to seven experts. Their comments were integrated and the entire volume was assembled. This revised edition of the Report was resubjected to review by 17 distinguished scientists outside the Federal Government, both in this country and abroad. Parallel to this review, the entire Report was also submitted to various institutes and agencies within the U.S. Public Health Service for review and comment.

The 1986 Report contains a Foreword by the Assistant Secretary for Health, a Preface by the Surgeon General of the U.S. Public Health Service, and the following chapters:

- Chapter 1. Introduction, Overview, and Summary and Conclusions
- Chapter 2. Health Effects of Environmental Tobacco Smoke Exposure
- Chapter 3. Environmental Tobacco Smoke Chemistry and Exposures of Nonsmokers
- Chapter 4. Deposition and Absorption of Tobacco Smoke Constituents
- Chapter 5. Toxicity, Acute Irritant Effects, and Carcinogenicity of Environmental Tobacco Smoke
- Chapter 6. Policies Restricting Smoking in Public Places and the Workplace

Overview

Inhalation of tobacco smoke during active cigarette smoking remains the largest single preventable cause of death and disability

for the U.S. population. The health consequences of cigarette smoking and of the use of other tobacco products have been extensively documented in the 17 previous Reports in the health consequences of smoking series issued by the U.S. Public Health Service. Cigarette smoking is a major cause of cancer; it is most strongly associated with cancers of the lung and respiratory tract, but also causes cancers at other sites, including the pancreas and urinary bladder. It is the single greatest cause of chronic obstructive lung diseases. It causes cardiovascular diseases, including coronary heart disease, aortic aneurysm, and atherosclerotic peripheral vascular disease. Maternal cigarette smoking endangers fetal and neonatal health; it contributes to perinatal mortality, low birth weight, and complications during pregnancy. More than 300,000 premature deaths occur in the United States each year that are directly attributable to tobacco use, particularly cigarette smoking.

This Report examines in detail the scientific evidence on involuntary smoking as a potential cause of disease in nonsmokers. Nonsmokers' exposure to environmental tobacco smoke is termed involuntary smoking in this Report because the exposure generally occurs as an unavoidable consequence of being in proximity to smokers, particularly in enclosed indoor environments. The term "passive smoking" is also used throughout the scientific literature to describe this exposure.

The magnitude of the disease risks for active smokers secondary to their "high dose" exposure to tobacco smoke suggests that the "lower dose" exposure to tobacco smoke received by involuntary smokers may also have risks. Although the risks of involuntary smoking are smaller than the risks of active smoking, the number of individuals injured by involuntary smoking is large both in absolute terms and in comparison with the number injured by some other agents in the general environment that are regulated to curtail their potential to cause human illness.

This Report reviews the evidence on the characteristics of mainstream tobacco smoke and of environmental tobacco smoke, on the levels of exposure to environmental tobacco smoke that occur, and on the health effects of involuntary exposure to tobacco smoke. The composition of the tobacco smoke inhaled by active smokers and by involuntary smokers is examined for similarities and differences, and the concentrations of tobacco smoke components that can be measured in a variety of settings are explored, as is smoke deposition and absorption in the respiratory tract. The studies that describe the risks of environmental tobacco smoke exposure for humans are carefully reviewed for their findings and their validity. The evidence on the health effects of involuntary smoking is reviewed for biologic plausibility, and compared with extrapolations of the risks of active

smoking to the lower dose of exposure to tobacco smoke found in nonsmokers. This review leads to three major conclusions:

- 1. Involuntary smoking is a cause of disease, including lung cancer, in healthy nonsmokers.**
- 2. The children of parents who smoke compared with the children of nonsmoking parents have an increased frequency of respiratory infections, increased respiratory symptoms, and slightly smaller rates of increase in lung function as the lung matures.**
- 3. The simple separation of smokers and nonsmokers within the same air space may reduce, but does not eliminate, the exposure of nonsmokers to environmental tobacco smoke.**

The subsequent chapters of this volume describe in detail the evidence that supports these conclusions; the evidence is briefly summarized here.

Environmental Tobacco Smoke Constituents

Important considerations in examining the risks of involuntary smoking are the composition of environmental tobacco smoke (ETS) and its toxicity and carcinogenicity relative to the tobacco smoke inhaled by active smokers. Mainstream cigarette smoke is the smoke drawn through the tobacco into the smoker's mouth. Sidestream smoke is the smoke emitted by the burning tobacco between puffs. Environmental tobacco smoke results from the combination of sidestream smoke and the fraction of exhaled mainstream smoke not retained by the smoker. In contrast with mainstream smoke, ETS is diluted into a larger volume of air, and it ages prior to inhalation.

The comparison of the chemical composition of the smoke inhaled by active smokers with that inhaled by involuntary smokers suggests that the toxic and carcinogenic effects are qualitatively similar, a similarity that is not too surprising because both mainstream smoke and environmental tobacco smoke result from the combustion of tobacco. Individual mainstream smoke constituents, with appropriate testing, have usually been found in sidestream smoke as well. However, differences between sidestream smoke and mainstream smoke have been well documented. The temperature of combustion during sidestream smoke formation is lower than during mainstream smoke formation. As a result, greater amounts of many of the organic constituents of smoke, including some carcinogens, are generated when tobacco burns and forms sidestream smoke than when mainstream smoke is produced. For example, in contrast with mainstream smoke, sidestream smoke contains greater amounts of ammonia, benzene, carbon monoxide, nicotine, and the carcinogens

2-naphthylamine, 4-aminobiphenyl, N-nitrosamine, benz[a]-anthracene, and benzo-pyrene per milligram of tobacco burned. Although only limited bioassay data comparing mainstream smoke and sidestream smoke are available, one study has suggested that sidestream smoke may be more carcinogenic.

Extent of Exposure

Although sidestream smoke and mainstream smoke differ somewhat qualitatively, the differing quantitative doses of smoke components inhaled by the active smoker and by the involuntary smoker are of greater importance in considering the risks of the two exposures. A number of different markers for tobacco smoke exposure and absorption have been identified for both active and involuntary smoking. No single marker quantifies, with precision, the exposure to each of the smoke constituents over the wide range of environmental settings in which involuntary smoking occurs. However, in environments without other significant sources of dust, respirable suspended particulate levels can be used as a marker of smoke exposure. Levels of nicotine and its metabolite cotinine in body fluids provide a sensitive and specific indication of recent whole smoke exposure under most conditions.

Widely varying levels of environmental tobacco smoke can be measured in the home and other environments using markers. The time-activity patterns of nonsmokers, which indicate the time spent in environments containing ETS, also vary widely. Thus, the extent of exposure to ETS is probably highly variable among individuals at a given point in time, and little is known about the variation in exposure of the same individual at different points in time.

Lung Cancer

The American Cancer Society estimates that there will be more than 135,000 deaths from lung cancer in the United States in 1986, and 85 percent of these lung cancer deaths are directly attributable to active cigarette smoking. Therefore, even if the number of lung cancer deaths caused by involuntary smoking were much smaller than the number of lung cancer deaths caused by active smoking, the number of lung cancer deaths attributable to involuntary exposure would still represent a problem of sufficient magnitude to warrant substantial public health concern.

Exposure to environmental tobacco smoke has been examined in numerous recent epidemiological studies as a risk factor for lung cancer in nonsmokers. These studies have compared the risks for subjects exposed to ETS at home or at work with the risks for people not reported to be exposed in these environments. Because exposure to ETS is an almost universal experience in the more developed countries, these studies involve comparison of more exposed and less

exposed people rather than comparison of exposed and unexposed people. Thus, the studies are inherently conservative in assessing the consequences of exposure to ETS. Interpretation of these studies must consider the extent to which populations with different ETS exposures have been identified, the gradient in ETS exposure from the lower exposure to the higher exposure groups, and the magnitude of the increased lung cancer risk that results from the gradient in ETS exposure.

To date, questionnaires have been used to classify ETS exposure. Quantification of exposure by questionnaire, particularly lifetime exposure, is difficult and has not been validated. However, spousal and parental smoking status identify individuals with different levels of exposure to ETS. Therefore, investigation has focused on the children and nonsmoking spouses of smokers, groups for whom greater ETS exposure would be expected and for whom increased nicotine absorption has been documented relative to the children and nonsmoking spouses of nonsmokers.

Of the epidemiologic studies reviewed in this Report that have examined the question of involuntary smoking's association with lung cancer, most (11 of 13) have shown a positive association with exposure, and in 6 the association reached statistical significance. Given the difficulty in identifying groups with differing ETS exposure, the low-dose range of exposure examined, and the small numbers of subjects in some series, it is not surprising that some studies have found no association and that in others the association did not reach a conventional level of statistical significance. The question is not whether cigarette smoke can cause lung cancer; that question has been answered unequivocally by examining the evidence for active smoking. The question is, rather, can tobacco smoke at a lower dose and through a different mode of exposure cause lung cancer in nonsmokers? The answer must be sought in the coherence and trends of the epidemiologic evidence available on this low-dose exposure to a known human carcinogen. In general, those studies with larger population sizes, more carefully validated diagnosis of lung cancer, and more careful assessment of ETS exposure status have shown statistically significant associations. A number of these studies have demonstrated a dose-response relationship between the level of ETS exposure and lung cancer risk. By using data on nicotine absorption by the nonsmoker, the nonsmoker's risk of developing lung cancer observed in human epidemiologic studies can be compared with the level of risk expected from an extrapolation of the dose-response data for the active smoker. This extrapolation yields estimates of an expected lung cancer risk that approximate the observed lung cancer risk in epidemiologic studies of involuntary smoking.

Cigarette smoke is well established as a human carcinogen. The chemical composition of ETS is qualitatively similar to mainstream smoke and sidestream smoke and also acts as a carcinogen in bioassay systems. For many nonsmokers, the quantitative exposure to ETS is large enough to expect an increased risk of lung cancer to occur, and epidemiologic studies have demonstrated an increased lung cancer risk with involuntary smoking. In examining a low-dose exposure to a known carcinogen, it is rare to have such an abundance of evidence on which to make a judgment, and given this abundance of evidence, a clear judgment can now be made: exposure to ETS is a cause of lung cancer.

The data presented in this Report establish that a substantial number of the lung cancer deaths that occur among nonsmokers can be attributed to involuntary smoking. However, better data on the extent and variability of ETS exposure are needed to estimate the number of deaths with confidence.

Respiratory Disease

Acute and chronic respiratory diseases have also been linked to involuntary exposure to tobacco smoke; the evidence is strongest in infants. During the first 2 years of life, infants of parents who smoke are more likely than infants of nonsmoking parents to be hospitalized for bronchitis and pneumonia. Children whose parents smoke also develop respiratory symptoms more frequently, and they show small, but measurable, differences on tests of lung function when compared with children of nonsmoking parents.

Respiratory infections in young children represent a direct health burden for the children and their parents; moreover, these infections, and the reductions in pulmonary function found in the school-age children of smokers, may increase susceptibility to develop lung disease as an adult.

Several studies have reported small decrements in the average level of lung function in nonsmoking adults exposed to ETS. These differences may represent a response of the lung to chronic exposure to the irritants in ETS, but it seems unlikely that ETS exposure, by itself, is responsible for a substantial number of cases of clinically significant chronic obstructive lung disease. The small magnitude of the changes associated with ETS exposure suggests that only individuals with unusual susceptibility would be at risk of developing clinically evident disease from ETS exposure alone. However, ETS exposure may be a factor that contributes to the development of clinical disease in individuals with other causes of lung injury.

Cardiovascular Disease

A few studies have examined the relationship between involuntary smoking and cardiovascular disease, but no firm conclusion on

the relationship can be made owing to the limited number of deaths in the studies.

Irritation

Perhaps the most common effect of tobacco smoke exposure is tissue irritation. The eyes appear to be especially sensitive to irritation by ETS, but the nose, throat, and airway may also be affected by smoke exposure. Irritation has been demonstrated to occur at levels that are similar to those found in real-life situations. The level of irritation increases with an increasing concentration of smoke and duration of exposure. In addition, participants in surveys report irritation and annoyance due to smoke in the environment under real-life conditions.

Determinants of Exposure

Exposure to ETS has been documented to be common in the United States, but additional data on the extent and determinants of exposure are needed to identify individuals within the population who have the highest exposure and are at greatest risk. Studies with biological markers and measurements of ETS components in indoor air confirm that measurable exposure to ETS is widespread. However, within exposed populations, levels of cotinine excretion and presumably ETS exposure vary greatly.

In a room or other indoor area, the size of the space, the number of smokers, the amount of ventilation, and other factors determine the concentration of tobacco smoke in the air. The technology for the cost-effective filtration of tobacco smoke from the air is not currently available, and because of their small size, the smoke particles remain suspended in the air for long periods of time; thus, the only way to remove smoke from indoor air is to increase the exchange of indoor air with clean outdoor air. The number of air changes per hour required to maintain acceptable indoor air quality is much higher when smoking is allowed than when smoking is prohibited.

Environmental tobacco smoke originates at the lighted tip of the cigarette, and exposure to ETS is greatest in proximity to the smoker. However, the smoke rapidly disseminates throughout any airspace contiguous with the space in which the smoking is taking place. Dissemination of smoke is not uniform, and substantial gradients in ETS levels have been demonstrated in different parts of the same airspace. The time course of tobacco smoke dissemination is rapid enough to ensure the spread of smoke throughout an airspace within an 8-hour workday. In the home, the presence of even one smoker can significantly increase levels of respirable suspended particulates.

These data lead to the conclusion that the simple separation of smokers and nonsmokers within the same airspace will reduce, but

not eliminate, exposure to ETS, particularly in those settings where exposure is prolonged, such as the working environment.

The exposure of an individual nonsmoker to ETS is also determined by that person's time-activity pattern; that is, the amount of time spent in various locations. For adults, the duration of time spent in smoke-contaminated environments at work or at home is the principal determinant of ETS exposure, along with the levels of smoke in those environments. For infants and very young children, the smoking habit of the primary caretaker, as well as that person's time-activity pattern, is likely to play a major role in determining ETS exposure.

Policies Restricting Smoking

Policies regulating cigarette smoking with the objective of reducing explosion or fire risk, or of safeguarding the quality of manufactured products, have been in force in a number of States since the late 1800s. More recently, and with steadily increasing frequency, policies regulating smoking on the basis of the health risk or the irritation of involuntary smoking have been promulgated.

State and local governments have enacted laws and regulations restricting smoking in public places. These policies have been implemented with few problems and at little cost to the respective governments. The public awareness of these policies that results from the media coverage surrounding their implementation probably facilitates their self-enforcement. Public awareness may best be fostered by encouraging the establishment of these changes at the local level.

Policies limiting smoking in the worksite have also become increasingly widespread and more restrictive. However, changes in worksite policies have evolved largely through voluntary rather than governmental action. In a steadily increasing number of worksites, smoking has been prohibited completely or limited to relatively few areas within the worksite. The creation of a smoke-free workplace has proceeded successfully when the policy has been jointly developed by employees, employee organizations, and management; instituted in phases; and accompanied by support and assistance for the smokers to quit smoking.

This trend to protect nonsmokers from ETS exposure may have an added public health benefit—helping those smokers who are attempting to quit to be more successful and not encouraging smoking by people entering the workforce.

Summary and Conclusions of the 1986 Report

The three major conclusions of this report are the following:

1. **Involuntary smoking is a cause of disease, including lung cancer, in healthy nonsmokers.**
2. **The children of parents who smoke compared with the children of nonsmoking parents have an increased frequency of respiratory infections, increased respiratory symptoms, and slightly smaller rates of increase in lung function as the lung matures.**
3. **The simple separation of smokers and nonsmokers within the same air space may reduce, but does not eliminate, the exposure of nonsmokers to environmental tobacco smoke.**

Individual chapter summaries and conclusions follow.

Health Effects of Environmental Tobacco Smoke Exposure

1. Involuntary smoking can cause lung cancer in nonsmokers.
2. Although a substantial number of the lung cancers that occur in nonsmokers can be attributed to involuntary smoking, more data on the dose and distribution of ETS exposure in the population are needed in order to accurately estimate the magnitude of risk in the U.S. population.
3. The children of parents who smoke have an increased frequency of hospitalization for bronchitis and pneumonia during the first year of life when compared with the children of nonsmokers.
4. The children of parents who smoke have an increased frequency of a variety of acute respiratory illnesses and infections, including chest illnesses before 2 years of age and physician-diagnosed bronchitis, tracheitis, and laryngitis, when compared with the children of nonsmokers.
5. Chronic cough and phlegm are more frequent in children whose parents smoke compared with children of nonsmokers. The implications of chronic respiratory symptoms for respiratory health as an adult are unknown and deserve further study.
6. The children of parents who smoke have small differences in tests of pulmonary function when compared with the children of nonsmokers. Although this decrement is insufficient to cause symptoms, the possibility that it may increase susceptibility to chronic obstructive pulmonary disease with exposure to other agents in adult life, e.g., active smoking or occupational exposures, needs investigation.
7. Healthy adults exposed to environmental tobacco smoke may have small changes on pulmonary function testing, but are unlikely to experience clinically significant deficits in pulmo-

nary function as a result of exposure to environmental tobacco smoke alone.

8. A number of studies report that chronic middle ear effusions are more common in young children whose parents smoke than in children of nonsmoking parents.
9. Validated questionnaires are needed for the assessment of recent and remote exposure to environmental tobacco smoke in the home, workplace, and other environments.
10. The associations between cancers, other than cancer of the lung, and involuntary smoking require further investigation before a determination can be made about the relationship of involuntary smoking to these cancers.
11. Further studies on the relationship between involuntary smoking and cardiovascular disease are needed in order to determine whether involuntary smoking increases the risk of cardiovascular disease.

Environmental Tobacco Smoke Chemistry and Exposures of Nonsmokers

1. Undiluted sidestream smoke is characterized by significantly higher concentrations of many of the toxic and carcinogenic compounds found in mainstream smoke, including ammonia, volatile amines, volatile nitrosamines, certain nicotine decomposition products, and aromatic amines.
2. Environmental tobacco smoke can be a substantial contributor to the level of indoor air pollution concentrations of respirable particles, benzene, acrolein, N-nitrosamine, pyrene, and carbon monoxide. ETS is the only source of nicotine and some N-nitrosamine compounds in the general environment.
3. Measured exposures to respirable suspended particulates are higher for nonsmokers who report exposure to environmental tobacco smoke. Exposures to ETS occur widely in the non-smoking population.
4. The small particle size of environmental tobacco smoke places it in the diffusion-controlled regime of movement in air for deposition and removal mechanisms. Because these submicron particles will follow air streams, convective currents will dominate and the distribution of ETS will occur rapidly through the volume of a room. As a result, the simple separation of smokers and nonsmokers within the same airspace may reduce, but will not eliminate, exposure to ETS.
5. It has been demonstrated that ETS has resulted in elevated respirable suspended particulate levels in enclosed places.

Deposition and Absorption of Tobacco Smoke Constituents

1. Absorption of tobacco-specific smoke constituents (i.e., nicotine) from environmental tobacco smoke exposures has been documented in a number of samples of the general population of developed countries, suggesting that measurable exposure to environmental tobacco smoke is common.
2. Mean levels of nicotine and cotinine in body fluids increase with self-reported ETS exposure.
3. Because of the stability of cotinine levels measured at different times during exposure and the availability of noninvasive sampling techniques, cotinine appears to be the short-term marker of choice in epidemiological studies.
4. Both mathematical modeling techniques and experimental data suggest that 10 to 20 percent of the particulate fraction of sidestream smoke would be deposited in the airway.
5. The development of specific chemical assays for human exposure to the components of cigarette tar is an important research goal.

Toxicity, Acute Irritant Effects, and Carcinogenicity of Environmental Tobacco Smoke

1. The main effects of the irritants present in ETS occur in the conjunctiva of the eyes and the mucous membranes of the nose, throat, and lower respiratory tract. These irritant effects are a frequent cause of complaints about poor air quality due to environmental tobacco smoke.
2. Active cigarette smoking is associated with prominent changes in the number, type, and function of respiratory epithelial and inflammatory cells; the potential for environmental tobacco smoke exposure to produce similar changes should be investigated.
3. Animal models have demonstrated the carcinogenicity of cigarette smoke, and the limited data that exist suggest that more carcinogenic activity per milligram of cigarette smoke concentrate may be contained in sidestream smoke than in mainstream cigarette smoke.

Policies Restricting Smoking in Public Places and the Workplace

1. Beginning in the 1970s, an increasing number of public and private sector institutions have adopted policies to protect individuals from environmental tobacco smoke exposure by restricting the circumstances in which smoking is permitted.
2. Smoking in public places has been regulated primarily by government actions, which have occurred at Federal, State,

and local levels. All but nine States have enacted laws regulating smoking in at least one public place. Since the mid-1970s, there has been an increase in the rate of enactment and in the comprehensiveness of State legislation. Local governments have enacted smoking ordinances at an increasing rate since 1980; more than 80 cities and counties have smoking laws in effect.

3. Smoking at the workplace is regulated by a combination of government action and private initiative. Legislation in 12 States regulates smoking by government employees, and 9 States and more than 70 communities regulate smoking in the private sector workplace. Approximately 35 percent of businesses have adopted smoking policies. The increase in workplace smoking policies has been a trend of the 1980s.
4. Smoking policies may have multiple effects. In addition to reducing environmental tobacco smoke exposure, they may alter smoking behavior and public attitudes about tobacco use. Over time, this may contribute to a reduction in smoking in the United States. To the present, there has been relatively little systematic evaluation of policies restricting smoking in public places or at the workplace.
5. On the basis of case reports and a small number of systematic studies, it appears that workplace smoking policies improve air quality, are met with good compliance, and are well accepted by both smokers and nonsmokers. Policies appear to be followed by a decrease in smokers' cigarette consumption at work and an increase in enrollment in company-sponsored smoking cessation programs.
6. Laws restricting smoking in public places have been implemented with few problems and at little cost to State and local government. Their impact on smoking behavior and attitudes has not yet been evaluated.
7. Public opinion polls document strong and growing support for restricting or banning smoking in a wide range of public places. Changes in attitudes about smoking in public appear to have preceded legislation, but the interrelationship of smoking attitudes, behavior, and legislation are complex.

CHAPTER 2

HEALTH EFFECTS OF ENVIRONMENTAL TOBACCO SMOKE EXPOSURE

CONTENTS

Introduction

Evaluation of Low-Dose Tobacco Smoke Exposures

Extrapolation of Active Smoking Data to Environmental Tobacco Smoke Exposure

Comparison of Mainstream Smoke and Side-stream Smoke

Deposition of Mainstream Smoke and Side-stream Smoke and Environmental Tobacco Smoke Dose Estimates

Dose-Response Relationships and Threshold for Risk

Pathophysiologic Considerations

Cancer

Lung Disease

Methodological Considerations in Epidemiologic Studies

Measurement of Exposure

Atmospheric Markers

Personal Monitoring

Questionnaires

Measurements of Absorption

Potentially Confounding Variables

Statistical Issues

Respiratory System Effects of Involuntary Cigarette Smoke Exposure

Infants and Children

Acute Respiratory Illness

Longitudinal Studies

Cross-Sectional Studies

Case-Control Studies

Cough, Phlegm, and Wheezing

Pulmonary Function

Bronchoconstriction

Ear, Nose, and Throat

Adults

Acute Respiratory Illness

Cough, Phlegm, and Wheezing

Pulmonary Function
Bronchoconstriction
Normal Subjects
Asthmatics
Ear, Nose, and Throat

Lung Cancer

Observed Risk

General Methodological Issues

Spousal Exposure: Prospective Studies

The Japanese Cohort Study

The American Cancer Society Cohort Study

The Scottish Study

Spousal Exposure: Case-Control Studies

The Greek Study

The Louisiana Study

The Hong Kong Studies

An Ongoing Study of Tobacco-Related Cancers

The Los Angeles County Study

The Four Hospitals Study

A United Kingdom Study

The Japanese Case-Control Study

The Swedish Study

The German Study

Other Sources of Tobacco Smoke Exposure

Parental Smoking

Coworker's Smoking

Dose-Response Relationship

Expected Lung Cancer Risk

Summary

Other Cancers

Cardiovascular Diseases

Conclusions

References

Introduction

In 1964, the first Report of the Surgeon General on smoking and health (US PHS 1964) determined that cigarette smoking was a cause of lung cancer in men and probably a cause of lung cancer in women. That Report also noted causal relationships between smoking and other cancers, as well as chronic lung disease. Subsequent Reports have described associations, both causal and noncausal, between tobacco smoking and a wide range of acute and chronic diseases. Epidemiological investigations have documented the effects of tobacco smoking in humans; complementary laboratory investigations have elucidated some of the mechanisms through which tobacco smoke causes disease.

More recently, the effects of the inhalation of environmental tobacco smoke by nonsmokers have become a pressing public health concern. Nonsmokers, as well as active smokers, inhale environmental tobacco smoke, the mixture of sidestream smoke and exhaled mainstream smoke. Various terms have been applied to the inhalation of environmental tobacco smoke by nonsmokers; the terms "involuntary smoking" and "passive smoking" are the most prevalent and are often used interchangeably by researchers and the public.

Many of the known toxic and carcinogenic agents found in mainstream cigarette smoke have also been demonstrated to be present in sidestream smoke. Furthermore, the combustion conditions under which sidestream smoke is produced result in the generation of larger amounts of many of these toxic and carcinogenic agents per gram of tobacco burned than the conditions under which mainstream smoke is generated (see Chapter 3). The characteristics of environmental tobacco smoke also differ from those of mainstream smoke because the sidestream smoke ages before it is inhaled and the mainstream smoke exhaled by the active smoker is modified during its residence in the lung. There is no evidence to suggest that environmental tobacco smoke has a qualitatively lower toxicity or carcinogenicity than mainstream smoke per milligram of smoke inhaled. In fact, the available evidence suggests that sidestream smoke contains higher concentrations of many known toxic and carcinogenic agents per milligram of smoke and is more tumorigenic than mainstream smoke in animal testing (Wynder and Hoffmann 1967). As a result, involuntary smoking should not be viewed as a qualitatively different exposure from active smoking, but rather as a low-dose exposure to a known hazardous agent—cigarette smoke.

Evaluation of Low-Dose Tobacco Smoke Exposures

Assessment of the health effects of any environmental exposure poses methodological problems, particularly when exposure levels

are low and therefore the magnitude of the expected effect is small. The evaluation of an effect due to a low-dose exposure such as environmental tobacco smoke requires the investigation of populations with differences in exposure large enough so that an effect could be anticipated. The population studied must also be of sufficient size to quantitate the effects in the range of interest with precision. Failure to fulfill these requirements may produce a false-negative result in a study of a low-dose exposure.

Exposure to environmental tobacco smoke is a nearly universal experience in the more developed countries, so the identification of a truly unexposed population is very difficult. Epidemiological studies of involuntary smoking have attempted to identify populations with lower exposure and higher exposure to environmental tobacco smoke, most notably by examining nonsmokers exposed to tobacco smoke generated by the smokers of their family. The effects of environmental tobacco smoke have been investigated in a number of populations throughout the world. The diversity of these populations is likely to be accompanied by a similar diversity of their exposure to environmental tobacco smoke. Thus, the gradient in exposure to environmental tobacco smoke between the "exposed" and "nonexposed" groups is likely to vary widely among the reported studies. For example, the husband's smoking status may be a strong predictor of total exposure to ETS in traditional societies, such as Japan and Greece, where the wife's exposure outside the home is limited. In contrast, the husband's smoking status in the United States, where substantial exposure may occur outside the home, may not be as predictive.

Sample size considerations are of particular concern for the epidemiological studies of lung cancer and involuntary smoking. Because the frequency of lung cancer in nonsmokers is low, many of these studies often included small numbers of nonsmokers and lacked the statistical power necessary to find the modest effect expected from this low-dose exposure. Given the constraints of sample size and the varying gradients of exposure, it would be expected that some studies would find no association between involuntary smoking and lung cancer, and that other studies would find associations that lacked statistical significance. Nonuniformity of the data, however, does not imply a lack of effect; rather, it is the coherence and trends of the evidence that must be judged. Thus, this Report examines the entire body of evidence on the health effects of involuntary smoking, as the basis for its conclusions.

In evaluating the hazards posed by an air pollutant such as environmental tobacco smoke, laboratory, toxicological, human exposure, and epidemiological investigations provide relevant data. Each approach has limitations, but the insights each provides are complementary. Epidemiological investigations describe the effects

in human populations, but their results must be interpreted in the context of the other types of investigations.

Risk assessment techniques have also been used to characterize the potential adverse health effects of human exposures to environmental pollutants, particularly those at low levels. The four steps of risk assessment have been described by the National Academy of Sciences as hazard identification, dose-response assessment, exposure assessment, and risk characterization (NAS 1983). Risk assessment has also been used to describe the consequences of exposure to ETS. However, unlike many environmental exposures for which risk assessment represents the only approach for estimating human risk, the health effects of ETS exposure can be examined directly using epidemiological methods. Although this Report reviews several risk assessments done by individual researchers on ETS, its conclusions are based on the laboratory, toxicological, and epidemiological evidence.

Extrapolation of Active Smoking Data to Environmental Tobacco Smoke Exposure

Comparison of Mainstream Smoke and Sidestream Smoke

A detailed comparison of mainstream and sidestream smoke can be found in Chapter 3. Mainstream smoke (MS) is the term applied to the complex mixture that is inhaled by the smoker from the mouthpiece of a cigarette, cigar, or pipe with each puff. Sidestream smoke (SS) is the aerosol that comes from the burning end of the cigarette, pipe, or cigar between puffs. Environmental tobacco smoke (ETS) is the term applied to the combination of SS and exhaled MS, which is diluted and aged in an area where smoking has taken place. Most of the existing data on mainstream and sidestream smoke characteristics relate to cigarette smoking and relatively little information is available pertaining to cigar and pipe smoking.

Because both MS and SS are generated from the tip of the burning tobacco product, it is not surprising that their compositions are similar. Of the thousands of compounds identified in tobacco smoke, many have been identified as present in both MS and SS. Among these are carcinogens, gases such as carbon monoxide and the oxides of nitrogen, and nicotine. Since there is a wealth of information relating to the toxicity and carcinogenicity of MS, it should be emphasized again that ETS cannot be treated as a new environmental agent for the purpose of assessing health risks. The presence of the same agents in MS and SS leads to the conclusion that ETS has a toxic and carcinogenic potential that would not be expected to be qualitatively different from that of MS. Quantitative differences between the active smoker's exposure to MS and the involuntary smoker's exposure to ETS are likely to be the more important

determinant of the differing magnitudes of risks associated with these two exposures.

Differences in the composition of MS and SS primarily reflect their generation at different temperatures in different oxygen environments. Also, SS is diluted very rapidly, under most circumstances, and has the opportunity to age before inhalation. The involuntary smoker usually inhales ETS, not SS, the aerosol that comes from the tip of a burning cigarette. In considering the characteristics of SS, it must be emphasized that much of the existing data about the composition of MS and SS is derived from studies carried out in special chambers rather than by sampling MS and SS generated by smokers. In these chamber studies, SS has been sampled by a probe located close to the burning tip. This experimental situation clearly differs from that of a room with one or more smokers freely smoking. In that situation, SS is mixed with exhaled MS, diluted and aged. Nevertheless, these chamber studies provide very useful information about the compounds present in the SS. These studies have established that SS in comparison with MS has a higher pH, smaller particle size, and more carbon monoxide, benzene, toluene, acrolein, acetone, pyridine, ammonia, methylamine, nicotine, aniline, cadmium, radon daughters, benzo[a]pyrene and benz[a]anthracene.

Comparison of the relative concentrations of the various components of SS and MS smoke provides limited insights concerning the toxicological potential of ETS in comparison with active smoking. As described above, SS characteristics, as measured in a chamber, do not represent those of ETS, as inhaled by the nonsmoker under nonexperimental conditions. Further, the dose-response relationships between specific tobacco smoke components and specific diseases are not sufficiently established for the necessary extrapolations from active smoking to environmental tobacco smoke exposure for individual agents. For that reason the extrapolations in this section are confined to the dose-response relationships of whole smoke for those diseases with established dose-response relationships.

With regard to the potential of ETS to cause lung cancer, undiluted SS has 20 to 100 times greater concentrations of highly carcinogenic volatile N-nitrosamines than MS (Brunnemann et al. 1978) as well as higher concentrations of benzopyrenes and benz[a]anthracenes.

For nonmalignant effects on airways and the lung parenchyma, the agents responsible for the development of acute and chronic respiratory disease have not been identified, although many tobacco smoke components have been shown to cause lung injury (US DHHS 1984). Presumably, both vapor phase (gaseous) and particulate phase (solid) components of MS are involved. Both airways disease and

parenchymal disease are probably a response to the total burden of respiratory insults, some of which, like active smoking, may be sufficient by themselves to cause physiologic impairment and ultimately, clinical disease. Others, such as ETS, may contribute to the total burden but be insufficient, individually, to cause clinical disease.

Deposition of Mainstream Smoke and Sidestream Smoke and Environmental Tobacco Smoke Dose Estimates

The dose of tobacco smoke delivered to the airways and alveoli depends, among other factors, on the volume of MS, SS, or ETS inhaled, on the rate and depth of inhalation, and on the size, shape, and density of the individual particles or droplets. Patterns of deposition of MS in the lungs have been described, but similar information about deposition patterns for ETS is not yet available. Without such data, it is necessary to extrapolate from the information on MS.

The major factors that affect the pattern of deposition and retention for particles are particle size distribution and breathing pattern. The particle size range and mean aerodynamic diameter for particulates in sidestream smoke are similar to those of mainstream smoke (particle size range of 0.01 to 0.8 μm for sidestream smoke and 0.1 to 1.0 μm for mainstream smoke, and mean aerodynamic diameter 0.32 μm for sidestream smoke and 0.4 μm for mainstream smoke) (see Chapters 3 and 4). The deposition site is determined largely by the size of the particles, with large particles being deposited preferentially in the nasopharynx and large conducting airways. Smaller particles are deposited more peripherally, and very small particles tend to be exhaled and to have a very low deposition fraction. The particulates of ETS, because of their size range, are likely to be deposited peripherally.

The breathing patterns for the inhalation of MS and ETS are also different; MS is inhaled intermittently by the smoker with an intense inhalation, often followed by a breathhold that results in a more equal distribution. Environmental tobacco smoke, on the other hand, is inhaled continuously with tidal breaths when the passive smoker is at rest and with deeper inhalations when the passive smoker is physically active. Breathholding does not normally occur with tidal breathing.

Estimates of the equivalent exposure, in terms of cigarettes per day, resulting from ETS, as compared with MS, vary quite widely and depend on the way in which the estimates were made. Repace and Lowrey (1985) estimated that nonsmokers in the United States are exposed to from 0 to 14 mg of tobacco tar (average 1.4 mg) per day. Vutuc (1984) estimated that the exposure to environmental cigarette smoke is equivalent to 0.1 to 1 cigarette per day actively