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Toward Less Hazardous Cigarettes

Current Advances

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• Critical levels of selected cigarette smoke constituents have been expressed in terms of maximum numbers of pre-1960 cigarettes that a smoker may consume daily without increasing his mortality risk substantially above that of a nonsmoker. This could still imply an important risk, although it may be difficult to detect. We relate these levels to the yields of 27 current low tar and nicotine commercial cigarettes, as measured at the Oak Ridge National Laboratory. In addition, the yields of these selected constituents concomitant with the yield of 1 mg of nicotine are provided as a guide for the smoker who titrates or adjusts his smoking pattern to accommodate a fixed daily intake of nicotine.

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SINCE the Surgeon General's report on smoking and health,¹ considerable attention has been focused on cigarette smoke constituents implicated in the cause of tobacco-related diseases. Many such components have been considered, the most frequently

cited being total particulate matter (tar), nicotine, carbon monoxide (CO), nitrogen oxides (NO_x), hydrogen cyanide (HCN), and acrolein. Several investigations document the contribu-

tion of these components to cancer, chronic pulmonary disease, or cardiovascular impairment.²⁻¹³ Many studies also indicate that there is a dose response between the number of cigarettes smoked and disease incidence and morbidity.^{1,3,6,9,10} Since publication of the Surgeon General's report, average tar values of commercial cigarettes have decreased by 29%, and nicotine yields have decreased by 21%, indicating a continuing preoccupation toward reduced hazard.¹⁴

Evaluation of health benefits resulting from these reductions would be premature because of the long latent periods involved. Available data suggest that, for the present, smoking-related diseases have not abated substantially, with the possible exception of cardiovascular diseases. However, factors contributing to the decline in these latter diseases are not yet clear. On the other hand,

mortality from tracheal, bronchial, and lung cancer has continued to rise; projections for the immediate future indicate that further increases may be expected. This probably is because smokers now in the age groups in which cancer is most likely to develop have spent a considerable part of their smoking history using high tar and nicotine cigarettes. As younger smokers who are exposed to lower tar and nicotine cigarettes approach cancer-susceptible ages, a reduction in morbidity and mortality rates could be expected. However, considering tar and nicotine alone may give an incomplete and misleading picture of hazard reduction: the full impact of low tar and nicotine cigarettes on health effects should be evaluated in

Table 1.—Average Critical Levels of Pre-1960 Cigarette Consumption¹⁵

Disease	No. of Pre-1960 Cigarettes
Cancer of the oral cavity	8.8
Pharyngeal cancer	2.5
Esophageal cancer	7.3
Pancreatic cancer	9.0
Laryngeal cancer	6.8
Lung cancer	5.7
Bladder and kidney cancer	9.5
Coronary artery disease	4.2
Coronary heart disease	3.5
Aortic aneurysm	4.5
Emphysema, bronchitis, or both	10.0
All causes for current smokers	2.0

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terms of all the major toxic smoke components mentioned previously.

Critical levels of daily smoke inhalation have been discussed recently in terms of the maximum number of pre-1960 cigarettes that may be smoked daily without detectable increase to the average smoker's risk of mortality beyond that of a nonsmoker.¹⁵ These are by no means safe levels but merely imply that, for a smoker whose daily consumption does not exceed these levels, any attendant tobacco-related mortality risk may be epidemiologically indiscernible from that of a nonsmoker.

This could still imply a substantial although less readily apparent risk. For instance, if the smoker's risk of developing lung cancer could be reduced from the present level of approximately 10:1 to some value less than 2:1, this risk, while considerable, could be difficult to establish epidemiologically. The inability to verify this reduced risk might lead to its being considered socially tolerable.

Average critical levels relative to diseases to which smokers are particularly susceptible are listed in Table 1, expressed as daily numbers of pre-1960 cigarettes. The last entry in Table 1, "All causes for current smokers," is a comprehensive category representing the effect of cigarette consumption on mortality in general. These values are based on typical yields per cigarette of pre-1960 cigarettes: 43 mg of tar, 3.0 mg of nicotine, 23 mg of CO, 270 µg of NO₂, 410 µg of HCN, and 130 µg of acrolein.¹⁵

CURRENT COMMERCIAL CIGARETTES

Most commercial brands today have yields that are below the typical pre-1960 levels, with particular interest in lowered tar and nicotine yields. A recent publication from the Oak Ridge National Laboratory¹⁶ lists the yields of the six constituents referred to previously for 32 brands of commercial low tar and nicotine cigarettes. Twenty-seven of these brands have measured tar yields that do not exceed 10.0 mg by more than two SEs. Results of testing for these 27 brands are summarized in Table 2. The lowest measured tar yield is 1.2 mg, and the highest is 10.3 mg (SE, 0.40 mg).

Table 3 presents the percentage

Table 2.—Analytical Data for Selected Low Tar and Nicotine Cigarettes^{16*}

Brand	Tar, mg/cig†	Nicotine, mg/cig	Carbon Monoxide, mg/cig	Nitrogen Oxides,‡ µg/cig	Hydrogen Cyanide, µg/cig	Acrolein, µg/cig
Benson & Hedges Lights	10.1	0.81	12.1	135	116	81
Carlton	1.5	0.15	2.6	34	16	15
Carlton Menthol	1.2	0.14	2.0	12	12	10
Decade	5.5	0.46	4.3	57	49	38
Decade Menthol	6.6	0.69	4.4	61	50	47
Iceberg 100's	3.1	0.32	5.7	44	44	42
Kent Golden Lights	8.9	0.71	9.2	61	51	47
Kent Golden Lights Menthol	8.3	0.66	8.3	71	62	37
King Sano	5.8	0.29	11.6	196	79	35
King Sano Menthol	5.3	0.25	13.6	205	102	44
L&M Flavor Lights (King)	7.2	0.80	4.8	40	65	30
L&M Long Lights (100's)	6.5	0.67	5.5	41	69	47
Lark II	7.5	0.61	7.3	83	84	44
Lucky 100	3.1	0.28	5.3	68	34	28
Merit	8.8	0.60	12.1	168	151	49
Merit Menthol	8.4	0.61	10.2	172	140	52
Newport Lights Menthol	10.3	0.85	12.5	86	133	57
Now	1.9	0.19	2.4	25	16	15
Now Menthol	1.8	0.16	2.1	30	9	13
Pall Mall Extra Mild	5.1	0.47	5.8	76	65	38
Real	10.2	1.01	12.9	99	155	76
Real Menthol	7.9	0.81	10.2	84	105	44
Stride	3.3	0.36	1.8	5	<10	12
Tareyton Lights	7.8	0.72	2.6	85	75	31
Tempo	6.9	0.56	10.1	166	98	31
True	4.8	0.46	5.2	72	34	29
True Menthol	5.2	0.42	5.7	64	43	31

*Data analyzed by Oak Ridge National Laboratory.

†Abbreviation cig indicates cigarette.

‡Total oxides of nitrogen.

Table 3.—Reduction in Yields as Percent of Pre-1960 Cigarette Yields

Brand	Tar, mg/cig*	Nicotine, mg/cig	Carbon Monoxide, mg/cig	Nitrogen Oxides, µg/cig	Hydrogen Cyanide, µg/cig	Acrolein, µg/cig
Benson & Hedges Lights	77	73	47	50	72	53
Carlton	97	95	89	87	96	88
Carlton Menthol	97	95	91	96	97	92
Decade	87	85	81	79	88	71
Decade Menthol	85	77	81	77	88	64
Iceberg 100's	93	89	75	84	89	68
Kent Golden Lights	79	76	60	77	88	64
Kent Golden Lights Menthol	81	78	64	74	85	72
King Sano	87	90	50	27	81	73
King Sano Menthol	88	92	41	24	75	66
L&M Flavor Lights (King)	83	73	79	85	84	77
L&M Long Lights (100's)	85	78	76	85	83	64
Lark II	83	80	68	69	80	66
Lucky 100	93	91	77	75	92	78
Merit	80	80	47	38	63	62
Merit Menthol	80	80	56	36	66	60
Newport Lights Menthol	76	72	46	68	68	56
Now	96	94	90	91	96	88
Now Menthol	96	95	91	89	98	90
Pall Mall Extra Mild	88	84	75	72	84	71
Real	76	66	44	63	62	42
Real Menthol	82	73	56	69	74	66
Stride	92	88	92	98	>98	91
Tareyton Lights	82	76	89	69	82	76
Tempo	84	81	56	39	76	76
True	89	85	77	73	92	78
True Menthol	88	86	75	76	90	76
Average	86	83	69	69	83	71

*Abbreviation cig indicates cigarette.

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Table 4.—Critical Levels of Selected Smoke Constituents

Brand	No. of Cigarettes Required							Lowest Row Entry	Highest Row Entry
	Tar	Nicotine	Carbon Monoxide	Nitrogen Oxides	Hydrogen Cyanide	Acrolein			
Benson & Hedges Lights	9*	7	4†	4†	7	4†	4	9	
Carlton	57*	40	18	16†	51	17	16	57	
Carlton Menthol	72*	43	23†	45	68	26	23	72	
Decade	16	13	11	9	17*	7†	7	17	
Decade Menthol	13	9	10	9	16*	6†	6	16	
Iceberg 100's	28*	19	8	12	19	6†	6	28	
Kent Golden Lights	10	8	5†	9	16*	6	5	16	
Kent Golden Lights Menthol	10	9	6†	8	13*	7	6	13	
King Sano	15	21*	4	3†	10	7	3	21	
King Sano Menthol	16	24*	3†	3†	8	6	3	24	
L&M Flavor Lights (King)	12	8†	10	14*	13	9	8	14	
L&M Long Lights (100's)	13*	9	8	13*	12	6†	6	13	
Lark II	11*	10	6†	7	10	6†	6	11	
Lucky 100	28*	21	9	8†	24	9	8	28	
Merit	10*	10*	4	3†	5	5	3	10	
Merit Menthol	10*	10*	5	3†	6	5	3	10	
Newport Lights Menthol	8*	7	4†	6	6	5	4	8	
Now	45	32	19	22	51*	17†	17	51	
Now Menthol	48	38	22	18†	91*	20	18	91	
Pall Mall Extra Mild	17*	13	8	7†	13	7†	7	17	
Real	8*	6	4	5	5	3†	3	8	
Real Menthol	11*	7	5†	6	8	6	5	11	
Stride	26	17†	26	108*	>82	22	17	108	
Tareyton Lights	11	8	18*	6†	11	8	6	18	
Tempo	12*	11	5	3†	8	8	3	12	
True	18	13	9	8†	24*	9	8	24	
True Menthol	17	14	8†	8†	19*	8†	8	19	

*Highest row entry.

†Lowest row entry.

Table 5.—Yields of Selected Constituents Concomitant With Yield of 1 mg Nicotine*

Brand	No. of Cigarettes Necessary to Yield 1 mg Nicotine	Tar, mg	Nicotine, mg	Carbon Monoxide, mg	Nitrogen Oxides, µg	Hydrogen Cyanide, µg	Acrolein, µg
Benson & Hedges Lights	1.2	12.1	1.0	14.5	162	139	73
Carlton	6.7	10.1	1.0	17.4	228	107	101
Carlton Menthol	7.1	8.5	1.0	14.2	85	85	71
Decade	2.2	12.1	1.0	9.5	125	108	84
Decade Menthol	1.4	9.2	1.0	6.2	85	70	66
Iceberg 100's	3.1	9.6	1.0	17.7	136	136	130
Kent Golden Lights	1.4	12.5	1.0	12.9	85	71	66
Kent Golden Lights Menthol	1.5	12.5	1.0	12.5	107	93	56
King Sano	3.4	19.7	1.0	39.4	666†	269	119
King Sano Menthol	4.0	21.2	1.0	54.4†	820†	408	176
L&M Flavor Lights (King)	1.3	9.4	1.0	6.2	52	85	39
L&M Long Lights (100's)	1.5	9.8	1.0	8.3	62	104	71
Lark II	1.6	12.0	1.0	11.7	133	134	70
Lucky 100	3.6	11.2	1.0	9.1	245	122	101
Merit	1.7	15.0	1.0	20.6	286	257	83
Merit Menthol	1.6	13.4	1.0	16.3	275	224	83
Newport Lights Menthol	1.2	12.4	1.0	15.0	103	160	68
Now	5.3	10.1	1.0	12.7	133	85	80
Now Menthol	6.3	11.3	1.0	13.2	189	57	82
Pall Mall Extra Mild	2.1	10.7	1.0	12.2	160	137	80
Real	1.0	10.2	1.0	12.9	99	155	76
Real Menthol	1.2	9.5	1.0	12.2	101	126	53
Stride	2.8	9.2	1.0	5.0	14	<28	34
Tareyton Lights	1.4	10.9	1.0	3.6	119	105	43
Tempo	1.8	12.4	1.0	18.2	299	176	56
True	2.2	10.6	1.0	11.4	158	75	64
True Menthol	2.4	12.5	1.0	13.7	154	103	74
Critical Value	Not Applicable	86.0	6.0	46.0	540	820	260

*Each column also gives constituent/nicotine ratio. For example, entries under column headed "Tar" give tar/nicotine ratios.

†Exceeds critical value.

reductions in yields of these brands compared with yields of typical pre-1960 cigarettes. Reductions range from a high of more than 98% (Stride HCN yield) to a low of 24% (King Sano Menthol NO₂ yield). On the average, the brands under consideration have had the greatest percentage reduction in tar yield (86%) and the least percentage reduction in CO and NO_x yields (69%) compared with pre-1960 cigarettes.

The numbers of these cigarettes smoked daily without exceeding critical levels have been calculated from the data in Tables 1 and 2, as in the following example: since the critical level for all causes is two pre-1960 cigarettes, each yielding 43 mg of tar, the number of Benson & Hedges Lights (10.1 mg of tar each) with the equivalent tar yield is 8.5. Thus, 8.5 Benson & Hedges Lights have a total tar yield equal to the critical level for the "All causes for current smokers" category.

Similar values for all of the brands and constituents considered in this article are given in Table 4, rounded off to the nearest integer. Critical levels were calculated under the assumption of a smoking pattern uniformly distributed over a ten-hour period for any given day. Deviations from such a smoking pattern could alter some critical values, such as those associated with CO effects.¹⁵

The lowest entry in each row of Table 4 represents the maximum number of cigarettes of that brand that if smoked daily would not exceed the critical level for any of the smoke constituents considered. The highest row entry represents the maximum number of cigarettes of that brand that if smoked daily would not exceed at least one of the smoke constituents considered. The range from highest to lowest row entries provides the smoker with intermediate goals for gradually reducing his smoking habit through progressively less hazardous smoking stages: proceeding in this manner, he would gradually reach the lowest row entry as a daily maximum cigarette consumption level. At this point, the smoker is likely to be more receptive to taking the final step toward total cessation.¹⁷ Similar considerations apply to brands not explicitly addressed in this article. If the majority of smokers proceeded

along these lines, it would be reasonable to predict a substantial decrease in tobacco-related morbidity and mortality.

It should be noted from Table 4 that the highest row entries for 14 brands are for tar yields, whereas the lowest row entries for 13 of the brands are for NO_x yields. In addition, lowest row entries for nine brands occur for CO and acrolein. These values suggest that the cigarette manufacturers should concentrate on the further reduction of NO_x yields, while still attempting to reduce further the yields of other constituents, particularly CO and acrolein.

With the introduction of relatively low nicotine yields, it has been suggested that some smokers may compensate by increasing the total number of cigarettes smoked to maintain a fixed daily level of nicotine intake.¹⁸ The daily intake of other constituents for such a person would depend on the nicotine compensation rate. Table 5 lists the yields of selected smoke constituents concomitant with the yield of 1 mg of nicotine for the brands under consideration. For example, for Benson & Hedges Lights, about 1.2 cigarettes yield 1 mg of nicotine. This same number of cigarettes yields 12.1 mg of tar, 14.5 mg of CO, 162 μg of NO_x, 139 μg of HCN, and 73 μg of acrolein. Thus, a smoker compensating to 1 mg of nicotine would be exposed also to these yields of other smoke constituents.

Compensating to other nicotine values would affect associated yields proportionately. Table 5 allows a smoker to estimate his smoke constituent intake, depending on his own nicotine compensation rates. The 1 mg of nicotine yield (one sixth or 17% of the critical value) is accompanied by an NO_x yield that exceeds the critical level for two brands and by a CO yield that exceeds it for one of these brands. For the remaining brands, the nicotine intake can exceed 1 mg before concomitant yields of other constituents exceed critical values.

COMMENT

Pre-1960 cigarettes have contributed most to the current epidemic of tobacco-related diseases, and epidemiologic studies show a relationship between number of cigarettes smoked daily and the risk of the development

of disease. From these studies, we can define the critical daily smoke intake that would not appreciably increase the risk of the smoker over that of the nonsmoker.

Because different cigarette brands deliver different amounts of smoke of different compositions, this critical smoke intake can be met by smoking different numbers of cigarettes, depending on brand.

Today, cigarettes having toxic constituent yields considerably below pre-1960 cigarettes are feasible, and forerunners of such cigarettes are commercially available. Twenty-seven brands that fall into this category were tested at the Oak Ridge National Laboratory, and the numbers of these cigarettes smoked daily without exceeding critical values have been estimated for six major toxic smoke constituents. These critical values may serve as intermediate goals for a smoker who is intent on reducing his smoking habit through progressively less hazardous smoking stages. These calculations are based on the assumption that the smoker of the low tar and nicotine cigarettes will not change his smoking habits in terms of depth of inhalation, frequency of puffing, and butt length. Findings of recent studies support this assumption.¹⁹

Although the yields for the 27 brands are considerably below the yields of the typical pre-1960 cigarettes, additional reductions are warranted, particularly with respect to NO_x, CO, and acrolein. Otherwise, smokers who compensate for fixed levels of nicotine intake, even though these levels do not exceed critical values for nicotine, may be subjecting themselves to daily intakes of other toxic smoke constituents in excess of their estimated critical values.

Methods for further reductions in yields of toxic smoke constituents have been developed through research such as that conducted by the National Cancer Institute's Smoking and Health Program.²⁰ One of the principal objectives of this program is to identify those characteristics of cigarettes that lead to toxic and other adverse effects and to develop methods for reducing or eliminating such factors. Progress has been made thus far in improving methods for reducing tar yields through the use of

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reconstituted tobacco sheet and in reducing nicotine yields through tobacco extraction processes and reblending. Other smoke yields have been adjusted through selected combinations of filters and smoke-dilution devices, the use of high-porosity paper, the use of tobacco blends rich in nitrates, and the adjustment of the cigarette's burning rate. Further incorporation of these and other state-of-the-art advances coupled with flavor acceptability characteristics can

improve commercially available cigarettes to the point where they may properly be termed less hazardous.

The rationale for developing less hazardous cigarettes rests on the fact that despite the publicity given to the health risks associated with smoking, more than 50 million Americans still smoke. While programs to discourage smoking should continue, these educational efforts should be coupled with others directed toward reducing the risks to persistent smokers.

Persuading the smoker to wean himself to progressively less hazardous cigarettes may provide an alternative to smoking cessation that is perhaps more effective than the self-denial approaches of current anti-smoking messages. Although this would not eliminate the risks to the smoker, it is an approach that has the potential to reduce the current epidemic of smoking-associated diseases to a considerably less serious public health problem.

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