The Association Between Marijuana Smoking and Lung Cancer

A Systematic Review

Reena Mehra, MD, MS; Brent A. Moore, PhD; Kristina Crothers, MD; Jeanette Tetrault, MD; David A. Fiellin, MD

Background: The association between marijuana smoking and lung cancer is unclear, and a systematic appraisal of this relationship has yet to be performed. Our objective was to assess the impact of marijuana smoking on the development of premalignant lung changes and lung cancer.

Methods: Studies assessing the impact of marijuana smoking on lung premalignant findings and lung cancer were selected from MEDLINE, PSYCHLIT, and EMBASE databases according to the following predefined criteria: English-language studies of persons 18 years or older identified from 1966 to the second week of October 2005 were included if they were research studies (ie, not letters, reviews, editorials, or limited case studies), involved persons who smoked marijuana, and examined premalignant or cancerous changes in the lung.

Results: Nineteen studies met selection criteria. Studies that examined lung cancer risk factors or premalignant changes in the lung found an association of marijuana smoking with increased tar exposure, alveolar macrophage tumoricidal dysfunction, increased oxidative stress, and bronchial mucosal histopathologic abnormalities compared with tobacco smokers or nonsmoking controls. Observational studies of subjects with marijuana exposure failed to demonstrate significant associations between marijuana smoking and lung cancer after adjusting for tobacco use. The primary methodologic deficiencies noted include selection bias, small sample size, limited generalizability, overall young participant age precluding sufficient lag time for lung cancer outcome identification, and lack of adjustment for tobacco smoking.

Conclusion: Given the prevalence of marijuana smoking and studies predominantly supporting biological plausibility of an association of marijuana smoking with lung cancer on the basis of molecular, cellular, and histopathologic findings, physicians should advise patients regarding potential adverse health outcomes until further rigorous studies are performed that permit definitive conclusions.

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Marijuana is the most commonly used illicit drug in the United States.1 According to the 2003 National Survey on Drug Use and Health, more than 94 million Americans, or 40% of Americans aged 12 years or older have tried marijuana at least once.2 Recent data indicate that past-year prevalence of marijuana abuse or dependence increased significantly in the population from 1.2% in 1991-1992 to 1.5% in 2001-2002, which translates into an increase from 2.2 million persons to 3.0 million.3 Given the widespread use of marijuana, its use for what are believed to be medicinal purposes, and the increasing abuse and dependence on this substance, it is important to examine potential adverse clinical consequences.

Marijuana smoking, like tobacco smoking, may be associated with increased risk of lung cancer. Marijuana smoke contains cannabinoid compounds in addition to many of the same components as tobacco smoke. For instance, benzopyrene, a carcinogenic polycyclic aromatic hydrocarbon, is found in both tobacco and marijuana smoke and has been implicated in mutations related to lung cancer.4-7 Furthermore, experimental studies support an association between marijuana smoke exposure and lung cancer, with lung cancer cell lines demonstrating tetrahydrocannabinol (THC)-induced malignant cell proliferation8,9 and a murine model suggesting that THC promotes tumor growth by inhibiting antitumor immunity by a cannabinoid-2 receptor mediated pathway.10 Although the preponderance of in vitro data supports a biologically plausible association, limited research exists that suggests anticarcinogenic cannabinoid effects.11-13 Given these contrasting data, we chose to systematically evaluate the association between smoking marijuana and lung cancer.

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The purpose of the current review is to determine whether (1) marijuana smoking is associated with lung cancer risk factors or premalignant changes assessed by known or potential mediators of lung carcinogenesis and (2) marijuana smoking is associated with increased incidence of lung cancer.

**METHODS**

**SEARCH STRATEGIES**

English-language studies in persons aged 18 years or older were identified from the OVID, MEDLINE, PSYCHLIT, and EMBASE databases from 1966 to the second week of October 2005, using the medical subject headings and text words shown in Table 1.

Retrieval of studies was performed by 2 reviewers (R.M. and B.A.M.) who examined the titles and abstracts obtained from the initial electronic search. We excluded letters, reviews, editorials (ie, non-research studies), and case series involving fewer than 10 patients, as well as studies that did not involve humans with direct, intentional marijuana smoking (eg, studies of hemp exposure in occupational settings) or did not examine lung function or lung conditions related to premalignant or cancerous changes. Studies involving cannabis, hashish, and/or kif (Moroccan hashish) were included owing to content overlap. Abstracts that could not be categorized based on the information provided were reviewed in manuscript form to allow a final decision regarding classification. Studies with discrepant categorizations by the 2 reviewers were resolved by a third member (D.A.F.) of the research team using consensus.

**ABSTRACTION AND VALIDITY ASSESSMENT**

Data regarding methods were extracted using a custom-designed data collection form. Data were collected on (1) amount, frequency, mode, and methods of marijuana smoking; lung cancer risk factors or premalignant changes and lung cancer outcomes; (2) assessment of tobacco or illicit substance use; (3) evaluation of preexisting lung disorders; (4) study setting; (5) subject selection; and (6) subject characteristics.

Two reviewers independently assigned a quality index score according to a 31-point scale that assesses reporting, external validity, bias (internal validity), confounding (external validity), and power. Based on these quality components, we graded articles as good (a score ≥12) or fair to poor (a score <12) based on an established cutoff. Differences between reviewers were resolved by consensus with input from the third reviewer. Interrater reliability was high (r = 0.77).

**SEARCH STRATEGIES**

We identified 186 abstracts through the literature search as described in the “Search Strategies” subsection (107 from MEDLINE, 67 from EMBASE, and 12 from PSYCHLIT); 37 were duplicates, leaving 149 unique abstracts. Of these, we categorized 119 based on abstract review and evaluated full manuscripts for the remaining 30 citations. The level of agreement regarding inclusion of potential manuscripts based on abstract review between the 2 reviewers was high (κ = 0.95). Of the 149 articles, 56 were excluded because they were not research studies (ie, they were letters, reviews, or editorials); 8 were case series of fewer than 10 cases; 51 did not involve humans with direct, intentional marijuana smoking; and 13 did not include measures related to lung cancer. Thus, 19 studies that examined the association between marijuana use and lung cancer were included in this systematic review (Figure).
The 19 studies on marijuana smoking and lung cancer that met our criteria for inclusion had diverse study designs that included 4 experimental studies, 15-18 5 prospective cohort studies (all involving a similar cohort), 19-23 2 retrospective cohort studies, 24,25 6 case-control studies, 26-31 and 2 case series. 32,33 Studies subjects included those who responded to newspaper advertisements and radio announcements, 19-23 army volunteers presenting with respiratory tract symptoms at a clinic, 30,33 volunteer surfers, 26,27 and patients recruited at hospital admission or outpatient clinic visits. 24,25,31,32 Five studies 15-18,34 did not specify recruitment procedures. Approximately 50% of these studies reported the ages of subjects (mean age, 32.5 years [range, 20.4-63 years]). Roughly 75% of the studies reported the subject’s sex (male, 43.9%; range, 43%-100%). Studies described marijuana exposure using a variety of methods, including frequency, duration, and quantity (Tables 2, 3, 4, 5, and 6). Most studies defined marijuana use as current smoking of marijuana, with an average of more than 10 marijuana cigarettes per week for 5 or more years. 19,23,34 Premalignant and lung cancer outcomes included those with (1) premalignant associated changes such as tar

<table>
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<tr>
<th>Table 2. Studies Reporting Marijuana (MJ) Use Exposure and Tar Exposure</th>
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<tbody>
<tr>
<td><strong>Source; Study Type</strong></td>
</tr>
<tr>
<td>Matthias et al a15; experimental</td>
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<tr>
<td>Tashkin et al a16; experimental</td>
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<tr>
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<td>Wu et al a18; experimental</td>
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</table>

<table>
<thead>
<tr>
<th>Source; Study Type</th>
<th>Cannabis Exposure</th>
<th>Results</th>
<th>Confounders Controlled</th>
<th>Mean Study Quality Score</th>
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<tbody>
<tr>
<td>Matthias et al a15; experimental</td>
<td>Habitual MJ smokers</td>
<td>Tar delivered and deposited in the lung in the most potent compared with the least potent MJ preparation</td>
<td>NA</td>
<td>11</td>
</tr>
<tr>
<td>Tashkin et al a16; experimental</td>
<td>Daily or near daily MJ use over ≥5 y</td>
<td>Longer breath-holding time significantly increased retention of inhaled tar in the lungs (P &lt; .001)</td>
<td>NA</td>
<td>11</td>
</tr>
<tr>
<td>Tashkin et al a17; experimental</td>
<td>Daily or near daily MJ use over ≥5 y</td>
<td>More tar was inhaled from the second half of the MJ cigarette than the first half (P &lt; .05)</td>
<td>MJ exposure compared with tobacco exposure</td>
<td>9.5</td>
</tr>
<tr>
<td>Wu et al a18; experimental</td>
<td>Habitual smokers</td>
<td>Compared with smoking tobacco, smoking MJ resulted in 3-fold increase in amount of tar inhaled (P &lt; .001)</td>
<td>MJ exposure compared with tobacco exposure</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Abbreviations: CO, carbon monoxide; NA, not applicable; NP, not provided; THC, tetrahydrocannabinol.

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<thead>
<tr>
<th>Table 3. Studies Reporting Marijuana (MJ) Use Exposure and Cytomorphologic Changes in Sputum Specimens</th>
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<tr>
<td><strong>Source; Study Type</strong></td>
</tr>
<tr>
<td>Roby et al a19; case-control</td>
</tr>
<tr>
<td>Starr and Renneker a20; case control</td>
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</tr>
</thead>
<tbody>
<tr>
<td>Roby et al a19; case-control</td>
<td>Smoking MJ regularly for ≥2 y without tobacco use</td>
<td>Cytologic changes in habitual MJ smokers similar to tobacco smokers and different from nonsmokers; MJ smokers had more of the following compared with nonsmokers: columnar cells (P &lt; .01), metaplastic cells (P &lt; .01), reactive columnar cells (P &lt; .03), and purse cells (P &lt; .01)</td>
<td>MJ smokers compared with tobacco smokers</td>
<td>9.5</td>
</tr>
<tr>
<td>Starr and Renneker a20; case-control</td>
<td>Regular MJ smokers (smoked at least twice weekly) for &gt; 2 y</td>
<td>MJ (n = 75) smokers show higher levels of metaplastic cells, macrophages, and column cells (P &lt; .05) compared with nonsmokers and lower levels of neutrophils (P &lt; .005) and pigmented macrophages (P &lt; .001) compared with tobacco smokers; dysplasia noted in 2 tobacco smokers, 1 MJ smoker, and no nonsmokers</td>
<td>Non–tobacco smoking MJ smokers compared with tobacco smokers</td>
<td>10.5</td>
</tr>
</tbody>
</table>
delivery, (2) cytomorphologic abnormalities in sputum, (3) alveolar macrophage tumoricidal activity, DNA damage, and oxidative stress, (4) histopathologic and molecular alterations in bronchial biopsy specimens, and (5) lung or respiratory tract cancer diagnosed radiographically or histopathologically.

The heterogeneous nature of the studies and their outcomes precluded quantitative synthesis (eg, a meta-analysis); therefore, this review focuses on a qualitative synthesis of the data.

## RESULTS

### MARIJUANA SMOKING AND TAR EXPOSURE

Tar is particulate matter residue from smoke and includes carcinogens. Tar exposure results from marijuana smoking and may serve as a potential mediator of lung carcinogenesis. In general, 4 experimental studies demonstrate that marijuana smoking is associated with increased tar delivery to the lungs compared with cigarette smoking; furthermore, there are several factors that affect the degree of tar exposure from smoking marijuana (Table 2). A study examining the association between marijuana smoking and tar exposure indicated that the longer breath-holding time typical of marijuana users significantly increased the percentage of retention of inhaled tar in the lungs compared with shorter breath-holding time in tobacco smokers. In a study of 15 male participants, smoking marijuana resulted in a 3-fold increase in amount of tar inhaled compared with smoking tobacco. The amount of tar delivered and deposited in the lung was reduced in the most potent marijuana smokers compared with the less potent marijuana preparation, which suggests that there is reduced exposure to carcinogenic components in the tar phase of marijuana with higher THC content.

Increased tar exposure in the proximal half of the marijuana cigarette compared with the distal half was also noted, which suggests that smoking fewer marijuana cigarettes to a shorter length results in a greater delivery of tar to the respiratory tract relative to a comparable amount of marijuana from more cigarettes smoked to a longer butt length.

This literature supports an increased exposure to tar in marijuana smoke compared with tobacco smoke based on comparable amounts of smoked contents and increased tar exposure associated with decreased marijuana potency in the proximal portion of a marijuana cigarette compared with the distal portion.

### MARIJUANA SMOKING AND CYTOMORPHOLOGIC CHANGES IN SPUTUM SPECIMENS

Two case-control studies examined marijuana smoking and sputum cytomorphicologic changes in habitual marijuana smokers without current or prior use of tobacco (Table 3). These studies noted that non–tobacco-smoking marijuana smokers had more metaplastic cells, macrophages, pigmented macrophages, and columnar cells compared with nonsmokers. In another study, dysplasia was observed in 3 of 25 tobacco smokers, of 23 marijuana smokers, and none of the 25 nonsmokers. Conversely, lower mean levels of neutrophils and pigmented macrophages were observed in marijuana smokers compared with tobacco smokers.

These studies suggest overall increased pathologic changes, in particular metaplastic changes, in select populations of marijuana smokers compared with tobacco smokers and nonsmokers.

### MARIJUANA SMOKING AND ALVEOLAR MACROPHAGE EFFECTS

Studies evaluating the associations between marijuana smoking and alveolar macrophages revealed decreased alveolar macrophage tumoricidal activity, DNA damage, and oxidative stress.

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Table 4. Studies Reporting Marijuana (MJ) Use Exposure and Alveolar Macrophage Effects

<table>
<thead>
<tr>
<th>Source; Study Type</th>
<th>Cannabis Exposure</th>
<th>Results</th>
<th>Confounders Controlled</th>
<th>Mean Study Quality Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baldwin et al; cohort</td>
<td>Smoked MJ for at least 5 d/wk for 5 y</td>
<td>Alveolar macrophages from MJ smokers were limited in their tumoricidal ability (P&lt;.01) compared with nonsmokers</td>
<td>Non–tobacco-smoking MJ smokers</td>
<td>11.5</td>
</tr>
<tr>
<td>Sarafian et al; case-control</td>
<td>&gt;10 MJ cigarettes/wk for ≥5 y</td>
<td>BAL from habitual MJ smokers revealed GSH levels that were 31% lower than cells from nonsmokers (P&lt;.03)</td>
<td>Non–tobacco-smoking MJ smokers and controls</td>
<td>7</td>
</tr>
<tr>
<td>Sherman et al; case-control</td>
<td>ND</td>
<td>Alveolar macrophages recovered from MJ smokers, either alone or in combination with tobacco smoking, show a trend toward DNA damage</td>
<td>MJ smokers compared with MJ + tobacco smokers</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Abbreviations: BAL, bronchoalveolar lavage; GSH, glutathione; ND, not defined; NM, not mentioned; NP, not provided.
Table 5. Studies Reporting Marijuana (MJ) Use Exposure and Bronchial Biopsy Histopathologic and Molecular Alterations

<table>
<thead>
<tr>
<th>Source; Study Type</th>
<th>Male Participants, No. (%)</th>
<th>Age, y</th>
<th>Setting</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barsky et al; cohort</td>
<td>104 (77.9)</td>
<td>Range, 21-50</td>
<td>Metropolitan Los Angeles</td>
<td>Histopathologic and molecular alteration in bronchial epithelium in habitual smokers of marijuana, cocaine, and/or tobacco (bronchial biopsy and brush specimens)</td>
</tr>
<tr>
<td>Fligiel et al; cohort</td>
<td>70 (NP)</td>
<td>NP</td>
<td>Metropolitan Los Angeles</td>
<td>Bronchial biopsy specimens, examining for epithelial changes and basement membrane changes</td>
</tr>
<tr>
<td>Fligiel et al; cohort</td>
<td>241 (83)</td>
<td>NP</td>
<td>Metropolitan Los Angeles</td>
<td>Bronchial biopsy specimens, light microscopic evaluation</td>
</tr>
<tr>
<td>Gong et al; cohort</td>
<td>37 (85)</td>
<td>NP</td>
<td>Metropolitan Los Angeles</td>
<td>Bronchial biopsy specimens, examining for epithelial changes, basement membrane changes, and submucosal inflammation</td>
</tr>
<tr>
<td>Henderson et al; case-control</td>
<td>n = 200, 6 of whom underwent bronchoscopy, 100%</td>
<td>NP</td>
<td>Army medical facility. Came to facility with respiratory complaint related to high-dose hashish use</td>
<td>Bronchial biopsy specimens</td>
</tr>
<tr>
<td>Tennant; case-control</td>
<td>36 (100)</td>
<td>Mean, 20.4 (range, 17-22)</td>
<td>US soldiers stationed in West Germany</td>
<td>Bronchial biopsy specimens showing atypical cells, basal cell hyperplasia, squamous metaplasia</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Source; Study Type</th>
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<th>Results</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Barsky et al; cohort</td>
<td>Current smoking of MJ with an average of &gt;10 MJ cigarettes/wk for ≥5 y</td>
<td>MJ-only smokers (n = 12) had more frequent histopathologic abnormalities than nonsmokers: squamous metaplasia (P&lt;.001), cell disorganization (P&lt;.001), nuclear variation (P&lt;.001), mitotic figures (P&lt;.001), increased nuclear-cytoplasmic ratio (P&lt;.001), MJ smokers had more abnormal expression of Ki-67 (P&lt;.01) and EGFR (P&lt;.01) compared with nonsmokers</td>
<td>MJ smokers non–tobacco smokers and compared with a tobacco smoking group</td>
<td>11</td>
</tr>
<tr>
<td>Fligiel et al; cohort</td>
<td>Smoking of MJ with an average of &gt;10 MJ cigarettes/wk for ≥5 y</td>
<td>Tobacco, cocaine, and marijuana smokers had severe effects on histopathologic alterations; abnormalities were more commonly seen in MJ-tobacco smokers as opposed to tobacco smokers; compared with nonsmokers, MJ and tobacco smokers more often had squamous metaplasia (P&lt;.001)</td>
<td>MJ smokers non–tobacco smokers and compared with a tobacco smoking group</td>
<td>10</td>
</tr>
<tr>
<td>Fligiel et al; cohort</td>
<td>Current smoking of MJ with an average of &gt;10 MJ cigarettes/wk for ≥5 y</td>
<td>Effects of MJ and tobacco on bronchial histopathologic findings is additive; those who smoked MJ only had more frequent histopathologic abnormalities than nonsmokers: squamous metaplasia (P&lt;.001), stratification (P&lt;.001), cell disorganization (P&lt;.05), mitotic figures (P&lt;.001), increased nuclear-cytoplasmic ratio (P&lt;.001)</td>
<td>MJ smokers non–tobacco smokers and compared with a tobacco smoking group</td>
<td>11.5</td>
</tr>
<tr>
<td>Gong et al; cohort</td>
<td>Current smoking of MJ with an average of &gt;10 MJ cigarettes/wk for ≥5 y</td>
<td>MJ smokers have more abnormal airway appearance and histopathologic alterations irrespective of tobacco use; MJ smokers had more basal cell hyperplasia (P&lt;.009) compared with nonsmokers; MJ smokers had more cellular disorganization (P&lt;.03) compared with tobacco smokers</td>
<td>MJ smokers (non–tobacco smokers) compared with tobacco only smokers</td>
<td>9.5</td>
</tr>
<tr>
<td>Henderson et al; case-control</td>
<td>Heavy hashish smokers</td>
<td>All 6 MJ smokers who underwent bronchoscopy had mucosal injection, and all biopsy specimens had epithelial abnormalities</td>
<td>Tobacco smoking not taken into account</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Abbreviations: EGFR, epidermal growth factor receptor; NP, not provided.

...lar macrophage function, DNA damage, and oxidative stress consisted of 1 cohort study and 2 case-control studies (Table 4). A study involving a prospective cohort revealed that alveolar macrophages recovered from marijuana smokers were severely limited in their ability to kill tumor cells (P<.01) compared with nonsmokers. Alveolar macrophages recovered from marijuana smokers with and without tobacco exposure were more likely to show DNA damage; however, results were not statistically significant. In a separate...
There were 6 studies evaluating histopathologic and/or molecular alterations from bronchial biopsy findings associated with marijuana smoking: 4 were cohort-based studies and 2 were case series (Table 5). All reported an increase in abnormal and precancerous findings in marijuana smokers compared with controls who smoked tobacco or controls with unspecified tobacco exposure. Observational cohort studies demonstrated a relationship between marijuana use and abnormal bronchial disease. One study demonstrated that marijuana-only smokers had more frequent abnormal histopathologic findings than nonsmokers with a significant association between marijuana use and pathologic changes, including squamous cell metaplasia and increased mitotic figures. Compared with nonsmokers, marijuana smokers were noted to more commonly have abnormal expression of Ki-67, a proliferation marker. Epidermal growth factor receptor, a surrogate marker for lung malignancy and a potential cause for the histopathologic alterations, was also noted more frequently in marijuana smokers compared with nonsmokers. A separate study concluded that all types of smokers (those who smoked tobacco, cocaine, and marijuana) had abnormal histopathologic findings; specifically, marijuana smokers were more likely to have pathologic bronchial mucosal alterations compared with nonsmokers. In this study, mucosal and basement membrane changes were observed with a greater frequency in the marijuana-smoking group than the tobacco-smoking group. Marijuana smokers demonstrated more frequent histopathologic alterations compared with nonsmokers in 8 of the 11 pathologic categories, and the effects of marijuana and tobacco smoking seemed to be additive.

This literature supports the conclusion that marijuana smokers were more likely to have basal, goblet, and squamous cell hyperplasia; stratification; cell disorganization; nuclear variation; an increased nuclear-cytoplasmic ratio; basement membrane

Abbreviations: CI, confidence interval; OR, odds ratio.
branе thickеnіng; squамоuѕ cell mеtаplаsіа; mіtocіtіс fіgurеs; аbноrmlе expression оf аn аlаnіnе mаrkеr, Ki-67; аnd іnсrеаsеd еріdеrmаl g роwth fасtоr рерtесоmеr сарареd wіth nоnsmоkеrs.20-30,33 The еffесts оf mаrijuаnа аnd tаbассо smoking ѕееmеd tо bе аdditіvе ассоrdіng tо 1 ѕtudу.21

MARIJUANA SMOKING AND LUNG CANCER

Studies ехаmіnіng thе аssоцитіоn оf mаrijuаnа smоkіng аnd dіагnоsіsеs оf lung cancer іnсludеd 1 lаrgе rеtросресtіvе соhоrt соutу (n=64855),25 2 саѕе-соntоluѕ соutуs,24,31 іnсludіng 1 соutу32 (Tаblе 6). Thе соuntу соuntу dеmоnstrаtеd thаt расt аndaceutоr сurеѕ оf mаrijuаnа wаѕ nоt ассоrдеd wіth аn іnсrеаsеd оduгs оf lung cancer, аftеr аdјusіng fоr tаbассо uсе іn mеn (odds rаіо [OR], 0.9; 95% сіdеntісо іntеrvаl [CI], 0.5-1.7) оr wоmеn (OR, 1.1; 95% CI, 0.5-2.6).25 А саѕе-соntоluѕ соutу (n=353) fоund thе оdduгs оf lung cancer іn uѕеrѕ оf hаshіsh оr kіff tо bе 1.93 (95% CI, 0.57-6.58) аftеr соntоluіng fоr tаbассо uсе.26 Аmоng раtіеntѕ оutеr thаn 45 уеаrs wіth lung cancer, mаrijuаnа smoking wаѕ rероrtеd іn 13 (13.4%) оf 97 соmраrеd wіth 6 (6.2%) оf 97 аmоng раtіеntѕ оutеr thаn 45 уеаrs (P<.001), dеmоnstrаtіng аn uсhаrасtеrіѕtіс рrеsеntаtіоn оf lung cancer іn yоung mаrijuаnа smоkеrs соmраrеd wіth оldеr mаrijuаnа smоkеrs, wісh ѕugасtісеѕ thаt mаrijuаnа еxраsуро uѕе mау ассеlеrаtе thе mаlgnаnсу lаtеnсу реіоd.24 However, mоѕt ѕubjесts іn thіѕ соutу wеrе аlso tаbассо smоkеrs, аnd thе іnѵестіgаtоrs dіd nоt ассоunt fоr thіѕ. А lаrgе соutу реrіоdе (n=10) rероrtеd rеріараtоr trасt mаlgnаnсу іn ассоrаtіоn wіth mаrijuаnа smоkіng; hоwеvеr, thіѕ рrоt р did nоt соntо rоr tаbассо smоkіng.32

Thеѕе ѕtudіеѕ wеrе nоt аblе tо dеmоnstrаtе а rеlаtіоnshір bеtееn mаrijuаnа smоkіng аnd а dіаgноѕіs оf lung cancer.

STUDY QUALITY

Оvеrаll, thе mеаn quаlіtу соrrеs wаѕ 9.5 (rаngе, 1.5-14) оn а 31-point ѕасе.14 Thе mеаn quаlіtу соrrеѕ fоr thе 4 еxреrіmеntаl соutуs wаѕ 10.75 (rаngе, 9-12); fоr thе 5 рrореrсtіvе соutуs, 10.75 (rаngе, 9.5-11.5); fоr thе 2 рrореrесtіvе соutуs, 8.5 (rаngе, 6-11); fоr thе 6 саѕе-соntоluѕ соutуs, 9.0 (rаngе, 3.5-14); аnd fоr thе 2 саѕе соutуs, 2.25 (rаngе, 1.5-3).

COMMENT

Тhеѕе 19 dіvеrѕе ѕtudіеѕ оffеr bіоlоgісаl еvіdеnсе fоr thе роtеntіаl аssоцитіоn bеtееn mаrijuаnа smоkіng аnd lung cancer. Most ѕtudіеѕ ѕuрроrt аn аssоcitіоn bеtееn mаrijuаnа smоkіng іn dаrе wіth thе lеngthеr bратh-hоldіng сhаrасtеrіѕtіс оf mаrijuаnа smoking mау еnhаnсе саrісіngеnіс rіsk bаѕеd оn рrіоr соutуs thаt hаvе dеmоnstrаtеd аn аssоcitіоn bеtееn tаr еxраsуро frоm tаbассо smоkіng аnd lung cancer.55-37

In ad соrе, thеrе wеrе mоrе суtоmорhоlоgіс hаnges, іn раrtісuluаr mеtаplаsіа, аl?vоrеlаr mаcрораhе tуморісіdаl dіѕуnсhуn, еnhаnсеd оxіdаtіvе trеsѕіс, аnd hіѕtоpаthоlоgіс/mоlесуlаr аlгаrаtіоns ассоrаtеd wіth mаrijuаnа smоkіng compared wіth соntоlѕ оr thоѕе wіоr dіd smоkіng ѕісо. Thеѕе fіndіngs оffеr bіоlоgісаl еvіdеnсе thаt mаrijuаnа smoking соuld bе ассоrаtеd wіth thе dеvеlоpmеnt оf lung cancer іn hумаns, аs hаs bееn ѕugасtісеd bу аnіmаl соutуs аnd сеll lіnе ехреrіmеnts. Срріcісаlly, mеtаplаsіс сеllуlаr сhаnсеѕ mау lеаd tо mаlgnаnt trаnѕfоrmаtіоn. Аbноrml mасрораhе tуморісіdаl fуnсtіоn mау rіѕult іn uсhесkеd сеllуlаr рроlіоtrаtіоn, аnd еnhаnсеd оxіdаtіvе trеsѕіѕ hаs bееn dесrіbеd аѕ a mесhаnісіс lіnіс thаt саrісіngеnеѕѕ рrеѕumаblу vіа mаtіgеnіс оxіdаtіvе bіоmаrkrе dаmаgе.38-41 Bnсhоnіс hіѕtоpаthоlоgіс аnd mоlесуlаr аlгаrаtіоns, аs thоѕе іnісludіng Ki-67 аnd еріdеrmаl g роwth fасtоr рерtесоmеr, mау rеprеsеnt а hаrбіngеr оf mаlgnаnt сvоr. Dіspеtе thеѕе fіndіngs, thе sіmаlеѕ роrt оf оb-
surveillance of lung cancer diagnosis, young age of study participants, and concerns regarding generalizability owing to the use of similar cohort in 9 (47.4%) of 19 of the reviewed studies. Of the 6 studies examining the association between marijuana use and histopathologic findings, 4 involved a similar prospective cohort. 20-23 These 4 studies revealed a positive association between marijuana use and pre-malignant bronchial disease; however, given the similar cohort involved, the external validity of these findings is uncertain. In addition, the case-control study evaluating marijuana smoking with lung cancer outcomes may be limited by the definition of lung cancer because some diagnoses were made radiographically rather than by tissue diagnosis, which may have led to misclassification bias. 24 In this study, an OR of 1.93 (95% CI, 0.57-6.38) assessing the strength of the relationship of marijuana use and lung cancer was observed, and lack of a statistically significant relationship may have been secondary to limited power to detect an effect as well as a potential outcome misclassification. 24 The large cohort study (n=64,855) involving a retrospective review may be subject to recall bias because data were not prospectively collected to evaluate the exposure and outcome variables of interest. 21 In addition, the overall young age of the participants (mean age, 33 years) poses a serious overall limitation of these studies because this may have precluded an adequate period of follow-up for the development of a malignancy. Finally, despite performing an extensive literature search in 3 electronic databases, there is the possibility that relevant studies that were not published or not included in databases were missed.

The findings of this systematic review have implications for research and clinical practice. Our assessment of study quality reveals that future research directions should include increased adherence to methodologic standards, more detailed assessment of marijuana exposure, larger sample sizes, adjustment for tobacco smoking, uniform surveillance for lung cancer diagnoses, multicenter evaluation, evaluation of dose-response relationships, and involvement of study participants who represent a wider spectrum of ages with longer follow-up periods. Continued research on the pathophysiologic mechanisms by which marijuana smoking may lead to development of malignancy should provide insight into shared and convergent pathways with tobacco-related lung cancer. The potential for additive or synergistic effects between marijuana and tobacco smoking, as suggested from this literature, deserves rigorous evaluation, especially given the significant comorbid prevalence of these 2 behaviors. Large, prospective studies with detailed assessment of marijuana exposure and definitive pathologic diagnosis of lung cancer are also needed. A population-based case-control trial that started in 1999 and recently concluded has assessed the association of marijuana smoking and lung cancer involving cases identified via the Los Angeles Surveillance Epidemiology and End Results registry and matched controls. This study 45, 50 with results forthcoming has incorporated marijuana exposure data collection in joint years obtained via trained interviewers in the home setting.

Although observational studies have not shown a substantive marijuana smoking–lung cancer association, these studies are fraught with serious methodologic limitations. Therefore, the combination of the widespread use of marijuana, potential marijuana-related health implications outlined in this review, and studies evaluating lung premalignant alterations supporting a biologically plausible association between marijuana smoking–lung cancer association, in addition to compelling in vitro data not included in this review, provide support for physician advice regarding the potential adverse effects, including the potential for premalignant lung changes, to their patients that use marijuana.

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