PAPERS AND ORIGINALS

Effect of Cigarette Smoking on Competence of the Pylorus: Preliminary Study

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Summary

The competence of the pylorus was studied in 13 normal volunteers and nine dyspeptic patients by means of a radiological technique involving intubation of the duodenum. The pylorus was found to be competent in most normal individuals and in fewer than half of the dyspeptic patients. However, on smoking a cigarette, appreciable increase in duodenogastric reflux was seen in nine out of the 13 normal volunteers and in seven out of the nine dyspeptic patients. Such induced pyloric incompetence and the resultant regurgitation of duodenal juices may explain the increased incidence of gastritis and gastric ulceration in heavy smokers.

Introduction

We believe that the association of smoking and gastric ulceration is mediated by incompetence of the pylorus and reflux of duodenal contents. We have therefore attempted to show that incompetence of the pylorus is usually induced while the patient actually smokes a cigarette.

An increasing amount of evidence indicates that reflux of bile and digestive juices is of considerable importance in the pathogenesis of gastric ulceration (Du Plessis, 1965; Capper, 1967; Janowitz, 1969; Delaney *et al.*, 1970; Rhodes, 1972). In normal healthy people there is usually very little reflux of duodenal contents. This has been shown by several techniques: measurement of bile in the stomach (Rhodes *et al.*, 1969; Black *et al.*, 1971 a), radiographic screening of a radio-opaque substance injected directly into the duodenum (Capper *et al.*, 1966; Nelson, 1969; Beneventano and Schein, 1970; Flint and Grech, 1970), direct observation via a gastroscope (Aste *et al.*, 1972), and measurement of the antral transmural potential difference (Anderson and Crossman, 1965; Geall *et al.*, 1970; Fisher and Cohen, 1973 a). Fisher and Cohen (1973) have shown by pressure recordings that the pylorus acts as a true physiological sphincter preventing access of noxious agents to the stomach. However, in the presence of gastritis (Flint and Grech, 1970) and gastric ulceration (Du Plessis, 1965; Capper *et al.*, 1966; Rhodes *et al.*, 1969; Nelson, 1969; Flint and Grech, 1970; Black *et al.*, 1971 a; Aste *et al.*, 1972; Cocking and Grech, 1973; Fisher and Cohen, 1973 b) the pylorus is incompetent and allows duodenal contents to bathe the gastric mucosa.

Bile disrupts the mucous membrane of the stomach, allowing luminal acid to leak back into the epithelium in exchange for sodium ions (Ivey *et al.*, 1970, 1971; Black *et al.*, 1971 b). This event is associated with a profound drop in transmural potential difference (Davenport *et al.*, 1965; Geall *et al.*, 1970; Fisher and Cohen, 1973 b) and results in histological changes of gastritis with bleeding (Davenport, 1964; Davenport, 1965 a; Davenport *et al.*, 1965; Overholt and Pollard, 1968). Lawson (1964) has shown in dogs that changes of gastritis develop in gastric mucosa exposed to duodenal juice in situ. A gastric ulcer is generally found in an area of gastritis and the two conditions probably have a common aetiology (Du Plessis, 1965).

Gastric ulceration (Toon *et al.*, 1951; Doll *et al.*, 1958; Edwards *et al.*, 1959; Monson, 1970; Bennett, 1972) and gastritis (Edwards and Coghill, 1966) are more common in smokers than in non-smokers. Also gastric ulcers heal more rapidly if the patient stops smoking (Jamieson *et al.*, 1946; Batterman and Ehrenfeld, 1949; Doll *et al.*, 1958). It is tempting to think that in some way smoking causes the pylorus to become incompetent.

Subjects and Methods

Two groups of experienced smokers were used in the trial: Group 1 were 13 normal volunteers who had no history of diseases involving the chest (Beeley and Grech, 1971) or gastrointestinal tract. Most of these were young and healthy members of the medical and nursing staff. Group 2 were nine patients who exhibited dyspeptic symptoms. The age, sex, pattern of smoking, and relevant clinical details are given in table II.

All the subjects were fully aware of the nature and aims of the trial and had given their full consent.

The examination was carried out using image intensification

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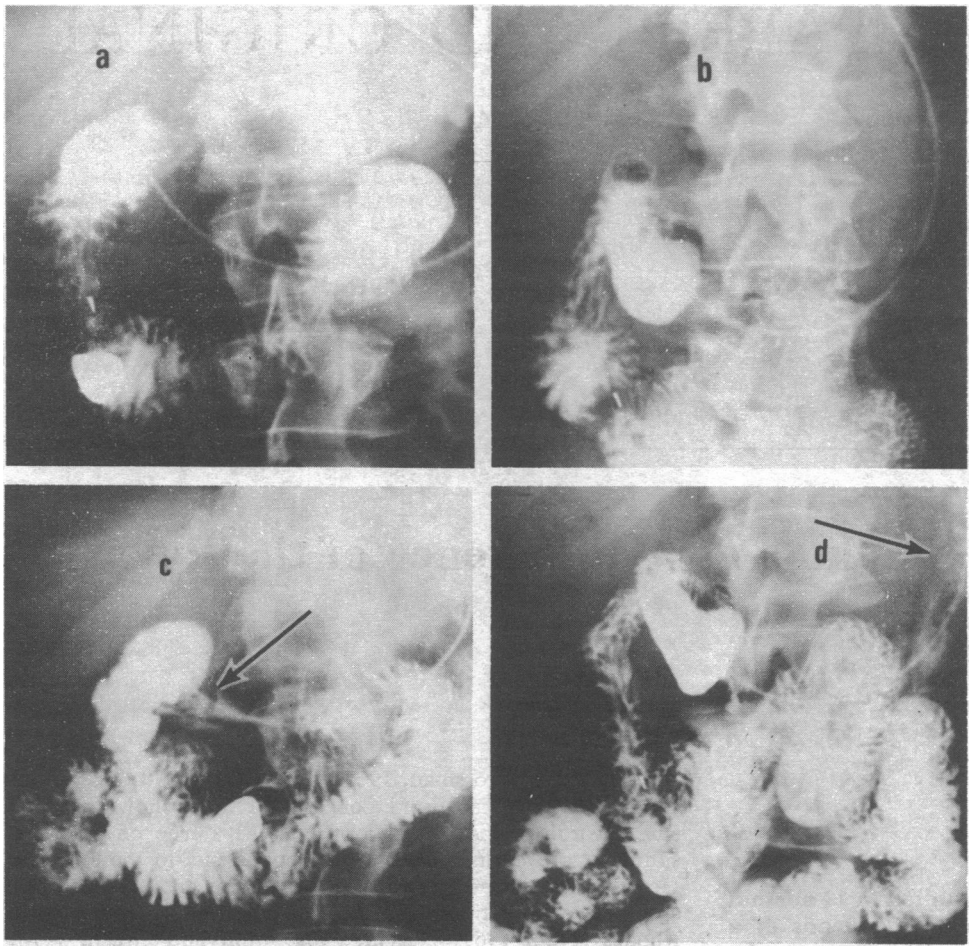

FIG. 1—(a) and (b) before smoking, supine and erect respectively. Pylorus is competent in both. (c) and (d) after smoking. (c) supine position showing mild reflux (arrowed), (d) erect position, pylorus is still incompetent and this gastric mucosal coating is well shown (arrowed).

and television screening. The radiological equipment consisted of a Zenith (Dean) table (1-2 mm focal spot) and a spot filmer supporting a 9·5 in (24 cm) Philips image intensifier. The image was transmitted to a Plumbicon television camera and monitors.

All possible precautions were taken to reduce radiation exposure to a minimum. All subjects wore lower back shields during the examination. Screening time for each person ranged from 2 min 5 sec to 2 min 55 sec. In most cases not more than two spot films were taken at each examination. Data concerning exposure factors were recorded and mean radiation dose was calculated: the mean amount of radiation each subject received was 0·97 r from screening and 0·47 r from radiography, totalling less than 1·5 r for each examination. This compares very favourably with the typical doses for barium-meal examinations as laid down by the Adrian committee (Ministry of Health, 1958, 1960, 1966).

The technique has been described previously by Grech (1960): a fine, soft tube weighted with a small balloon containing elemental mercury was swallowed. When the orifice of the tube was properly positioned in the second part of the duodenum 20 ml of weak barium solution (1 in 3 Micropaque suspension) was gradually injected, first in the supine position, and the contrast bolus was observed. The subject was then tilted up in the erect position. Another 20 ml of contrast was injected and again observed. The subject then smoked a cigarette, inhaling deeply, and the procedure was repeated—first in the supine and then in the erect position. The duodenal cap was always empty of barium before a fresh injection was made.

The findings were recorded by conventional radiography (figs. 1 and 2).

Grading of duodenogastric reflux depends on assessing (*a*) the amount of barium present in the stomach five minutes after the start of each phase of the examination, and (*b*) the amount actually refluxing during each phase. Criteria for assessment of duodenogastric reflux have been set down by Cocking and Grech (1973).

The degree of reflux is graded in the following manner. Mild reflux (+) = coating of the antrum in the supine position, no fluid level in the erect position. Moderate reflux (++) = partial coating of the gastric mucosa in the supine position, small fluid level in the erect position. Marked reflux (+++) = coating of the whole of the gastric mucosa in the supine position, large fluid level in the erect position.

Both authors observed the examination and made independent evaluation of the degree of reflux before and after smoking. In most instances there was such gross and obvious increase in reflux after smoking that the results were in complete agreement.

Results

Thirteen normal volunteers were examined. The results together with age, sex, and smoking pattern are given in table I.

Eleven of the 13 volunteers had a completely competent pylorus before they smoked. The remaining two had mild or moderate reflux. During smoking there was marked reflux in seven subjects, moderate reflux in three, and no reflux in the remaining three. In four there was no appreciable change before and after smoking, while in the remaining nine subjects there was increase in the amount of reflux on smoking. In most cases the reflux occurred within 30 seconds of starting to smoke.

Nine dyspeptic patients were examined (table II) all of whom had had a conventional barium meal. One (subject 14) was shown to have a duodenal ulcer and another (subject 16) a benign gastric ulcer, while the rest had a negative barium meal. One patient (subject 21) had the gastroscopic appearance of antral gastritis.

All of this group showed either a competent pylorus or mild

TABLE I—*Relevant Details on 13 Normal Volunteers together with Results of Pyloric Reflux Test before and after Smoking*

Subject No.	Sex	Age	Smoking Pattern	Pyloric Reflux Test	
				Before Smoking	After Smoking
1	M.	27	5 a week after meals only	0	+++
2	M.	27	Smokes nil now	0	+++
3	F.	23	Smokes nil now	+	++
4	M.	37	Smokes occasional cigar but no cigarettes now	0	0
5	M.	23	10 a week after meals	0	0
6	M.	67	10 a day after meals	0	+++
7	M.	30	Smokes pipe, but no cigarettes now	++	++
8	F.	27	30 a day, all day including early morning before and after meals	0	+++
9	M.	30	20 a day all day, early morning and after meals	0	+++
10	F.	25	20 a week before meals	0	+++
11	F.	21	20 a day, all day early morning before and after meals	0	++
12	M.	21	3-5 a day after meals	0	0
13	F.	20	10 a day after meals	0	+++

+ = Mild reflux. ++ = Moderate reflux. +++ = Marked reflux.

TABLE II—*Relevant Details on Nine Dyspeptic Patients together with Pyloric Reflux Test Results before and after Smoking*

Subject No.	Sex	Age	Clinical Details	Smoking Pattern	Pyloric Reflux Test	
					Before Smoking	After Smoking
14	M.	57	Chronic D.U. Admitted with haematemesis. Barium meal—D.U.	25 a day, all day, but not before breakfast	+	+++
15	M.	47	Abdominal pain, half hour after meals. Negative barium meal	20 a day, all day	0	+++
16	F.	43	Epigastric pain, half hour after meals, associated with vomiting. Barium meal—G.U.	30 a day, all day	+	+++
17	F.	42	Early morning bilious vomiting associated with epigastric discomfort. Negative barium meal	20 a day, all day but not before breakfast	+	+++
18	M.	29	Early morning bilious vomiting associated with epigastric pain. Negative barium meal	25 a day, all day	0	0
19	M.	50	Continuous epigastric pain. Flatulence. Negative barium meal	25 a day, all day	+	++
20	M.	64	Epigastric pain, one hour after meals associated with vomiting. Negative barium meal	20 a day, all day	0	++
21	M.	35	Early morning bilous vomiting associated with epigastric discomfort. Negative barium meal. Gastroscopy—antral gastritis	20 a day, all day	0	++
22	F.	42	Heartburn during meals and bending over regurgitation. Negative barium meal	10 a day, after meals	0	0

+ = Mild reflux. ++ = Moderate reflux. +++ = Marked reflux. D.U. = Duodenal ulcer. G.U. = Gastric ulcer.

reflux before smoking and appreciable increase in the reflux was noted in seven subjects after smoking. Two patients (subjects 18 and 22) maintained competence of the pylorus during smoking.

In addition six subjects were examined while drawing on an unlit cigarette. The cigarette was then ignited and the examination repeated. The results are given in table III.

In five of the six subjects the pylorus remained competent when they "smoked" an unlit cigarette. Five showed dramatic increase in reflux when the cigarette was lit. One (subject 22) failed to show reflux under any circumstance.

TABLE III—*Comparison of Results of Pyloric Reflux Tests during "Dummy" Smoking and Real Smoking*

Subject No.	Pyloric Reflux Test		
	Before Smoking	Smoking Unlit Cigarette	Smoking Lit Cigarette
1	0	+	+++
9	0	0	+++
13	0	0	+++
21	0	0	+++
22	0	0	0
10	0	0	++

+ = Mild reflux. ++ = Moderate reflux. +++ = Marked reflux.

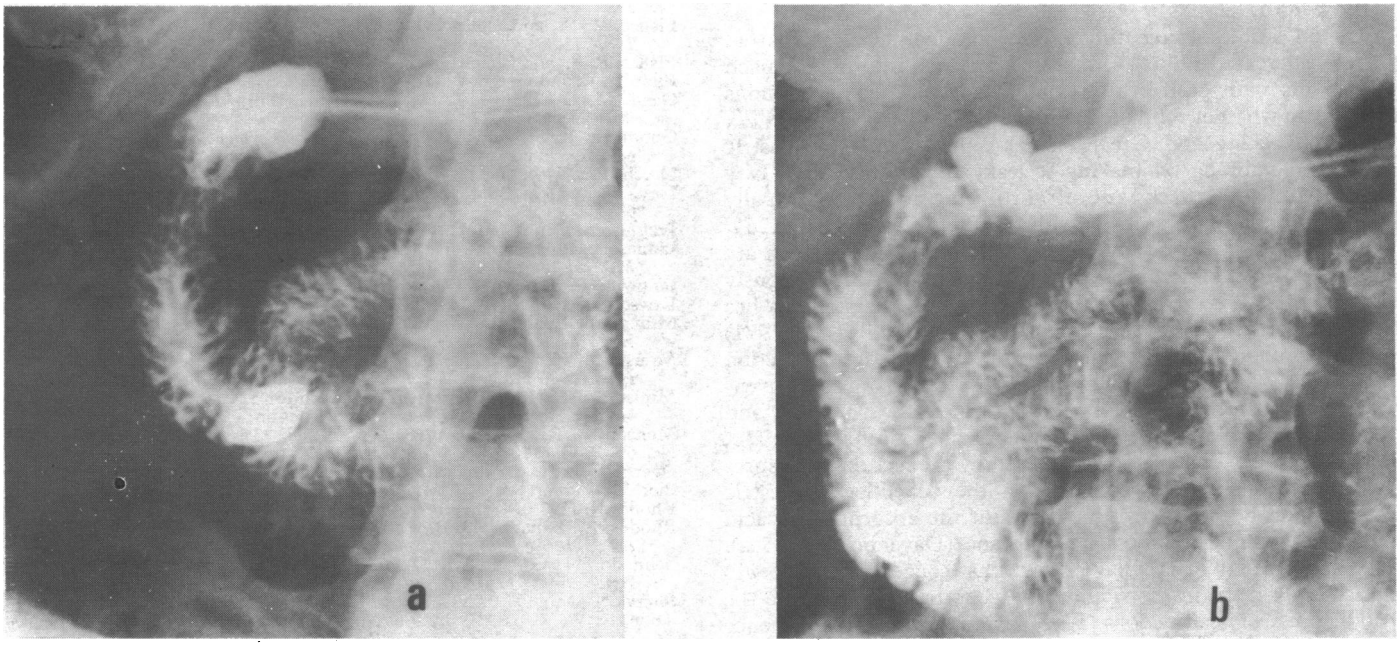

FIG. 2—(a) before smoking—supine position, competent pylorus. (b) after smoking—supine position, marked reflux is now present.

Discussion

Our results indicate that in most subjects smoking induced a dramatic increase in the reflux of barium from the duodenum to the stomach. This applied both to normal volunteers and to patients with dyspepsia. In most cases reflux was seen as a jet of contrast medium which entered the stomach and quickly produced a fluid level. This was usually associated with retroperistalsis in the duodenum. Some subjects experienced mild epigastric discomfort when reflux took place.

Reflux of barium as a quantitative assessment is somewhat crude and subject to observer error. In our study, however, we were more interested in the qualitative change in the pattern of reflux induced by smoking. In most cases this meant that smoking induced reflux in a previously competent pylorus. In others there was an obvious increase in the amount of regurgitation after smoking.

The technique may be criticized on account of the presence of a transpyloric tube, which may induce abnormal motility in the pylorus and duodenum. However, previous results using this technique have been similar to other studies which do not involve transpyloric intubation. Also in this study we used the subjects as their own controls by recording the change in competence of the pylorus or in the amount of reflux.

Reflux occurred more rapidly and was more dramatic if the subject inhaled the cigarette smoke. Deep inhalation with an unlit cigarette did not induce reflux.

Nicotine's actions on the gut are both stimulatory and inhibitory (Goodman and Gilman, 1965; Burgen and Mitchell, 1968). It increases motility and relaxes the sphincters, but with high dosage this is followed by a stage of diminished tone.

It therefore seems likely that the action of smoking on the gastroduodenal reflux is due directly to nicotine. However, Schnedorf and Ivey (1939) indicated that at least some of the effects of smoking on gut motility are not due to nicotine, but rather are a result of a vagal reflex possibly induced by irritation of the air passages. The brand of cigarette used in the trial was the same in every case (Embassy Gold Filter), giving a yield of 1·3 mg of nicotine (Blundy, 1973). The tobacco used in the manufacture of the test cigarettes is flue cured and hence burns with an acidic smoke. At acid pH very little nicotine is absorbed through the oral mucosa, but appreciable absorption can take place through the larger surface area of the lung (Armitage and Turned, 1970; Sherwood, 1973).

In our study we found that the three subjects who could not inhale cigarette smoke failed to show any increase in reflux. In addition in most instances reflux occurred too rapidly for juice to collect in the mouth, be swallowed, and exert a direct effect at the pylorus.

Several studies using different techniques have shown that there is increased reflux of duodenal contents into the stomach of patients with gastric ulcer and gastritis. To date opinions differ as to whether reflux lessens as the ulcer heals (Black *et al.*, 1971 a; Cocking and Grech, 1973). Bile disrupts the gastric mucous membrane by making it leaky to luminal acid (Ivey *et al.*, 1970, 1971; Black *et al.*, 1971 b). This situation eventually results in changes of gastritis with bleeding (Davenport, 1964; Davenport *et al.*, 1965; Overholt and Pollard, 1968) which are enhanced if a cholinergic agent is administered simultaneously (Davenport, 1965 b). The presence of bile in the stomach has been shown to increase gastrin production (Bedi *et al.*, 1971) which stimulates acid secretion. However, there are conflicting reports as to whether smoking enhances secretion of acid (Ehrenfeld and Sturtevant, 1941; Cooper and Knight, 1956; Pier and Raine, 1959; Debas *et al.*, 1971; Wilkinson and Johnston, 1971; Bennett, 1972). This may be explained by the fact that measurement of acid secretion is based on the collection of gastric samples and does not take into account the absorption of acid through a damaged mucous membrane (Davenport, 1965 a). Byers and Jordan (1962) have shown that concentrated bile will not cause gastritis in gastric mucosa when transplanted into the gall bladders of healthy dogs. This may indicate that the presence of an acid pH is important for the production of gastritis.

We believe, therefore, that smoking damages the gastric mucosa by allowing bile to enter the stomach and disrupt the mucous membrane. This injury is probably enhanced by increased acid production. Bile is usually neutralized by food and as such would be expected to cause much more damage in the empty stomach. The pattern of smoking is therefore important: in particular, smoking before meals and in the early morning should be discouraged. Eight of the nine dyspeptic patients included in this trial were heavy smokers and smoked regularly before meals.

This study is in the nature of a preliminary report. Further work is necessary to confirm the findings by another method, to elucidate the mechanism by which smoking causes pyloric incompetence, and to show mucosal damage in heavy smokers.

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