Papers and Originals

Chest Complications after Upper Abdominal Surgery: Their Anticipation and Prevention

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Though many advances have been made in surgery, anaesthetics, and physiotherapy in the past few years, the incidence of postoperative chest infection has changed little in the last 30 years. Since the report by King (1933) it has been recognized that upper abdominal operations carry an increased risk of chest complications (Palmer, 1955; Wightman, 1967).

This survey was planned primarily to determine whether a combination of penicillin and streptomycin would reduce this incidence if used prophylactically. Crystamycin was used because it contains standard quantities of both penicillin and streptomycin and is easily administered by the nursing staff. Previous trials have failed to show any benefit from prophylactic antibiotics (Palmer and Sellick, 1952; Griffiths, 1957; Thulbourne and Young, 1962) because the antibiotic—penicillin—used in each series is not effective against *Haemophilus influenzae*. Miller and Jones (1964) examined the sputum of 130 working men in London capable of producing early morning phlegm and found *H. influenzae* in 45% and pneumococci in 38%. Mulder *et al.* (1952) and May (1953) reported that *H. influenzae* could be isolated from the sputum of 80–90% of patients with chronic mucopurulent bronchitis. Stuart-Harris *et al.* (1953) found that in Sheffield *H. influenzae* and pneumococci were the important pathogenic bacteria. It was therefore thought essential to use an antibiotic regimen capable of destroying both the pathogenic bacteria likely to be found in the bronchial system of patients, 40% of whom were expected to have bronchitic symptoms. Penicillin with streptomycin, given in a five-day course, is known to be therapeutically effective in acute exacerbations of bronchitis and to be free from toxic effects in all but a few hypersensitive patients. This was therefore thought to be the drug combination most likely to reduce the incidence of postoperative chest infections.

A secondary objective was to establish the value of isoprenaline inhalations and morphine in frequent regular doses in preventing postoperative chest complications.

The opportunity was also taken to assess the importance of preoperative history and ventilatory function on the development of chest complications. From these data an attempt was made to define the characteristics of a group of patients who would be most likely to suffer these complications, and in whom it would therefore be justifiable to institute such prophylactic measures as were shown by the trial to be effective.

Plan of Investigation

During the 12 months of the survey 132 male patients undergoing elective upper abdominal surgery were admitted to the study. They were allocated at random to one of eight treatment groups, as shown in Table I, which specified the use of antibiotics (A), morphine (M), and bronchodilators (B) as follows:

- A+ Crystamycin (sodium penicillin G 300 mg. (500,000 units)+ streptomycin base 0.5 g. as sulphate) 1 ml. i.m. six-hourly for a period of five days (total 20 doses), four doses to be given before the operation.
- A− No antibiotic routinely.
- M+ Morphine sulphate 1/6 gr. (10 mg.) four-hourly for 48 hours postoperatively—that is, a total of 2 gr. (120 mg.); the average total dose given to patients in this group was 1.8 gr. (110 mg.).
- M− Morphine sulphate 1/6 gr. (10 mg.) p.r.n. postoperatively to a maximum of 1½ gr. (90 mg.) in 48 hours; the average total dose given to patients in this group was 0.8 gr. (50 mg.).
- B+ Use of Collison inhaler with 1% isoprenaline sulphate solution for a period of three to five minutes three- to four-hourly during the day, for a minimum of two days postoperatively.
- B− No use of the Collison inhaler.

TABLE I.—*Allocation of Patients to the Treatment Groups*

Treatment Group	Antibiotics	Morphine	Bronchodilators	No. of Patients
1	−	−	−	16
2	−	−	+	16
3	−	+	−	15
4	−	+	+	16
5	+	−	−	17
6	+	−	+	16
7	+	+	−	19
8	+	+	+	17
All groups				132

In addition, each patient was given routine physiotherapy and steam inhalations of tinct. benzoin. co. through a Nelson's inhaler.

All the patients were anaesthetized with intravenous thiopentone followed by nitrous oxide, oxygen, and halothane through a cuffed endotracheal tube. Muscle relaxants were used in every case.

A comprehensive history was taken, with particular interest in smoking habits, occupation, and respiratory symptoms as elaborated in Table II. For this purpose the M.R.C. Questionary on Respiratory Symptoms (1960) was used, but, since a few of the questions were omitted, the definition of prevalence rates in this study are not necessarily comparable with those used by other workers.

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The pulmonary condition was assessed after operation by clinical methods, a chest *x*-ray examination on the second postoperative day, and ventilatory function studies.

Each patient was examined by one person before operation and daily for the first 10 postoperative days. The patient's symptoms, physical signs, and temperature were recorded. The postoperative chest condition was graded as follows:

Grade I. Normal.

Grade II. Mild.—Basal bronchitis and/or collapse as shown by diminished breath sounds with numerous rhonchi and fine crepitations at the bases with slight elevation of the temperature but not giving rise to any anxiety.

Grade III. Moderate.—Bronchitis with mucopurulent sputum and collapse and/or segmental consolidation with marked elevation of the temperature.

Grade IV. Severe.—Consolidation and/or collapse with severe constitutional disturbance giving rise to considerable anxiety.

Portable *x*-ray films of the chest were taken on the second postoperative day and on the ninth or tenth day where any abnormality had been found previously. All the *x*-ray films were interpreted by a radiologist who was not aware of the treatment group to which the patient had been allocated, nor of the clinical grading.

The films were classified as (1) clear: no signs other than raised diaphragm; (2) minor lesions: linear or segmental collapse in one or both lung fields; or (3) major lesions: signs of lobar collapse or of consolidation in one or both lung fields.

The forced expiratory volume in one second ($F.E.V._1$), forced vital capacity (F.V.C.), and peak expiratory flow rate (P.E.F.R.) were measured preoperatively with the patient standing and on each day postoperatively while the patient was in bed. The preoperative $F.E.V._1$ and F.V.C. were measured by both a Pulmometer (Godart) and by a Vitalor (McKesson) but postoperatively by a Vitalor only. The P.E.F.R. was measured by a Wright Peak Flow Meter throughout.

Results

Though the behaviour of each of the eight treatment groups shown in Table I was analysed separately, and is summarized in Table VIII, Tables III–VII present the three main treatment comparisons: (1) with and without antibiotics; (2) regular dosage of morphine and lower doses as necessary; and (3) with and without bronchodilators.

These comparisons are made by a recombination of the individual groups as follows:

(1) A− Groups 1+2+3+4=63 patients; A+ Groups 5+6+7+8=69 patients
(2) M− Groups 1+2+5+6=65 patients; M+ Groups 3+4+7+8=67 patients
(3) B− Groups 1+3+5+7=67 patients; B+ Groups 2+4+6+8=65 patients

It can be seen from Table I that in each comparison the other two variables are balanced; for example, of the 63 A− patients, 31 were M+ and 32 M−, while of the same group 32 were B+ and 31 B−. A similar close balancing occurs in the group of 69 A+ patients.

Table II shows the preoperative comparability of the treatment groups. In average age, height, and weight, history of respiratory disease, symptoms, smoking habits, and occupational exposure to dust the A−, A+, M−, M+, B−, and B+ patients were very similar.

Influence of Prophylactic Treatment on Postoperative Chest Condition

The response to the different prophylactic regimens is compared by four methods of assessing the postoperative chest condition: radiological, clinical, temperature record, and pulmonary function tests.

X-ray Evidence

Films taken on the second postoperative day were available for 120 of the 132 patients. Comparing those with and without prophylactic Crystamycin, Table III shows that the proportion with "clear" films was twice as great in those given Crysta-

TABLE III.—*Comparison of Prophylactic Regimens by Radiological Findings on Second Postoperative Day (Percentages)*

Radiological Category	Antibiotics		Morphine		Bronchodilators		All Treatment Groups
	−	+	−	+	−	+	
Clear	29	57	45	42	48	38	43
Minor lesions	32	23	23	31	21	34	28
Major lesions	29	13	22	19	21	20	20
No *x*-ray examination	11	7	11	7	10	8	9
All categories	100	100	100	100	100	100	100
No. of patients	63	69	65	67	67	65	132

TABLE II.—*Preoperative Comparability of Main Treatment Groups*

Patients' Characteristics	Antibiotics		Morphine		Bronchodilators		All Treatment Groups
	− Groups 1, 2, 3, 4	+ Groups 5, 6, 7, 8	− Groups 1, 2, 5, 6	+ Groups 3, 4, 7, 8	− Groups 1, 3, 5, 7	+ Groups 2, 4, 6, 8	
No. of patients	63	69	65	67	67	65	132
Average age (years)	47·1	47·7	46·2	48·6	46·3	48·5	47·4
„ height (in.)	67·6	67·6	67·6	67·6	67·6	67·6	67·6
„ weight (lb.)	146·2	147·1	148·2	145·1	146·5	146·8	146·6
History of bronchitis	9	12	12	9	12	9	21
„ „ pneumonia	15	13	13	15	13	15	28
„ „ pleurisy	13	13	17	9	15	11	26
Chest illness in past 3 years	21	23	28	16	23	21	44
Symptoms:							
Morning phlegm in winter	22	33	26	29	33	22	55
„ „ „ summer	19	16	18	17	20	15	35
Breathlessness grade 2	23	24	20	27	24	23	47
„ grades 3–5	9	10	9	10	8	11	19
Wheezing	15	24	15	24	17	22	39
Weather affects chest	10	16	11	15	15	11	26
No symptoms	22	16	18	20	19	19	38
Smoking:							
Non-smokers	2	3	4	1	4	1	5
Ex-smokers	12	9	9	12	10	11	21
Cigarette smokers	43	56	48	51	50	49	99
Pipe and mixed smokers	6	1	4	3	3	4	7
Occupations:							
Coal mining	19	21	18	22	24	16	40
Other mining and quarrying	5	4	4	5	4	5	9
Foundry	7	17	13	11	15	9	24
All "dusty" occupations	41	47	42	46	50	38	88
Ventilatory function:							
$F.E.V._1$ (litres)	3·01	3·00	3·11	2·90	3·05	2·96	
F.V.C. (litres)	3·92	4·01	4·04	3·89	4·03	3·90	
P.E.F.R. (litres/min.)	501	469	499	470	488	481	

mycin as in those who did not receive antibiotics prophylactically (A+ 57%, A− 29%); on the other hand, the proportion with "major lesions" was over twice as great in those without antibiotics (A+ 13%, A− 29%). These differences are significant ($P<0.02$). There is, therefore, an obvious advantage, in radiological terms, to those given Crystamycin, but there was no obvious benefit to be gained from the use of either bronchodilators or regular analgesia with morphine.

Clinical Grading

Table IV shows the clinical grading of the treatment groups on the first, third, seventh, and tenth postoperative days. On each of these days it will be seen that by this method of assessment the patients receiving Crystamycin prophylactically were at an advantage compared with the group without antibiotics. On Day 1 35% of the A+ group had no chest complications, as compared with 10% of the A− group, a significant difference ($P<0.001$). On subsequent days the proportion free from chest complications increased progressively in each group, but this was consistently and significantly greater in the A+ groups. Furthermore, in the early postoperative period the proportion with serious complications (grades III and IV) was greater in those without prophylactic antibiotics. On Days 7 and 10, however, the proportion with serious complications appeared to be greater in those receiving prophylactic antibiotics, but this anomalous result was due to the fact that by this time several patients had been withdrawn from the trial because their condition caused anxiety and alternative treatment was required. By Day 3 four A− patients had been withdrawn because of severe chest infection, which was treated successfully with penicillin and streptomycin, but none of the A+ patients required alteration of treatment (Table IV).

On Days 7 and 10 the number withdrawn was clearly greater in the A− than in the A+ group, indicating their relatively unfavourable progress. The only death occurred in a patient not given prophylactic antibiotics.

The clinical grading on the four postoperative days, like the radiological assessment, showed little difference between the M− and M+ or between the B− and B+ groups. The small apparent advantage of the M− over the M+ group was not significant.

Fig. 1 summarizes these comparisons by showing for Days 1 and 7 the proportion of patients in each treatment group who were in the moderate or severe clinical grades, changed treatment, or died.

Table IV shows the clinical grading on each of four postoperative days, but in the previous section it has been indicated that some of the patients who were reasonably fit on Day 1 subsequently developed serious chest complications, whereas

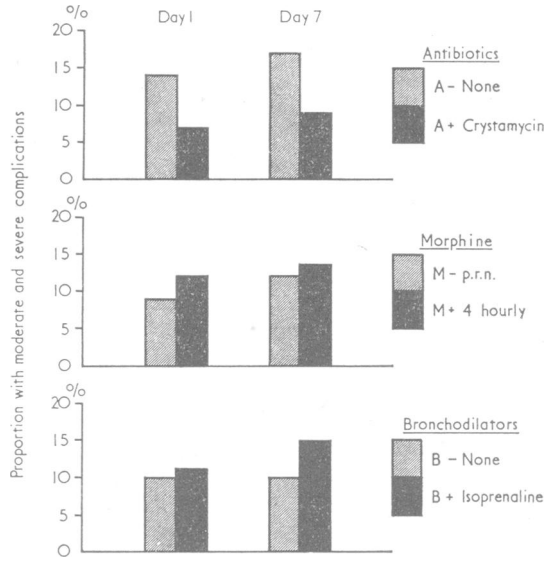

FIG. 1.—Proportion of patients with moderate or severe clinical complications on first and seventh postoperative days.

others caused no anxiety at any time. To summarize the clinical condition over the whole of the 10 postoperative days, Table V classifies the patients into four categories: (1) grade I (normal) throughout; (2) grade II (mild) on one or more days, but no worse; (3) grade III (moderate) on one or more days, but no worse; and (4) grade IV on one or more days, changed treatment, or died. This overall assessment is probably of greater importance than the condition of the patient on any one day.

Table V shows that of the 132 patients 14% had no chest complications at any time and 62% had at their worst only mild complications; a further 11% suffered moderate complications not requiring any modification of the allotted regimen, and the remaining 12% had severe complications which necessitated a change in treatment or withdrawal from the trial.

TABLE IV.—*Comparison of Prophylactic Regimens by Clinical Gradings on 1st, 3rd, 7th and 10th Postoperative Days*

Clinical Grade	Postoperative Day							
	1		3		7		10	
Antibiotics:	A−	A+	A−	A+	A−	A+	A−	A+
I, normal	6 (10%)	24 (35%)	10 (16%)	30 (43%)	35 (56%)	51 (74%)	41 (65%)	59 (86%)
II, mild	48	40	39	33	17	12	10	5
III, moderate	8	5	8	6	1	4	—	1
IV, severe	1	—	2	—	—	—	—	—
Changed treatment	—	—	4	—	9	2	11	4
Died	—	—	—	—	1	—	1	—
Total	63	69	63	69	63	69	63	69
Morphine:	M−	M+	M−	M+	M−	M+	M−	M+
I, normal	17 (26%)	13 (19%)	24 (37%)	16 (24%)	44 (68%)	42 (63%)	49 (75%)	51 (76%)
II, mild	42	46	33	39	13	16	7	8
III, moderate	6	7	5	9	—	5	—	1
IV, severe	—	1	—	2	—	—	—	—
Changed treatment	—	—	3	1	8	3	9	6
Died	—	—	—	—	—	1	—	1
Total	65	67	65	67	65	67	65	67
Bronchodilators:	B−	B+	B−	B+	B−	B+	B−	B+
I, normal	13 (19%)	17 (26%)	22 (33%)	18 (28%)	47 (70%)	39 (60%)	54 (81%)	46 (71%)
II, mild	47	41	37	35	13	16	7	8
III, moderate	7	6	6	8	4	1	1	—
IV, severe	—	1	1	1	—	—	—	—
Changed treatment	—	—	1	3	3	8	5	10
Died	—	—	—	—	—	1	—	1
Total	67	65	67	65	67	65	67	65

These proportions were hardly modified at all by the alternative morphine and bronchodilator regimens, but were altered considerably depending on whether or not the patients received prophylactic Crystamycin ; the A+ group had a larger proportion with no complications at any time and a smaller proportion in which treatment had to be changed. The difference between the A+ and A− distribution shown in Table V is significant ($P<0.01$).

TABLE V.—*Comparison of Prophylactic Regimens by Clinical Gradings Summarized for the 10 Postoperative Days (Percentages)*

Summary of Clinical Grading during the 10 Postoperative Days	Antibiotics		Morphine		Bronchodilators		All Treatment Groups (%)
	−	+	−	+	−	+	
Grade I throughout ..	5	23	15	13	10	18	14
Grade II on some day(s) but no worse	65	59	65	60	64	60	62
Grade III on some day(s) but no worse	11	12	9	13	15	8	11
Grade IV on some day(s) changed treatment or died	19	6	11	13	10	14	12
All grades	100	100	100	100	100	100	100
No. of patients	63	69	65	67	67	65	132

Temperature

Though factors other than chest infection cause postoperative pyrexia, it is believed that an increase in temperature during the first 48 hours is almost always caused by chest infection, whereas sepsis elsewhere usually causes pyrexia later in the convalescent period. Fewer patients treated with Crystamycin have a temperature of 100.4° F. (38° C.) or more on the first and third days after operation than those without antibiotics (Table VI). There is no such difference in the morphine and bronchodilator groups.

TABLE VI.—*Percentage of Patients* with Maximum Temperature 100.4° F. (38° C.) or Over on the 1st, 3rd, 7th, and 10th Postoperative Days*

Post-operative Day	Antibiotics		Morphine		Bronchodilators	
	−	+	−	+	−	+
1	46	29	42	33	31	43
3	15	9	13	12	12	13
7	6	5	2	8	5	5
10	2	2	0	3	2	2

* This table excludes patients withdrawn from the trial on the third and subsequent postoperative days.

Ventilatory Function Tests

The preoperative and postoperative results of $F.E.V._1$, F.V.C., and P.E.F.R. estimations are shown in Table VII. There is little evidence of any difference between the treatment groups. In all three tests average performance on the first day after operation was restricted to less than half of the preoperative level, but subsequently rose to more than 80% by the tenth day (Fig. 2).

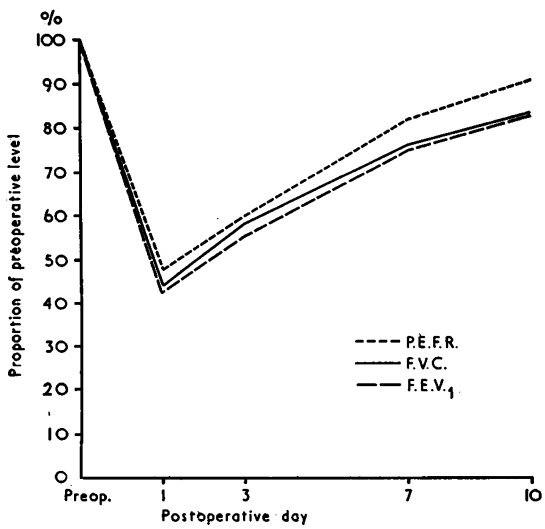

FIG. 2.—Changes in mean ventilatory function test performance in the postoperative period.

TABLE VII.—*Performance in Ventilatory Function Tests on 1st, 3rd, 7th, and 10th Postoperative Days as a Percentage of Preoperative Level*

		Antibiotics		Morphine		Bronchodilators	
		−	+	−	+	−	+
No. of Patients		63	69	65	67	67	65
		F.E.V.1					
Preoperative		100	100	100	100	100	100
Postoperative days	1	41	45	42	44	45	41
	3	55	56	58	53	58	53
	7	74	75	76	73	76	72
	10	84	82	85	80	84	81
		F.V.C.					
Preoperative		100	100	100	100	100	100
Postoperative days	1	41	45	43	43	46	40
	3	59	58	61	56	61	55
	7	75	76	78	73	78	73
	10	82	84	86	80	84	82
		P.E.F.R.					
Preoperative		100	100	100	100	100	100
Postoperative days	1	45	50	47	47	49	45
	3	61	60	62	58	63	58
	7	81	82	83	80	82	81
	10	91	91	92	90	91	91

Radiological and Clinical Grading

The preceding sections have dealt with the response to prophylaxis in the three main comparisons: A−/A+, M−/M+, and B−/B+. Table VIII shows, for radiological and clinical gradings only, the pattern of response in each of the eight treatment groups to which patients were allocated.

The numbers of patients in each group were relatively small, but within these limits Table VIII suggests that there was little interaction between the antibiotic, morphine, and bronchodilator components of each regimen ; the four A− groups behaved alike, as did the four A+ groups, and the response to prophylactic Crystamycin was not appreciably modified by morphine or bronchodilators.

TABLE VIII.—*Radiological Findings and Summary of Clinical Grading in the Eight Treatment Groups*

Treatment Group	A	M	B	Radiological Category				Clinical Grading (See Table V) during 10 Postoperative Days				Total in Group
				N.K.	Clear	Minor	Major	I	II	III	IV	
1	−	−	−	2	5	5	4	—	13	2	1	16
2	−	−	+	3	5	3	5	1	10	1	4	16
3	−	+	−	—	6	3	6	1	7	3	4	15
4	−	+	+	2	2	9	3	1	11	1	3	16
5	+	−	−	2	11	2	2	3	12	1	1	17
6	+	−	+	—	8	5	3	6	7	2	1	16
7	+	+	−	3	10	4	2	3	11	4	1	19
8	+	+	+	—	10	5	2	4	11	1	1	17
All groups				12	57	36	27	19	82	15	16	132

Relation of Clinical and Radiological Response to Prophylactic Regimens

In the previous sections it was shown that the clinical gradings in the postoperative days and the radiological findings on the second day were both favourably influenced by prophylactic antibiotics, but were not significantly altered by variation in the morphine or bronchodilator regimens. Table IX shows that the radiological findings were closely related to the subsequent clinical course. Only 2 (4%) of the 57 patients with clear x-ray films on the second day developed serious chest complications—that is, grade III or worse—compared with 14 (52%) of the 27 with major lesions.

Both radiological and clinical assessment were to some degree subjective, but with clinical measures in this study there is also the possibility of bias, since the observers could not fail to be aware which regimen each patient was on. The only known bias was in fact a slight reluctance on the part of the surgeons to have patients on prophylactic penicillin and streptomycin,

TABLE IX.—*Relation Between Radiological Findings on Second Post-operative Day and Clinical Course (Percentages)*

Radiological Category	Clinical Grading (See Table V)				All Grades	No. of Patients
	I	II	III	IV		
Clear	21	75	2	2	100	57
Minor lesions	6	69	14	11	100	36
Major lesions	7	41	15	37	100	27
All categories	13	66	8	13	100	120*

* 12 patients did not have second-day *x*-ray examination.

and this could not have contributed to the favourable clinical response to the antibotics. Furthermore, the similarity in response, whether measured clinically or radiologically, argues in favour of a real effect, particularly since the *x*-ray films were read "blind."

Influence of Preoperative State on Development of Chest Complications

The radiological assessment has been taken as the index for determining which symptoms or personal characteristics predispose the patient to a postoperative chest complication.

Of the total group of 120 patients who had films taken on the second day the proportion with clear films was 48%, with minor lesions 30%, and with major lesions 22%. Table X shows that the proportion with clear *x*-ray films was greater (63%) in the 19 patients under 35 years of age, but less (only 31%) in the 35 patients 55 years and over. Though the proportions with major lesions do not give a consistent trend with age, overall the younger patients showed fewer abnormalities, the differences between the three age groups being significant ($P<0.01$).

TABLE X.—*Influence of Age on the Risk of Developing Radiological Evidence of Chest Complications*

Age in Years	No. of Patients	Radiological Category		
		Clear (%)	Minor Lesions (%)	Major Lesions (%)
Under 35 ..	19	63	5	32
35–54 ..	66	52	36	12
55 and over ..	35	31	31	37
All ages ..	120	48	30	22

$P<0.01$

Apart from the effect of age, patients with respiratory symptoms, cough, phlegm, and wheezing (but not breathlessness), and those who said the weather affected their chest, had fewer clear *x*-ray films and more with major lesions than those who were symptomless preoperatively; none of these trends was, however, significant at the 0.05 level.

The remaining characteristics examined—past chest illness, chest illness in the last three years, smoking, dusty occupation or exposure to irritant gas—showed no evidence of an influence on the likelihood of developing postoperative chest complications. This negative result with smoking may have arisen because the number of non-smokers, only 4 out of the total of 120, provided too small a group for comparison.

Table XI makes comparisons between patients with different performance at the preoperative ventilatory function tests. Those with low F.E.V.$_1$, F.V.C., P.E.F.R., and F.E.V.$_1$/F.V.C.% had a higher risk of developing radiological abnormality, and for the first two of these tests the trend was significant ($P<0.05$). However, reduced levels of all these measurements are found in older persons. When the F.E.V.$_1$ and F.E.V.% were examined separately for the age groups, under 35, 35–44, 45–54, and 55 and over, there was no significant indication that patients with major lesions were those with a reduced preoperative performance. On the other hand, Table XII shows that the degree to which the preoperative level of F.E.V.$_1$, F.V.C., or P.E.F.R. had fallen by postoperative Day 1 had no influence on the development of radiological abnormalities on the second postoperative day. This finding is perhaps remarkable, since about a fifth of the patients had Day 1 readings of less than 30% of their preoperative performance.

TABLE XI.—*Influence of Patients' Preoperative Ventilatory Function Assessment on Risk of Developing Radiological Evidence of Chest Complications*

Ventilatory Function Test		No. of Patients	Radiological Category			Significance
			Clear (%)	Minor Lesions (%)	Major Lesions (%)	
All patients		120	48	30	22	
F.E.V.$_1$ (ml.)	Under 2,400	25	32	24	44	$P<0.05$
	2,400–3,399	60	47	32	22	
	3,400 and over	35	60	31	9	
F.V.C. (ml.)	Under 3,400	23	35	22	43	$P<0.05$
	3,400–4,399	58	45	33	22	
	4,400 and over	39	59	31	10	
P.E.F.R. (l./min.)	Under 400	18	28	33	39	N.S.
	400–499	41	51	22	27	
	500 and over	61	51	34	15	
F.E.V.$_1$/F.V.C.%	Under 70	32	28	38	34	N.S.
	70–79	51	51	25	24	
	80 and over	37	59	30	11	

TABLE XII.—*Relation Between Decline in Ventilatory Function Performance by Postoperative Day 1 and Radiological Findings on Day 2*

Day 1 as a Proportion of Preoperative Level		No. of Patients	Radiological Category			Significance
			Clear (%)	Minor Lesions (%)	Major Lesions (%)	
F.E.V.$_1$	Under 30% ..	25	40	36	24	N.S.
	30–49% ..	57	51	28	21	
	50 and over% ..	38	47	29	24	
F.V.C.	Under 30% ..	22	32	45	23	N.S.
	30–49%	59	54	24	22	
	50 and over% ..	39	46	31	23	
P.E.F.R.	Under 30% ..	21	48	29	24	N.S.
	30–49%	53	40	34	26	
	50 and over% ..	46	57	26	17	

Neither the duration nor the type of upper abdominal operation could be related to the development of postoperative chest complications.

The same general response to antibiotics and lack of response to analgesics and bronchodilators was seen in young or old and in those with or without unfavourable histories.

Discussion

The patients in this study were drawn from those ordinarily admitted to a professorial surgical unit for elective surgery. Any patient who through age, clinical state, or past history was regarded as a poor risk was excluded, the study group consisting of only those whom it was thought safe to put on any of the prophylactic regimens of the trial. Nevertheless, since the group comprised men, average age 47 years, undergoing upper abdominal operations, they were expected to have a relatively high risk of postoperative chest complications, which might be enhanced because they were nearly all cigarette smokers and came from an industrial environment.

The incidence of complications was assessed by a grading based on clinical observations made on each of the 10 postoperative days, and by a chest *x*-ray film taken on the second day. Judged clinically, 85.6% of the patients had some degree of complication during the 10 days, and 52.5% had some *x*-ray

lesion on the second day. As each of these measures includes minor abnormalities which caused little concern, a more realistic assessment might be given by the 23.5% who had grade III or IV (moderate or severe) clinical complications during the postoperative period, or by the 22.5% who had major radiographic lesions on the second day. These measures, clinical and radiographic, were highly correlated. The proportions of patients affected clearly depend on the degree of severity chosen, and the figures from this study cannot readily be compared with those from other investigations using different definitions and methods of assessment.

The comparison of regimens, whether judged clinically or radiographically, showed that the group of patients given the five-day course of penicillin and streptomycin had significantly less pulmonary complications than the group with no prophylactic antibiotics; on the other hand, variations in the dose of morphine and the giving or withholding of isoprenaline inhalations had little effect on the incidence.

Prophylactic use of antibiotics is generally viewed with reserve (*Lancet*, 1955), because inadequate dosage may lead to the emergence of resistant strains of bacteria (Howe and Mozden, 1963), and high dosage, particularly of streptomycin, to irreversible toxic effects. Despite these reservations, the decision was made to give the powerful combination penicillin and streptomycin, because a considerable proportion of the patients might be expected to be harbouring *H. influenzae*. The dosage scheme, 0.5 g. six-hourly for five days, was intended to provide effective blood levels to cover the operation and for four subsequent days, and to keep the total dose, 10 g., within safe limits. The results fully justified the decision, since the favourable response in the group given antibiotics was achieved without any toxic effects being observed.

The contrast between our findings and those of Palmer and Sellick, 1952; Griffiths, 1957; Barnes *et al.*, 1959; and Thulbourne and Young, 1962, who were unable to demonstrate benefit from the use of prophylactic antibiotics, might be explained on two grounds: (1) the first three studies used penicillin alone, which is not effective against *H. influenzae*, and (2) the fourth used a combination of penicillin V 60,000 units and dihydrostreptomycin 0.5 g. given once immediately after the operation, which is clearly inadequate.

In this study there was a sharp reduction in ventilatory function on the first postoperative day, the mean values of $F.E.V._1$, F.V.C., and P.E.F.R. being less than 50% of the preoperative levels, with a steady rise subsequently. The extent of this fall in individual patients, however, bore no relation to the risk of complications. If this fall was largely due to pain, as suggested by Churchill and McNeil (1927), it was surprising that the M+ group, who received an average 1.8 gr. (110 mg.) of morphine, showed the same pattern of ventilatory function as the M− group, who had an average dose of 0.8 gr. (50 mg.) in the first 48 hours.

The similarity in incidence of complications for the groups of patients given and not given isoprenaline inhalations contrasts with the findings of Palmer and Sellick (1953). This might be accounted for by important differences between the two series. Palmer and Sellick used this regimen for a longer period —preoperatively for up to two weeks in very poor risk cases and for at least five days after operation—and the accompanying physiotherapy may have been more intensive than that used in this study. Furthermore, very few of our patients showed significant reversibility of airways obstruction preoperatively, or had $F.E.V._1/F.V.C.\%$ values of less than 60, and would therefore have been expected to benefit by bronchodilators.

An examination of the factors which might increase the risk of postoperative chest complications in our group of men, who were almost all cigarette smokers, indicated a significantly increased risk in older patients, and a slight though insignificant increase in incidence in those with a history of wheezing or a productive cough. As might be expected, patients with a poor preoperative ventilatory function were also at greater risk, but this factor was closely correlated with age and did not appear to operate independently.

Summary

One hundred and thirty-two male patients undergoing upper abdominal surgery were investigated clinically, radiologically, and with ventilatory function tests before and after operation in a controlled trial in order to assess the effect of prophylactic Crystamycin, regular analgesia with morphine, and isoprenaline inhalations on the incidence of postoperative chest complications. Crystamycin, given in a total dose of 10 mega units of sodium penicillin G + 10 g. of streptomycin sulphate over a period of five days starting on the day before operation, reduced the incidence of serious chest complications by more than 50%; no benefit was observed from the use of regular analgesia with morphine or from isoprenaline inhalations.

With the use of preoperative ventilatory function tests and a detailed history, an attempt was made to define a group of patients with an increased risk of developing a postoperative chest complication. In this series the older patients were found to have a significantly greater risk; those with a preoperative history of wheeze, productive morning cough, and impaired ventilatory function had a slightly, but insignificantly, increased risk. No other characteristics of the patients examined were found to influence the risk.

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References

Barnes, J., Pace, W. G., Trump, D. S., and Ellison, E. H. (1959). *Arch. Surg.*, **79**, 190.
Churchill, E. D., and McNeil, D. (1927). *Surg. Gynec. Obstet.*, **44**, 483
Griffiths, E. (1957). *Brit. med. J.*, **1**, 803.
Howe, C. W., and Mozden, P. J. (1963). *Surg. Clin. N. Amer.*, **43**, 859.
King, D. S. (1933). *Surg. Gynec. Obstet.*, **56**, 43.
Lancet, 1955, **2**, 755.
May, J. R. (1953). *Lancet*, **2**, 534.
Miller, D. L., and Jones, R. (1964). *J. Path. Bact.*, **87**, 182.
Mulder, J., Goslings, W. R. O., van der Plas, M. C., and Lopes Cardozo, P. (1952). *Acta med. scand.*, **143**, 32.
Palmer, K. N. V. (1955). *Postgrad. med. J.*, **31**, 25.
—— and Sellick, B. A. (1952). *Lancet*, **1**, 345.
—— —— (1953). Ibid., **1**, 164.
Stuart-Harris, C. H., Pownall, M., Scothorne, C. M., and Franks, Z. (1953). *Quart. J. Med.*, **22**, 121.
Thulbourne, T., and Young, M. H. (1962). *Lancet*, **2**, 907.
Wightman, J. A. K. (1967). Personal communication.