POSTOPERATIVE ATELECTASIS AND PNEUMONIA

DIAGNOSIS, ETIOLOGY AND MANAGEMENT BASED UPON 1,240 CASES OF UPPER ABDOMINAL SURGERY

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DURING THE PERIOD July, 1941 to October, 1945 there were 1240 upper abdominal operations completed at the Hospital of the University of Pennsylvania. On the basis of data obtained from this group of patients it is our opinion that the incidence of postoperative atelectasis and pneumonia can be sharply reduced if a rational prophylactic regimen is observed prior to surgery, during operation, and immediately following operation. Indifferent attention to such a program will inevitably be followed by a rise in postoperative respiratory morbidity, particularly in individuals to whom general anesthesia has been administered.

There have been scores of papers on the subject of postoperative pulmonary complications. Certain broad principles relating to etiology and treatment have been established, and, on the basis of these, what formerly constituted one of the chief hazards of surgical convalescence has now become much less of a danger, despite the fact that surgeons today are performing more extensive operations, and are likewise subjecting older and older patients to surgical intervention. The background for this decrease in respiratory morbidity is a comprehensive one. Among the contributing factors should be included the development of anesthesiology as a medical specialty, greater knowledge of the preoperative preparation of the surgical patient, the application of physiologic principles to therapy, the introduction of chemotherapy and antibiotics, blood banks, and blood substitutes. The combination of these and other advances enables the surgical patient to anticipate a postoperative course marked by minimal disturbance of function. This paper will not present any fundamentally new concepts, therefore, but will concern itself with details, the minutiae which are essential to the successful application of well-recognized general principles.

As stated above, this study was begun in July, 1941. An analysis of the first 250 cases was completed in December, 1942 (Series I). Certain facts became apparent at once. The incidence of postoperative atelectasis and pneumonia was 11.0 per cent for patients receiving inhalation anesthesia, and only 4.2 per cent in the group given spinal anesthesia. Since it has been conclusively proven by many investigators[1, 2] that the anesthetic agent and technic are not major factors in postoperative morbidity, it was evident that something was amiss. Accordingly, a positive program was adopted for the management of patients scheduled for inhalation anesthesia. An analysis of the next 990 upper abdominal operations (Series II—December, 1942 to October, 1945)

demonstrated the efficacy of the change. Following spinal anesthesia the incidence of atelectasis and pneumonia in the postoperative period had remained essentially unchanged (5.0 per cent), whereas after inhalation anesthesia the incidence had decreased to 4.1 per cent. Since these data have proved statistically significant, it seemed of interest to report them and to attempt an explanation for our experience.

METHOD OF STUDY

There are two general surgical services at this hospital. One prefers general anesthesia, the other spinal anesthesia. These services use the same wards, operating rooms, anesthetists, interns and nursing staff. They care for the same general type of patient, since admissions are alternated from the receiving ward or are sent in by a large but relatively constant group of referring physicians. There has been, therefore, opportunity for more or less standardizing such factors as preoperative preparation of the patient, the ability of the anesthetist, surgical technic and skill, and postoperative care, leaving as the outstanding variable the method of anesthesia. This latter, of course, is not the sole variable, but the 1,240 cases are as carefully controlled as is possible in the average clinical case study.

The value of a statistical study of clinical material varies directly with the accuracy of each individual observation. In this particular instance accuracy in diagnosis determines statistical reliability. Failure to recognize even a few cases or inclusion of doubtful ones will alter final figures considerably unless the series be much larger than those usually reported. For this reason data gathered from hospital record rooms is more liable to error than is data obtained directly from each patient as that patient is being treated. The authors of this paper have, therefore, followed each case during the entire postoperative course until discharge from the hospital. Careful progress notes have been made in each instance.

It is unfortunate that diagnostic criteria for postoperative atelectasis and pneumonia have not been standardized, and many surveys have not indicated clearly the basis on which diagnoses have been established. There is general agreement as to the clinical picture and radiologic findings of the so-called "massive collapse," described first by Pasteur. Lobar atelectasis is also readily recognized. There are, however, a great many patients whose pulmonary status is equivocal. Diagnosis for these individuals ranges from "bronchitis" through "patchy or lobular atelectasis" to "pneumonitis or pneumonia." It is this larger group for which diagnostic standards will be discussed, for they form the borderline cases which are so difficult to evaluate.

We have made a diagnosis of patchy or lobular atelectasis in the presence of the following findings:

Symptoms.—1. *Cough:* Dry at start, soon becoming productive tenacious mucus, or mucopurulent secretions.

2. *Respiratory Distress:* A sense of discomfort over the lung field, vague tightness in the chest, or dyspnea.

Signs.—1. *Inspection:* Asymmetrical respiratory movements (retraction of affected side on inspiration, restriction of movement on affected side); slight cyanosis (not essential).

2. *Auscultation:* Diminished or absent breath sounds, râles (these may be coarse or fine).

3. *Percussion:* Dullness (not essential).

4. *Vital Signs:* Rise in pulse rate, respiratory rate, or temperature (the usual range in patchy atelectasis is 99–101 degrees F.).

Roentgenologic Findings.—1. *Linear Shadows:* Well-described by Fleischner, Hampton and Castleman,[3] indicative of collapse of alveoli.

2. *Hypoventilation:* Increased density of lung tissue (decreased air-bearing), prominent trunk shadows.

3. *Elevation of Diaphragm, and Reduced Excursion of Diaphragm:* Seen in majority of upper abdominal cases whether or not signs and symptoms indicate pulmonary dysfunction.[4]

4. *Mediastinal Shift:* An uncommon finding unless the collapse involves many areas unilaterally.

If the clinical course is prolonged, if the febrile reaction decreases only slowly, if toxemia is evident, and if there are roentgenographic signs of consolidation, a diagnosis of bronchopneumonia is made.

The differential diagnosis between bronchitis and lobular atelectasis presents the greatest problem. If the only objective finding is a productive cough, with little febrile response, and little evidence of respiratory distress, the former diagnosis seems more accurate. Admittedly, there are instances in which we have erred, but our tendency has been to include doubtful cases in the category of major pulmonary complications.

All the data have been subjected to statistical analysis according to the method of chi-square.

RESULTS

I. *Incidence.*—The results of the entire group of cases are shown in Table

TABLE I

TOTAL INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING 1,240 UPPER ABDOMINAL OPERATIONS

	No. of Cases	No. of Complications	Per Cent
Series I	250	19	7.6
Series II	990	49	4.9
	1,240	68	5.5

I, where it is seen that the incidence of postoperative atelectasis and pneumonia cases was 5.5 per cent in 1,240 cases of upper abdominal surgery. This incidence of 5.5 per cent must be compared to that expected in a general surgical service with all types of operations. Representative figures are those of Eliason and McLaughlin[5] of 1.38 per cent in 22,962 cases, and of Taylor, *et al.*[6] of 1.2 per cent in 12,349 cases. Thus, as has long been known, the incidence of major

pulmonary complications in the postoperative period is distinctly greater after surgery in the upper abdomen.

II. *Anesthetic Method.*—Table II indicates the incidence of postoperative atelectasis and pneumonia in relation to the use of general anesthesia, spinal anesthesia, or a combination of these two methods. Analyzed statistically, there is no significant difference between the three groups of cases. Of statistical

TABLE II

INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO ANESTHETIC METHOD

	General			Spinal			Spinal Plus General		
	Cases	Compl.	%	Cases	Compl.	%	Cases	Compl.	%
Series I.....	90	10	11.1	144	6	4.2	16	3	18.7
Series II.....	343	14	4.1	543	27	5.0	104	8	−7.8
	433	24	5.5	687	33	4.8	120	11	9.0

significance, however, is the breakdown of cases in the group "general anesthesia." Series I shows a significant difference in incidence from that found for the entire group, and from that found in Series II.

These observations confirm a fact, also well-established, that the anesthetic method need not influence the incidence of respiratory complications in the postoperative period. Ferguson and Latowsky[7] have published data, however, which indicate that general anesthesia is followed by major pulmonary complications four times more frequently than is spinal anesthesia. In Series I of our own figures the incidence in favor of spinal anesthesia is almost 3:1. How can one reconcile these two viewpoints? Why do many surgeons and internists insist, on the basis of personal experience, that spinal anesthesia is preferable if atelectasis or pneumonia are to be avoided?

The explanation for these differences in opinion lies in the fact that general anesthesia is more hazardous unless administered skillfully, and unless the patients receive conscientious, competent supervision in the immediate six hours postoperatively. Ferguson and Latowsky's figures were gathered in an institution where nurse-anesthetists or interns administered all of the general anesthesia, and where the importance of immediate postoperative care was not stressed repeatedly by the anesthesia and surgical staffs. Series I in this study represents somewhat similar conditions, particularly as regards postoperative management. This was entirely left up to the initiative of the nursing staff. In some instances care was excellent. In others the rationale underlying intelligent treatment of the unconscious patient was not appreciated at all. Postoperative rounds were not started until the whole schedule of cases was completed, so that physician supervision was often delayed for hours unless emergency measures were required. With such a regimen the incidence of postoperative atelectasis and pneumonia was significantly lower in those patients given spinal anesthesia. It is our opinion, therefore, that with mediocre anesthetic skill and indifferent or uninformed postoperative attendants spinal anesthesia is the safer method. If certain well-recognized measures are adopted, however, this need not be the case.

As stated in the introduction, we instituted a definite program for the management of surgical patients scheduled for general anesthesia when Series I revealed that our incidence of pulmonary complication was so much higher following this type of anesthesia. Table II indicates the value of this prophylactic program, the details of which will be presented:

PROPHYLACTIC REGIMEN

A. *Preoperative.*—(1) All cases with acute upper respiratory infections were postponed for one to two weeks unless the problem was a surgical emergency.[8, 9]

(2) Patients with recent irritation of the respiratory passages were given larger doses of atropine, since such individuals tend to pour out a greater amount of secretion in response to inhalation anesthesia.

(3) Negroes were given larger doses of atropine (0.6-0.8 mg.) since they, too, seem to have greater tendency towards secretions. The value of the belladonna derivatives in preventing postoperative respiratory complications has been debated on many occasions. Opponents claim that increased viscidity of secretions results with tendency toward formation of plugs. DeTakats[10] has recently denied this, nor have we seen any harmful effects. Large doses of atropine have been shown to prevent reflex bronchoconstriction and bronchosecretion following intra-abdominal manipulations, such as traction on the cystic duct or on the mesentery.[10] Atelectasis has been reported occurring during surgery,[11] and it is possible that the reflex narrowing of bronchi together with increased secretions are predisposing factors in such instances. Atropine in larger than usual doses might therefore be justified as a prophylactic measure.

(4) Patients with chronic respiratory disease or irritation (bronchitis, bronchiectasis, heavy smokers, *etc.*) were urged to cough up the night's accumulation of secretions,[12] were placed later in the schedule so that this could be accomplished, and were even subjected to preoperative bronchoscopic aspiration if such measures as cough and postural drainage were insufficient in clearing the tracheobronchial tree. Wherever possible these patients were placed on the operating table in positions favorable for gravity drainage.[9]

The various mechanisms responsible for the elimination of secretions and fluids from the respiratory tract have been listed by Boyd, *et al.*[13] These include the ciliary mechanism, cough, the milking-like contractions of the bronchial muscles, the churning movements of breathing and reabsorption into the lymphatics and veins of the lung. These workers found the cilia capable of moving an amount of respiratory fluid considerably in excess of that normally present. In the presence of congestion or edema of the tracheobronchial mucosa, however, drainage was inadequate and secretions pooled in the lungs. So long as the experimental animals remained horizontal, relatively little respiratory fluid was eliminated. Tilting to 30°-50° head-down increased the drainage 30-fold:

Tracheobronchial Mucosa:	*Intact*	*Congested & Edematous*
Animals at angle 0°	3.2 cc./kilo/24 hrs.	1.7 cc./kilo/24 hrs.
Animals at angle 30°	3.5 cc./kilo/24 hrs.	32.7 cc./kilo/24 hrs.
Animals at angle 50°	3.6 cc./kilo/24 hrs.	34.1 cc./kilo/24 hrs.

This quantitative data clearly illustrates that respiratory disease is associated with accumulation of fluids, and that postural drainage is a valuable therapeutic measure in such instances.

(5) Oral hygiene was practiced, *i.e.*, correction of oral sepsis, use of mouth washes and brushing of teeth.[14]

B. *During Surgery.*—(1) The lightest plane of surgical anesthesia which was compatible with the task at hand was maintained. For example, during resection of the stomach, or during the anastomosis of the jejunum to the stomach in a gastric resection relatively light anesthesia sufficed. This was then increased during exploration, inversion of the duodenal stump, and closure. This substantially reduced the time required for postoperative awakening and the amount of anesthetic agent required. Many of the patients were awake before leaving the operating room.

(2) Anesthesia was stopped as a rule as soon as the peritoneum was closed. This permitted the patient to "blow-off" anesthetic agent, and also to fill his lungs with room air as respiration was stimulated by placing of the abdominal wall sutures. The presence of nitrogen in the alveoli is regarded as a prophylactic measure for collapse due to vascular absorption of readily absorbable mixtures high in oxygen content.[13]

(3) If patients with intestinal obstruction or gastric retention were operated upon under general anesthesia great care was taken to recognize any regurgitation of intestinal contents into the oropharynx. Although practically all of these patients had some form of suction-drainage prior to operation this was no guarantee against such an occurrence. When regurgitation was noted, immediate suction of the tracheobronchial tree was carried out through an endotracheal tube. Even in instances in which rather large amounts had been aspirated such a procedure was quite successful. These patients were bronchoscoped immediately after operation and the cleanliness of the respiratory passages was impressive. Tracheal suction can be instituted at once before a bronchoscopist can be summoned, and is apparently quite effective. Regurgitation and aspiration can occur with any type of surgery, of course, but these complications can be anticipated more frequently in the presence of intestinal obstruction. We also employ cuffed endotracheal tubes in cases of intestinal obstruction to prevent aspiration, but occasionally fluid has slipped past even this barrier.

C. *Postoperative.*—(1) The patient was turned at least every hour. A radical change in position was insisted upon from the nursing staff.

(2) Secretions in the nose and mouth were aspirated by catheter as often as necessary.

(3) Inhalation of 100 per cent CO_2 was prescribed for 2–3 minutes

(unless no hyperpnea developed) every 20–30 minutes for six hours, then every hour for 24 hours. The CO_2 was delivered from a tank at the bedside through a rubber tube held six inches from the patient's face. This permitted the inhalation of a mixture of CO_2 in air rather than in oxygen, minimizing absorption of alveolar gases during the post-CO_2 depression of breathing. The rationale of this has been discussed by Waters.

The value of CO_2 inhalations is a controversial matter. King[16] treated 648 patients postoperatively with such inhalations, using another group of 667 individuals as controls. He was unable to demonstrate any decreased incidence of major pulmonary complications following CO_2. It should be pointed out, however, that the treated cases were divided into several groups: One breathed an increased CO_2 mixture for three minutes three times a day; another for 3–6 times a day, while another received such therapy 6–10 times a day. We feel that the chief value of such inhalations lies in the first six hours, and insist that our patients receive this treatment 2–3 times an hour during that period. King's cases, in our opinion, did not receive CO_2 therapy of sufficient intensity to prove or disprove its value.

A recent report by Mushin and Faux[17] is interesting along this same line. These workers demonstrated a decreased incidence of postoperative respiratory morbidity in a series of 24 patients placed in a respirator for the first 24 hours postoperatively. Since such a procedure ensured full respiratory movements, one can use such data to substantiate the belief that the respiratory stimulation caused by frequent exposure to CO_2 mixtures is valuable.

We propose to employ a similar approach by hyperventilating patients with a positive pressure technic soon to be described. Again, the virtue of full respiratory excursions (together with the increased speed of elimination of anesthetic agent) can be submitted to analysis.

(4) Narcotics were kept to a minimum and codeine sulfate was used whenever possible for the relief of pain. There were two reasons for this practice. First, we desired to maintain the cough reflex as active as possible. Second, morphine suppresses ciliary activity considerably, interfering with elimination of secretions from the respiratory tract.[18]

(5) The abdominal wall was supported whenever the patient could be made to cough. This was accomplished manually, and not with binders. Adhesive was limited to the maintenance of light gauze dressings.

(6) Aged individuals were mobilized as early as possible.[19]

(7) Intestinal suction tubes were removed early to avoid nasal and pharyngeal irritation with outpouring of secretions.

(8) Chemotherapeutic or antibiotic agents were administered prophylactically if respiratory morbidity was especially likely.

(9) We have only rarely attempted to improve ventilation by blocking painful impulses from the operative site. Starr and Gilman[20] describe an increase in vital capacity (23 per cent) following unilateral intercostal block in eight patients who had had biliary tract operations. This is worthy of further study, particularly if a safe, long-lasting local anesthetic can be discovered.

Johnson[21] appears to have minimized postoperative complications following pneumonectomy by crushing the intercostal nerves supplying the operative site.

(10) Finally, the problem of postoperative complications was placed squarely before the nursing staff as a challenge. They were instructed in the rationale of the "stir-up regimen";[22] they were praised for the successful management of difficult cases and shared in our concern when a complication arose.

With the institution of the program outlined above, the incidence of postoperative atelectasis and pneumonia following general anesthesia decreased from 11.0 per cent to 4.1 per cent, an incidence slightly lower than that seen after spinal anesthesia.

That these two methods of anesthesia should have a similar incidence of postoperative respiratory morbidity is not strange when one considers that regardless of the anesthetic technic the surgical patient's resistance is lowered to the same degree in each instance by his primary disease, the insult of surgery, exposure to drafty corridors and to the respiratory flora of attendants. It has been argued that the decreased ventilation associated with high spinal anesthesia (block of intercostal muscles) predisposes to atelectasis; and that as the patient awakens from an inhalation anesthetic, he tends to struggle, retch, move about and, hence, expand pulmonary alveoli more efficiently than the individual recovering from spinal. For these reasons some anesthetists expect a higher respiratory morbidity following this latter technic. Most reports, however, indicate no statistically significant difference.

The importance of the immediate postoperative care of surgical patients is being increasingly recognized. Lundy[23] describes a "postanesthetic room" staffed by personnel specially trained in the management of the unconscious patient, and fully equipped to handle all emergencies. These observation rooms should form an integral part of all surgical services, for they can almost certainly reduce postoperative morbidity and mortality.

III. *Anesthetic Agent.*—Table III presents the incidence of atelectasis and pneumonia following various general anesthetics. Analyzed statistically,

TABLE III

INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING GENERAL ANESTHESIA LISTED ACCORDING TO ANESTHETIC AGENT

	Series I		Series II		Total		
	Cases	Compl.	Cases	Compl.	Cases	Compl.	%
Ether	84	8	232	10	316	18	5.7
Cyclopropane	6	2	23	3	39	5	12.8
Cyclo. and curare or dihydro-B-erythroidin	0	0	87	1	87	1	1.1
Local and pent	0	0	1	0	1	0	

there is no significant difference between the various drugs. The extremely low incidence of respiratory complications following the combination of cyclopropane and curare or dihydro-B-erythroidin deserves comment. A larger series of cases is required before definite conclusions can be reached, but it is highly suggestive that the use of an inhalation anesthetic to produce uncon-

sciousness and of another substance to produce muscular relaxation is a valuable technic as far as postoperative respiratory morbidity is concerned. The data also indicate that ethyl ether does not constitute the threat to the lungs which is assumed by many internists. The relatively high morbidity after cyclopropane alone is probably due to the fact that this agent was selected for individuals whose physical status was abnormal. These patients respond with an increased incidence of postoperative complications by the very nature of their debility.

IV. *Endotracheal Tubes.*—Table IV indicates the influence of an endotracheal tube on the development of atelectasis or pneumonia. Although the percentage of complications is greater in the presence of endotracheal technics,

TABLE IV

INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING GENERAL ANESTHESIA LISTED ACCORDING TO USE OF ENDOTRACHEAL TUBE

	Series I			Series II			Total		
	Cases	Compl.	%	Cases	Compl.	%	Cases	Compl.	%
With tube.....	69	9	13.0	234	10	4.3	303	19	6.3
Without tube..	21	1	4.7	109	4	3.7	130	5	3.9

these data are not statistically significant. This agrees with the findings of other workers.[24, 33] In the presence of preëxisting upper respiratory tract infection endotracheal intubation may be followed by increased respiratory morbidity, but the value of this form of anesthesia is so great that when indicated it should not be withheld because of the hazard of a postoperative pulmonary complication.

V. *Age of Patient.*—In Table V are listed the number of cases according to age-groups, together with the percentage of respiratory complications and the statistical significance of the data.

TABLE V.

THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO THE AGE OF PATIENT

Years	No. of Cases	Atel. and Pneum.	%	Significance
1-20	22	2	9.0	0
21-30	129	6	4.7	0
31-40	213	5	2.4	+
41-50	296	18	6.1	0
51-60	355	19	5.3	0
61-70	180	11	6.1	0
71-80	32	6	18.7	+
81-90	4	1	25.0	0
?	7	0	0	0

This relationship is perhaps better illustrated by a graph (Chart I).

It would appear that there was a period of maximal resistance in the age-group 31–40, with susceptibility increasing considerably in patients over 70 years of age. This has been noted by Taylor, *et al.*[6]

VI. *Sex of Patient.*—Table VI indicates the sex distribution in this series of cases. As has been pointed out before[2, 25] the incidence of pulmonary com-

plications is significantly higher in men than in women. Of all of the many reasons given for this sex difference the one which appeals to the authors is the suggestion of Ravdin and Kern[25] that women have a higher resistance to infections of the respiratory tract. A survey of comparable populations in an effort to demonstrate this point would be profitable. Other theories listed

TABLE VI

THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO SEX

	No. of Cases	Atel. and Pneum.	%
Male	501	45	90
Female	739	23	31

include the greater incidence of smoking in men,[34] and the fact that respirations are more diaphragmatic in men and, hence, more affected by intra-abdominal surgery. Women seem more able to withstand pain. Could the difference in respiratory morbidity be due to the fact that men are more apt to splint respiratory muscles because of discomfort?

VII. *Duration of Operation.*—Table VII lists the incidence of atelectasis and pneumonia according to the duration of the surgical procedure. Again none of the data are statistically significant. It is interesting, however, that

TABLE VII

THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO THE DURATION OF OPERATION

Hours	No. of Cases	Atel. and Pneum.	%	Significance
0–.5	14	0	0	0
.5–1	346	14	4.0	0
1–1.5	329	15	4.6	0
1.5–2	212	14	6.6	0
2–3	227	11	4.9	0
3–4	85	9	10.5	0
4–5	20	4	20.0	0
5	7	1	14.3	0

respiratory morbidity does not begin to increase until after the third hour of surgery. Since many of the radical procedures for management of biliary tract obstruction, or intra-abdominal malignancy require a prolonged operative time this fact is reassuring. It should be recognized, however, that other surveys[6] indicate a linear relationship between the incidence of postoperative respiratory complications and duration of operation.

VIII. *Type of Operation.*—Table VIII indicates the relationship between the type of operation and the postoperative respiratory morbidity. Several facts are apparent from these data. First, gastric surgery, as a whole, is followed by the highest incidence of atelectasis and pneumonia. For example, Mimpriss and Etheridge[26] report 30 instances of atelectasis in a series of 100 consecutive partial gastrectomies. Second, emergency surgery or surgery upon ill patients is more of a hazard. This accounts in all probability for the increased incidence following cholecystostomy, cholecystenterostomy, gastro-enterostomy and

TABLE VIII

RELATION OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA TO TYPE OF OPERATION

Operation	General Anesthesia						Spinal Anesthesia						Spinal and General						Total Series I and II		
	Series I			Series II			Series I			Series II			Series I			Series II					
	Cases	Compl.*	%	Cases	Compl.*	%	Cases	Compl.*	%	Cases	Compl.*	%	Cases	Compl.*	%	Cases	Compl.*	%	Cases	Compl.*	%
Biliary Surgery:																					
Cholecystectomy	47	4	9	114	0	0	84	3	4	195	4	2	11	2	18	27	1	4	478	14	3
Cholecystectomy and Choledochostomy	2	0	0	22	1	5	20	0	0	70	2	3	2	0	0	8	1	13	124	4	3
Cholecystostomy	0	0	0	12	4	33	4	0	0	40	5	13	0	0	0	4	0	0	60	9	15
Choledochostomy	1	0	0	6	0	0	3	0	0	13	1	8	2	1	50	1	0	0	26	2	8
Cholecystenterostomy	2	0	0	5	0	0	4	1	25	5	1	20	1	0	0	3	0	0	20	2	10
Plastic on common duct	0	0	0	7	0	0	5	0	0	8	0	0	0	0	0	3	0	0	23	0	0
Biopsy of gallbladder	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	2	0	0	6	0	0
Repair of fistula	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	4	0	0
Gastric Surgery:																					
Resections	22	4	18	85	6	7	15	2	13	48	4	8				17	2	12	187	18	10
Gastro-enterostomy	5	2	40	10	1	10	4	0	0	9	1	11				2	0	0	30	4	14
Gastrostomy	2	0	0	9	0	0	3	1	33	12	1	9				0	0	0	26	2	8
Repair of ruptured ulcer	1	0	0	6	1	17	1	0	0	17	3	18				4	0	0	29	4	14
Polypectomy	0	0	0	2	0	0	0	0	0	1	0	0				0	0	0	3	0	0
Pyloroplasty	0	0	0	1	0	0	0	0	0	1	0	0				0	0	0	2	0	0
Upper Abdominal:																					
Exploratory celiotomy	4	0	0	24	0	0				28	1	4				8	0	0	64	1	2
Exploratory celiotomy and biopsy or elysis of adhesions	3	0	0	5	0	0				15	0	0				2	0	0	25	0	0
Splenectomy	0	0	0	11	1	0				7	1	14				7	1	14	25	3	12
Ileotransverse colostomy	1	0	0	2	0	0				13	1	8				5	1	20	21	2	10
Other bowel surgery				4	0	0				12	0	0				3	1	33	19	1	5
Pancreatic adenectomy or resection				7	0	0				5	1	20				0	0	0	12	1	8
Transperitoneal nephrectomy				1	0	0				2	0	0				0	0	0	3	0	0
Adrenalectomy				2	0	0				0	0	0				0	0	0	2	0	0
I & D subdiaphragmatic abscess				3	0	0				6	0	0				0	0	0	9	0	0
Marsupialization of liver cysts				0	0	0				1	0	0				1	0	0	2	0	0
Splenectomy and nephrectomy				1	0	0				0	0	0				0	0	0	1	0	0
Colectomy				4	0	0				28	1	4				7	0	0	39	1	3

* Compl. = Number of patients with atelectasis or pneumonia.

repair of ruptured ulcer. In the present series the incidence of atelectasis and pneumonia after cholecystectomy is low (3 per cent), as is that following partial gastric resection (10 per cent).

IX. *Economic Status of the Patient.*—It has been suggested[2] that the poorer classes of people are more likely to suffer from chronic respiratory tract diseases, particularly chronic bronchitis, and that it is this group which should

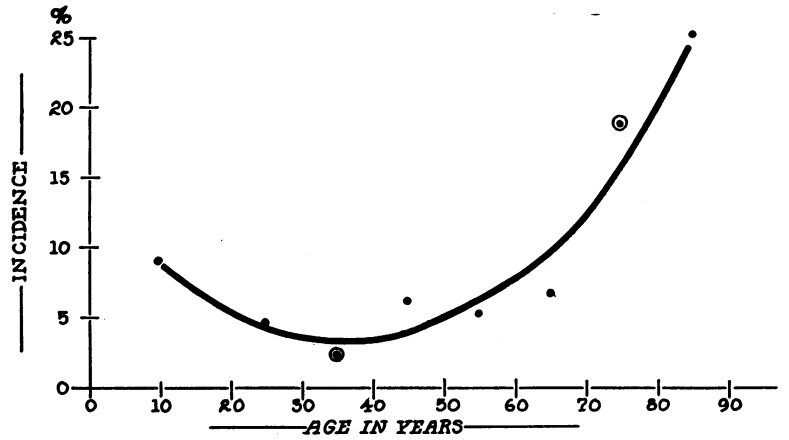

CHART I.—Relation of age of patient to incidence of postoperative atelectasis and pneumonia. (*The circled points are statistically significant.*)

show the highest incidence of postoperative atelectasis and pneumonia. Table IX is a study of the 1,240 cases divided according to their status as ward, semiprivate or private patients. We do not believe that this breakdown is a reflection of the original physical status of the patient. More likely explanations for the difference in incidence include the fact that most of the semiprivate and private patients had individual nurses caring for them, and had the benefit of surgeons of greater experience.

TABLE IX

THE INCIDENCE OF ATELECTASIS AND PNEUMONIA ACCORDING TO THE ECONOMIC STATUS OF THE PATIENT

	Cases	Compl.	%
Private	192	6	3.1
Semiprivate	395	13	3.5
Ward	653	50	7.7

TREATMENT

Once the diagnosis of atelectasis was established certain definite therapeutic efforts were made. These varied with the degree of collapse. In the presence of massive or lobar collapse either tracheobronchial toilet, as described by Waters,[27] or bronchoscopic aspiration[32] was immediately instituted. The

advantage of the former method is that it can be carried out by the anesthetist who is readily available; it is an atraumatic procedure and an effective one. The activation of the cough reflex by stimulation at the carina removes secretions from the bronchioles even though the suction catheter does not reach the obstructing material directly. On the other hand bronchoscopy as performed at this hospital is also a relatively simple, bedside maneuver which we do not hesitate to employ. It is unfortunate that many clinicians feel such a valuable therapeutic tool to be too hazardous for the ill patient. This has not been our experience.

If patchy or lobular atelectasis was found, more conservative measures were attempted first. These included slapping the patient on the back vigorously with the flat of the hand, encouragement to cough with the operative incision well supported, and the introduction into the trachea of an urethral catheter passed nasally, according to the method of Haight.[28] A theoretic objection to this latter technic of tracheobronchial aspiration is that alveolar gases may be sucked out as the vocal cords close around the aspirating catheter. Thus, further collapse might result. This objection can be overcome by passing the aspirating catheter through a wide-bored endotracheal tube.

Finally, each patient with atelectasis was placed upon sulfadiazine or penicillin therapy to prevent development of bronchopneumonia.

In several recent articles other conservative approaches have been suggested. We have had no experience with these. They include administration of ascorbic acid in an attempt to decrease pulmonary capillary permeability,[29] the use of large doses of ammonium chloride as an expectorant to liquefy tenacious bronchial secretions together with ephedrine as a bronchial dilater,[30] and the use of postural drainage.[31]

Discussion.—The data presented in this paper serve merely to confirm other surveys of the relation of the anesthetic agent and method, the age, sex and economic status of the patient, and the duration and type of operation to the development of atelectasis and pneumonia in the postoperative period. We feel that our figures are of value for two reasons. First, they have been subjected to statistical analysis; and, second, they offer statistical evidence that general anesthesia is more likely to be followed by respiratory morbidity unless a rational prophylactic regimen is carried prior to surgery, during surgery and after surgery. There is, therefore, justification for the feeling of many clinicians that regional or spinal anesthesia is preferable from the standpoint of pulmonary complications. In hospitals in which unskilled anesthetic technic and unintelligent postoperative care characterize the management of the surgical patient such an opinion is sound. It must be emphatically pointed out, however, that such a sequence of events represents poor medical and surgical management. Our data, and those of other workers, conclusively demonstrate that the patient under general anesthesia need not anticipate a higher incidence of respiratory morbidity. Since many surgeons and many patients prefer this method of pain relief this point must be emphasized.

This survey lends impetus to the movement publicized by Lundy and directed towards the addition of an observation room to hospital facilities. Such a room will contribute materially towards a reduction in postoperative morbidity. Surgery has now reached a point where it can offer the patient an extremely low mortality rate. We are no longer as concerned with whether a patient will "come off the table." This is expected in the vast majority of operations. Rather, our concern is directed toward minimizing disturbance of function in such a way that the patient's operative and postoperative course is as smooth as possible. One's ultimate goal is that of minimal morbidity. For the respiratory tract this can be achieved only by attention to the details listed above. With surgeons preparing their patients more adequately for operation, with anesthetic skill available through the services of a specialist in this branch of medicine and with competent postoperative nursing in an observation room such a goal can be realized.

We also wish to urge more standardization in the diagnosis of atelectasis. In some English and Canadian reports it is difficult to avoid the conclusion that rather marked degrees of collapse are required before the condition is listed. Their classification of "chests" includes many instances of productive cough, fever and dyspnea which we feel are associated with patchy or lobular atelectasis. Criteria should be established so that data from various clinics can be more uniformly compared.

Should pulmonary embolus be included in a study such as this? There can be no doubt but that such a catastrophe must be classed as a respiratory complication. There is considerable doubt in our minds, however, as to whether intelligent management of the respiratory tract during surgery or postoperatively can affect the incidence of this complication. The occurrence of thrombophlebitis is related to the broad problem of anesthetic management, *e.g.,* poor position of the patient with resulting venous obstruction, low blood pressure with resulting thrombus formation, *etc.,* but these conditions do not involve the respiratory tract primarily and should be considered separately. The data of deTakats[10] which suggests that emboli may be the forerunner of certain cases of atelectasis in no way affects this reasoning. It is only by defining a condition clearly that one can subsequently define the problems requiring solution. Atelectasis and pneumonia fall into one group, embolus into another. To combine them invites confused thinking.

What are the problems of atelectasis? In this and other papers the clinical picture of atelectasis has been described. We find that the incidence is higher: (1) in men; (2) in smokers; (3) after surgery in the upper abdomen; (4) in patients with acute or chronic respiratory infections; (5) with increasing age; and (6) with increasing length of operation.

Faced with these clinical facts, various investigators have studied the respiratory tract, attempting to correlate alteration of function with bedside observations. Thus, a number of experimental facts have been equally well established. It can be stated with certainty that after abdominal surgery one can expect: (1) A sharp reduction in vital capacity;[35, 36, 37] (2) a decrease in sub-

tidal volume of the lungs;[38] (3) an elevation of the diaphragm;[4] and (4) a decreased excursion of the diaphragm.[4]

These mechanical changes produce hypoventilation of the lungs. The question is, does hypoventilation alone cause the clinical picture of atelectasis or must there be an additional factor, such as bronchial obstruction? If one could eliminate hypoventilation in the postoperative period by blocking painful impulses from the incision, by ensuring full respiratory movements with CO_2, a respirator or by positive pressure breathing, could atelectasis be prevented? We propose to test this hypothesis by forcing patients to ventilate under conditions of increased pressure within the respiratory tract.

If bronchial obstruction is found to be a requisite, there is another problem to be solved. Is atelectasis caused by absorption of alveolar gases behind an obstructing plug, or is the collapse secondary to the creation of negative pressure behind mucus moving up the bronchioles through ciliary action? This latter thesis has been advanced by Hilding[39] after a series of ingenious experiments.

Finally, there is the problem of reflex atelectasis. How important are the reflex bronchoconstrictor and bronchosecretory phenomena described by deTakats? What are the nerve pathways over which these reflexes are mediated and what can be done towards their prevention?

Once the relative importance of hypoventilation, secretions and afferent impulses is established one can hope for a further reduction in the incidence of postoperative atelectasis. With careful attention to theoretic and practical details, it is our opinion that this reduction in incidence can approach zero.

SUMMARY

(1) The incidence of postoperative atelectasis and pneumonia in 1,240 cases of upper abdominal surgery is reported. The data are analyzed statistically from the standpoint of anesthetic agent and method, the age, sex and economic status of the patient, and the type and duration of operation.

(2) Factors concerned with the prevention of these respiratory complications are listed and a prophylactic regimen is outlined.

(3) Current theories as to the etiology of atelectasis are discussed and problems requiring further investigation are defined.

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