THORACOTOMY AND THE CONTRALATERAL LUNG

A STUDY OF THE CHANGES OCCURRING IN THE DEPENDENT AND CONTRALATERAL LUNG DURING AND AFTER THORACOTOMY IN LATERAL DECUBITUS

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While examining and reporting on the radiographs taken routinely following all thoracic surgical procedures at St. Mary's Hospital, it was noted that in a high proportion of cases extensive and diffuse peripheral opacification was present in that hemithorax which was dependent and unopened during the thoracotomy, i.e., in the lung and/or pleural cavity contralateral to that of the surgical approach. This opacification was frequently observed in the immediate post-operative radiograph and, in a number of cases, in radiographs taken on subsequent days.

The operations were undertaken for a variety of cardiac and pulmonary lesions which may be grouped as follows: (1) Mitral valvotomy; (2) miscellaneous cardiac operations, including aortic valvotomy, resection of coarctation of aorta, pericardiectomy, and congenital heart operations; (3) pneumonectomy and lobectomy for bronchial carcinoma; (4) miscellaneous pulmonary and pleural operations, e.g., pulmonary biopsy, lobectomy for bronchiectasis, abscess and tuberculoma, and pleurodesis.

It was apparent that the opacification which had stimulated our interest was found only in those patients who had been in a lateral decubitus position for the whole of the duration of the operative procedures. For all these procedures, the position of the patient on the operating table was as shown in Fig. 1. The duration of the operations varied from one to three hours.

These opacifications were dominantly peripheral and either widespread from apex to base or more localized, but at no time presented a segmental pattern or showed any well-defined margination (Figs. 2a and b). Further, the opacification did not appear to be associated in the earlier stages with any clinical evidence of pneumonia or pleurisy with effusions or with any untoward respiratory difficulty. The only physical sign noted in those patients showing such opacification was

a variable decrease in breath sounds on the affected side. These opacifications had been reported on by various members of the radiological staff as possibly due to pneumonic consolidation, collapse, oedema, infarction, and pleural effusion, and it therefore seemed very desirable to ascertain their nature by further radiological study, especially concerning the time and mode of development of the opacifications which were temporarily termed "de-aeration changes."

It was decided to examine radiographically a series of approximately 100 patients in the following manner:

(1) A primary control film was taken immediately before the induction of anaesthesia with a mobile unit in the supine antero-posterior position in the anaesthetic room.

(2) After full anaesthetization, an antero-posterior film was taken with the patient in lateral decubitus on the operating table immediately before the thoracotomy incision with the support pads in position.

FIG. 1.—The operative position for left thoracotomy (right lateral decubitus).

FIG. 2a

FIG. 2b

FIG. 2.—Patient K. (a) Post-operative film in right lateral decubitus.
(b) Post-operative film in supine position.

(3) Immediately post-operatively, radiographs were taken (a) in lateral decubitus, as in (2), and (b) in the antero-posterior supine position. These two radiographs were taken with the shortest possible interval of time between them.

(4) Subsequently, in the customary routine, films were taken in the antero-posterior position on the first, second, third, fifth, and seventh post-operative days.

Throughout, the radiographs were taken on inspiration and occasionally on expiration also.

It was not always feasible to carry out the full technique of (2) and (3) in all the cases, but it was achieved in the majority. In every case an immediate post-operative film was secured. One hundred and five cases were thus examined, four films being discarded because of technical inadequacy, leaving the examinations of 101 cases for analysis. There was no especial case selection, but it cannot be claimed that all thoracotomy patients were sequentially investigated: cases were chosen at random when it was feasible for one of us (J. O. C. C.) personally to conduct or supervise the radiography in and adjacent to the operating theatres. The cases were collected over a period of 18 months.

Throughout the investigation every effort was made to ensure that the radiographs were obtained under as similar conditions as possible in each case.

The number of cases in each "operation group" is shown in Table I.

TABLE I
CASES IN EACH OPERATION GROUP

Operation Group	No. of Cases
Mitral valvotomy	40
Miscellaneous cardiac operations	12
Pneumonectomy and lobectomy for neoplasm	22
Miscellaneous pleuro-pulmonary operations	27
	101

At the end of the survey the two radiologists (J. O. C. C. and R. W.) reviewed all the films on three occasions, and the number of positive and negative findings in the operation groups are shown in Table II. A positive finding was the

TABLE II
POSITIVE AND NEGATIVE FINDINGS IN OPERATION GROUPS

Operation Group	Positive	Negative	Total
Mitral valvotomy	22	18	40
Miscellaneous cardiac	3	9	12
Bronchial carcinoma	2	20	22
Miscellaneous pleuro-pulmonary operations	2	25	27
	29	72	101

presence of a definitely abnormal peripheral opacity in the contralateral lung, due regard being given to the shadows caused by the thoracic supporting pad and soft tissues overlapping the lung fields.

The largest operative group was the "mitral valvotomy" group (for mitral stenosis), and, of the 40 cases, over 50% showed positive de-aeration

FIG. 3.—Patient R. Post-anaesthetic pre-operative film in right lateral decubitus.

FIG. 4.—Patient W. Post-operative film in right lateral decubitus.

changes. In the 22 positive cases in this group, 12 showed the de-aeration in the post-anaesthetic but pre-operative radiographs (Fig. 3). In the remaining 10 cases the de-aeration changes were found only post-operatively (Fig. 4).

In the bronchial carcinoma group there were two cases with positive changes: in one of these the neoplasm was left-sided, but in the other there was a right lower lobe neoplasm which was removed by lobectomy, the patient being in left lateral decubitus for the operation. This latter case is illustrated in Figs. 5a, b, c, and d, and the radiographs show the de-aeration changes on the left side, of which we have few examples.

RATE OF CLEARANCE OF DE-AERATION CHANGES

There was very marked variation in the rate of clearance of the de-aeration changes. In most cases but not in all, there was a marked clearance of the changes between the post-operative film in lateral decubitus and that taken within a very short time in the supine position (see Fig. 2). In eight cases in the mitral valvotomy group, the changes had cleared completely in 24 hours. The clearance times are shown in Table III.

TABLE III
CLEARANCE TIMES

Mitral valvotomy	..	..	..	..	8 clear in 24 hours
				1	" " 2 days
				2	" " 3 "
				3	" " 4 "
				4	" " 5 "
				2	" " 6 "
				1	" " 7 "
				1	" " 22 "
Miscellaneous heart operations	..	..		3	" " 24 hours
Bronchial carcinoma operations	..	..		1	" " 2 days
				1	" " 3 "
Miscellaneous pleuro-pulmonary operations				1	" " 24 hours
				1	" " 8 days

CONSIDERATION OF CAUSATIVE FACTORS

It now seems appropriate to consider what factors may be wholly or partly responsible for the de-aeration changes. The following deserve consideration: (1) Posture, (2) compression of the underside lung, (3) anaesthetic technique, and (4) the act of opening the thorax.

The combination of posture and compression of the underside lung as a causative factor clearly required further study. A healthy volunteer, after a control film, was placed on the operating table in lateral decubitus with the usual roll-pad beneath the dependent chest margin. This posture was maintained for one hour and then antero-posterior films were taken in lateral decubitus and supine positions. There were no de-aeration changes.

It was clear that the de-aeration changes could follow posture in the lateral decubitus with general anaesthesia induced by thiopentone, nitrous oxide, oxygen, and a muscle relaxant. This was observed post-operatively in 12 of the 22 positive cases in the mitral valvotomy group. Whereas the act of opening the left chest in these cases might add to the de-aeration appearance, this was not the primary contributory factor.

As all the patients were subjected to a thoracotomy and were suffering primarily from some pleuro-pulmonary or cardiac lesion, we next sought to examine a patient operated upon in a similar posture without the thorax being opened. A patient undergoing a renal operation was obviously appropriate, and a patient about to

FIG. 5a

FIG. 5b

FIG. 5c

FIG. 5d

FIG. 5.—Patient B. (a) Preliminary film showing carcinoma of right lower lobe. (b) Post-anaesthetic, pre-operative film in left lateral decubitus. (c) Post-operative film in left lateral decubitus. (d) Post-operative film in supine position.

undergo a planned partial nephrectomy was examined in our routine investigatory manner. This case showed de-aeration changes in the post-anaesthetic pre-operative phase, and the changes had increased in the post-operative films (Fig. 6).

At this stage of the inquiry it was apparent that the changes could and often did occur before

operation but apparently always after the anaesthetic.

The combination of posture and compression, and of anaesthesia, requires further discussion and investigation.

(1) In the majority of the positive cases, it was noticed that the dome of the diaphragm on the

FIG. 6.—Patient P (renal case). Post-anaesthetic pre-operative film in right lateral decubitus.

underside was raised, especially peripherally, when the patient was in lateral decubitus (Fig. 7). On adopting the supine position, the diaphragmatic elevation lessened and the de-aeration appearances also usually lessened correspondingly, but this correspondence was not invariable. This diaphragmatic behaviour, suggestive of a lessened lung volume, led to an attempted comparison with the degree of mediastinal displacement: it will be appreciated that, under the technical conditions, it was very difficult to be certain about the lesser

FIG. 7.—Patient J. Post-operative film in right lateral decubitus.

degrees of mediastinal shift. It was apparent that the peripheral de-aeration could be present without mediastinal shift and, in a few cases, without diaphragmatic elevation.

(2) The combination of relative splintage and fixation of the dependent hemithorax with the weight of the abdominal contents through a "paralysed" diaphragm after muscle relaxants and inhalation anaesthesia might have all been operative factors, but it seemed necessary to inquire further into the effect of muscle relaxants and anaesthesia.

A further series of investigations was planned in the following manner in the various pre-operative phases.

(i) A primary control film was taken in the anaesthetic room.

(ii) After routine premedication and with local anaesthesia, an endotracheal tube was passed and the patient placed in the operation position, i.e., lateral decubitus, and a further antero-posterior film was taken.

(iii) The patient was fully anaesthetized (thiopentone, nitrous oxide, and oxygen) and a further film was taken.

(iv) The muscle relaxant (curare) was then given and after five minutes a further film was taken.

(v) Routine post-operative films were taken.

The first patient thus examined did not show any de-aeration changes until after the inhalation anaesthesia (Fig. 8), but these occurred before muscle relaxants were given. In a second patient identical observations were made (Fig. 9). Judging from these cases, it is clear that the muscle relaxant did not play a primary role in causing the de-aeration changes.

A third patient was similarly examined in whom, for technical reasons, two films were taken in lateral decubitus before anaesthesia and before any muscle relaxant had been given. The first showed no abnormality, but in the second film the de-aeration changes were clearly present (Figs. 10a and b). The interval between these films was not more than one minute and the lateral decubitus position had not been maintained for more than five to six minutes. This observation implied that, at least in this patient with mitral stenosis who had received a routine premedication of pethidine (100 mg.), the posture and compression alone had initiated the changes.

In a fourth patient, who was due to have a mitral re-valvotomy on the next day, a preliminary film was taken supine and the patient was placed

in lateral decubitus for one hour: no de-aeration changes occurred.

COMMENT

The de-aeration changes have been found in all the operative groups, but their occurrence has been proportionately greater in the mitral valvotomy group, the largest group in our series.

In over one-half of the positive cases the de-aeration changes occurred pre-operatively but

after induction of anaesthesia and the administration of a muscle relaxant.

During subsequent inquiries it was shown (in single cases, all examples of mitral stenosis) that the giving of a muscle relaxant was not an essential precursor of the changes; the posture alone after premedication could result in the de-aeration changes.

Thus posture alone in a patient with mitral stenosis can be responsible (one example). During or following anaesthesia the de-aeration changes

FIG. 8.—Patient L. Post-anaesthetic, pre-relaxant, and pre-operative film in right lateral decubitus.

FIG. 9.—Patient F. Post-anaesthetic, pre-relaxant, pre-operative film in right lateral decubitus.

FIG. 10a

FIG. 10b

FIG. 10.—Patient O. (a) Post-anaesthetic, pre-relaxant and pre-operative film in right lateral decubitus. (b) Immediately after 10 (a) in same position.

occur quite frequently (especially in patients with mitral stenosis). More come to light following the contralateral thoracotomy, but, during the operation, the postural and anaesthetic factors are operative over a longer time. The evidence indicates that the act of surgery is not a primary factor and probably plays little part as a secondary or contributory factor.

The evidence does indicate that posture and compression is an essential factor and that premedication and anaesthesia may be important contributory factors.

THE NATURE OF THE CHANGES

The following possibilities are worthy of consideration.

DE-AERATION AND COLLAPSE.—The use of the term “collapse” implies to us that there is lobular, segmental, or lobar absorption of air of either abrupt or gradual origin, as in a bronchial occlusion. When the lung is compressed and is not permitted for mechanical reasons fully to expand, de-aeration presumably occurs which does not follow a segmental or lobar distribution. This may result in some loss of volume which can usually be restored immediately but not necessarily so.

PNEUMONIC CONSOLIDATION.—This must be firmly rejected as an explanation of the de-aeration changes. In none of the patients showing positive changes, either transiently or more persistently, was there any clinical evidence of an infective pneumonic consolidation.

PULMONARY OEDEMA.—We have considered the possibility that the changes could be due to a local dependency oedema. In the majority of our cases, there was mitral stenosis and one could imagine the impaired venous return being associated with a transient oedema of the persistently dependent lung. However, in one case in the experimental series with mitral stenosis, the mere posture did not cause any de-aeration. The very rapid development and clearance of the changes is hardly consistent with oedema.

We are forced to conclude provisionally that the de-aeration changes are the result of compression of the chest wall and a relative fixation of the parietes preventing the elastic movements of the lung peripherally: deep anaesthesia may add to the lung splintage and the de-aeration may worsen.

It is probable that the act of opening the opposite side of the chest has no direct influence on these changes, but during the operation the

splintage factor will be acting over a much longer period.

The important feature is that in a proportion of cases (17 out of 29 cases from all operative groups) the de-aeration changes persist for 48 hours or more and will readily be observed in routine post-operative radiographic series and may be erroneously diagnosed as pneumonia.

The de-aeration changes are thought to be of interest not only to radiologists but also to anaesthetists, surgeons, and physicians who may be called upon to comment on a “post-operative chest.”

Owing to the erroneous interpretation of these opacities, it is possible that antibiotic therapy, anticoagulant therapy, or both may be started. This study indicates that in the vast majority of cases neither of these forms of treatment plays any part in the prevention or control of these changes. Both antibiotic and anticoagulant drugs introduce their own complications, and should be avoided in the absence of confirmatory evidence of superimposed inflammatory, thrombotic, or embolic disease.

It is felt that the occurrence of de-aeration changes in the dependent lung may have an importance beyond radiological diagnosis. Posture will play some part in the production of pulmonary changes in selected areas during the nursing of acutely or chronically ill patients, due to mechanical factors and of a greater extent than has previously been appreciated.

In those of our cases showing the most extreme de-aeration, one wonders what changes may occur in the gaseous exchange at the alveolar-capillary level. Measurement of arterial oxygen saturation and ventilation-perfusion studies under these circumstances might prove interesting and of importance in view of the fact that the de-aerated lung is, sometimes during contralateral thoracotomy, the sole organ of respiration.

SUMMARY

Because of the frequency with which pulmonary opacification was observed in the contralateral lung in routine post-operative radiographs after thoracotomy, we conducted a radiological investigation before, during, and after thoracotomy in 105 patients. It has been shown that the de-aeration changes, which often preceded the thoracotomy, were probably due to prolonged compression of the lung and rarely had any clinical significance. Radiologically, the changes could readily be mistaken for pneumonic consolidation or obstructive atelectasis.