SECOND COMMUNICATION

ON

ARTIFICIAL RESPIRATION IN STILL-
BORN CHILDREN.

THE EXPANSIBILITY OF VARIOUS PARTS OF
THE LUNGS.

AN EXPERIMENTAL INQUIRY.

BY

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Preface.

THE present communication being one of a series on the subject of Artificial Respiration in Stillborn children proposes to deal with the question, "which part of the lungs of a child which has been subjected to various methods of manipulation with this object is most frequently expanded and which most frequently unexpanded?"

It would have been interesting to answer this question for each separate method, but material is not plentiful

enough. Nothing short of a series of observations on the appearances in a considerable number of cases manipulated by each method would suffice for a satisfactory answer to this subdivision of the question.

Moreover, it is probable that all the methods which are effectual in producing inspiration would be found to produce aëration of very much the same parts of the lungs, since they all act principally in the same way, namely by raising the ribs, clavicles, and sternum.

Even the method of Schultze, which does produce some descent of the diaphragm, still acts principally in the same way as the Silvester group, as I have elsewhere shown.

It would also be very interesting to determine the order in which various parts of the lungs become expanded by inspiring any desired quantity of air.

Unfortunately this is beyond our power; the bodies of stillborn children possess (so to say) individual peculiarities, and some lend themselves much more favourably to experiments than others.

It would have been easy to remove the respiratory organs or open the thorax, and force a measured quantity of air into the chest, observing the order of expansion of the several parts, but the conditions would be so essentially changed, both as regards the method of aëration and the surroundings of the lungs, that the similarity between artifice and nature would cease, and the investigation possess little probable and absolutely no demonstrable value.

This question, however, is more or less elucidated by the following experiments, in which the amount of air changed can be compared with the condition of the lungs as shown by dissection.

In the first table the first column shows the reference to the experiment, the second the methods of manipulation employed, the third the amount of air changed, and the fourth the conditions of the thorax as shown by dissection.

With regard to the amount of air changed, it may be necessary to say that where abdominal and thoracic pressure was employed for the purpose of expelling as much air as possible, the amount of aëration is calculated from the air they expelled as well as from the height of the column of fluid drawn up by inspiration.

This air is of course not under equal pressure, as would have been the case with a spirometer, but the figures are sufficiently near to give an idea of the amount of air received by the lungs in each case.

It may be added that the experiments were instituted with a view to ascertaining the inspiratory value of the different methods, and have been utilised for the present inquiry.

The use of a spirometer would have prevented several important observations, such as the force with which the air is inspired under Schultze's method.

Although twenty-six subjects were experimented on, only such experiments as refer to our subject are here recorded; and no case has been quoted in which direct inflation of the lungs was practised.

The observations quoted are twelve in number.

The second table, referring to the same experiments, needs no additional explanation.

TABLE I.

No. of experiment.	Methods employed.	Maximum inspiratory effect.	Autopsy.
5	Marshall Hall..... Silvester Schroeder Schultze Schultze-Silvester {	0 2½ in. 5 cc. 0 2½ in. 5 cc. 4 in. 8 cc.	<i>Left lung</i> .—All parts contain air; most expanded part, anterior portion of upper lobe; next to this, posterior part of base of lower lobe; least expanded part is the “lingula.” <i>Right lung</i> more uniformly distended; middle lobe most expanded. Every lobe floats in water. Of the right lung the most buoyant lobe is the middle, then the lower, then the upper; of the left lung the more buoyant lobe is the upper. Several small portions of both lungs do not float alone, among them the left apex. The most expanded portion of the whole lungs is the anterior part of the left upper lobe.
8	Marshall Hall..... Silvester (forcible) { Schroeder Schultze {	0 6 in. 12 cc. 0 3 in. 6 cc.	Mediastinal emphysema and double pneumothorax. <i>Left lung</i> airless. <i>Right lung</i> .—All the middle lobe and upper and inner edge of lower lobe fully inflated, the rest airless.
9	Marshall Hall..... { Silvester (forcible) { Schultze Schultze-Silvester { Howard {	¾ in. 1½ cc. 6 in. 12 cc. 5½ in. 11 cc. 7 in. 14 cc. ½ in. 0.25 cc.	<i>Left lung</i> completely inflated, except a patch along anterior inferior edge, which was partially inflated. <i>Right lung</i> completely inflated, but lower lobe less than the rest.
10	Marshall Hall..... { Silvester (forcible) { Schultze {	½ in. 1 cc. 8 in. 16 cc. 8 in. 16 cc.	<i>Left lung</i> floats as a whole, but upper lobe sinks; lower lobe floats, apex sinks; lingula floats with difficulty; lower lobe more buoyant than lingula. <i>Right lung</i> floats as a whole; both lobes (there is no middle lobe) float at first, but upper lobe soon sinks; left lower

No. of experiment.	Methods employed.	Maximum inspiratory effect.	Autopsy.
11	Marshall Hall..... Silvester (forcible) Schultze	$\frac{7}{8}$ in. 1-75 cc. 11 in. 22 cc. 7 in. 14 cc.	lobe is less buoyant than right lower lobe. No lobe of either lung is thoroughly inflated. Mediastinal emphysema, right pneumothorax. <i>Left lung</i> floats as a whole; each lobe floats, the lower lobe the better; apex is airless; of lower lobe, lingula floats best, posterior part of base worst. <i>Right lung</i> floats as a whole; upper lobe sinks apex downwards, the other lobes float; apex airless; middle lobe floats best; posterior part of base is airless.
12	Marshall Hall..... Silvester (forcible) Schultze Schultze-Silvester	$\frac{1}{8}$ in. 0-25 cc. 8 in. 16 cc. 7 in. 14 cc. 7 in. 14 cc.	Mediastinal emphysema, left pneumothorax. <i>Left lung</i> sinks as a whole; upper lobe airless; lower lobe floats, but when divided the lingula floats, the rest sinks. <i>Right lung</i> floats as a whole, anterior surface uppermost; all the anterior surface fairly inflated, the rest airless; lower and middle lobes float; upper lobe sinks, and is nearly airless.
13 Mercury manometer	Marshall Hall..... Silvester (forcible) Schultze Schultze-Silvester	0 $\frac{1}{8}$ in. 1 cc. 1 in. 2 cc. 1 in. 2 cc.	<i>Left lung</i> quite airless. <i>Right lung.</i> —A few inflated lobules along lower front edge of upper lobe and extreme inner part of this border, and at corresponding point of middle lobe; lower lobe contains most air, then upper lobe; lower lobe partly inflated along anterior surface and along upper and lower edges.
E.	(Child laid on its face after death) ¹ Silvester forcible)	...	Both lungs mostly inflated, right more than left. <i>Left lung</i> all inflated, except a vertical strip lying alongside vertebral column from apex to base, and a small patch of upper lobe just anterior to root. <i>Right lung</i> all inflated, except a patch of lower lobe just anterior to root.

¹ The object was to see whether posture had anything to do with the matter, allowing the blood to gravitate to the front instead of to the back of the lungs.

No of experiment.	Methods employed.	Maximum inspiratory effect.	Autopsy.
G. (14)	Silvester (forcible) {	6 in. 12 cc.	Each lung floats as a whole, but the above-named airless parts sink when separated. Mediastinal emphysema, no pneumothorax. Both lungs expanded; least inflated part being two strips running vertically along the back, opposite the angles of the ribs.
	Marshall Hall..... {	1 in. 0.25 cc.	
	Schultze {	2 in. 4 cc.	
J. (17)	Pacini {	16 in. 32 cc.	<i>Left lung</i> floats; both lobes separately float; all parts well expanded except lower and posterior edge of upper lobe and a line along the costal angles of the lower lobe, which is quite airless, and sinks. <i>Right lung</i> florid and expanded; one or two airless patches, the largest along the costal angles of the lower lobe.
	Bain..... {	16 in. 32 cc.	
	Silvester (forcible) {	16 in. 32 cc.	
	Schultze {	4 in. 8 cc.	
K. (18)	Pacini-Bain {	5 in. 10 cc.	Mediastinal emphysema, right pneumothorax. <i>Left lung</i> .—Anterior inferior part of upper lobe and lingula fairly expanded; front of lower lobe fairly expanded; lowest part of base posteriorly fairly expanded. <i>Right lung</i> airless.
	Schüller {	0 2½ in.	
	Schultze {	4.5 cc.	
L. (19)	Pacini-Bain {	5½ in. 11 cc.	Mediastinal emphysema, no pneumothorax. <i>Left lung</i> quite airless. <i>Right lung</i> airless, except middle lobe and anterior internal part of lower lobe. At anterior internal part of middle lobe is a patch of subpleural emphysema.
	Silvester (forcible) {	5½ in. 11.5 cc.	
	Schücking {	Do. 5 in.	
	Schultze {	10 cc.	

TABLE II.

No. of experiment.	Left lung.		Right lung.		
	Upper lobe.	Lower lobe.	Upper lobe.	Middle lobe.	Lower lobe.
5	Anterior surface best expanded of all parts of lungs; apex not floating	Posterior part of base well expanded; lingula least expanded	Least expanded	Most expanded	Fairly expanded.
8	Airless	Mediastinal emphysema and double pneumothorax.	Airless	Well expanded	Upper and inner edge well expanded; the rest airless.
9	Completely expanded	Completely expanded; except a patch on anterior inferior edge	Completely expanded	Completely expanded	Less well expanded.
10	Sinks in water	More buoyant than upper lobe (lingula hardly floats); less buoyant than right lower lobe	Less buoyant than lower lobe; soon sinks	Absent	More buoyant than right upper or left lower lobe.
11	Less buoyant than lower lobe; apex airless	Mediastinal emphysema; right pneumothorax. More buoyant than upper lobe; lingula best expanded; posterior part of base least expanded	Sinks in water; apex airless	Best expanded	Floats; posterior part of base airless.
12	Airless	Sinks as a whole. Floats; but when divided lingula floats, the rest sinks	Mediastinal emphysema; left pneumothorax. Floats as a whole. Nearly airless; part of anterior surface inflated, the rest airless	Floats; anterior surface inflated, the rest airless	Floats; anterior surface inflated, the rest airless.

No. of experiment.	Left lung.		Right lung.		
	Upper lobe.	Lower lobe.	Upper lobe.	Middle lobe.	Lower lobe.
13	Quite airless		A few inflated lobules along lower anterior edge and inner part	A few inflated lobules at inner extremity of upper anterior border; the least expanded of the three lobes	Partly inflated along anterior surface and upper and lower edges; the best expanded of the three lobes.
E	Less expanded than right	All expanded except vertical strip along angles of ribs, and a small patch anterior to root	Completely expanded	More expanded than left. Completely expanded	All expanded except a patch anterior to root.
G (14)	Well expanded, except angles of ribs behind.	Well expanded except vertical strip along angles of ribs.	Mediastinal emphysema, no pneumothorax. Well expanded, except a vertical strip along angles of ribs behind.		
J (17)	Well expanded, except lower and posterior edge	Well expanded except line along angles behind	Well expanded	Well expanded	Well expanded except patch along costal angles.
K (18)	Anterior inferior part fairly expanded	Lingula front and posterior inferior border fairly expanded	Mediastinal emphysema; right pneumothorax. Airless	Airless	Airless.
L (19)	Airless	Airless	Mediastinal emphysema; no pneumothorax. Airless	Partly expanded; at anterior internal part a patch of subpleural emphysema	Airless except anterior internal part.

Remarks.

Mediastinal emphysema occurred in six cases; in four cases with pneumothorax

Pneumothorax of the four cases : one affected both pleural cavities, two the right, one the left.

In all cases the lung on the side of the pneumothorax was less expanded than the other.

The pneumothorax was probably partly the cause and partly the effect of the complete or incomplete collapse of the lung. Pneumothorax of course impedes the expansion of the lung. On the other hand, the rupture will probably occur into that side on which the lung expands the less, the pressure being greater on that side.

This subject will hereafter be treated more particularly.

In seven cases one lung could be said to be generally better expanded than the other.

In six cases the right was the better expanded, in one the left.

The apices were frequently the least expanded parts of the lungs, *e. g.* No. 5 both apices; No. 8 right; No. 10 both; No. 11 both; No. 12 left; L. (19) right.

The anterior surfaces were frequently better expanded than the posterior surfaces, *e. g.* No. 5 left upper lobe; No. 12 whole of right lung; No. 13 whole of right lung; K. (18) left lung; L. (19) middle and lower lobes.

In several of these cases the expanded patch was not bounded by lobes, but extended over the fissures to adjacent lobes, *e. g.* No. 12 whole of right lung; No. 13 right lung; K. (18) left lung; L. (19) middle and lower lobes.

In several cases an unexpanded strip lay vertically along the costal angles on each side of the vertebral column, *e. g.* E. left lung; G. (14) both lungs; J. (17) lower lobes both lungs.

In two cases these strips were not limited by lobes but crossed the fissures, *e. g.* E. ; G. (14).

In one case, J. (17), the strip was seen on both lower lobes.

In some cases the lingula was better expanded than the rest of the left lung, *e. g.* 11 ; 12 ; K. (18).

In two cases it was airless or little expanded, *e. g.* 5 ; 10.

In no case was the posterior aspect of the lung generally better expanded than the anterior aspect, indeed, in one case (in which, with a view to testing whether the more frequent expansion of the anterior aspect of the lungs was due to supine decubitus after death, and consequent hypostatic gravitation of blood to the posterior aspect) the unexpanded vertical strip along the angles of the ribs was particularly well marked (Exp. E.).

On the whole it may be said that the parts of the lungs most frequently and thoroughly expanded were the anterior surfaces, not including the apices or anterior inferior edges.

The parts less frequently and thoroughly expanded were the apices, lower edges, and the vertical strips along the angles of the ribs posteriorly.

The more frequent and thorough expansion of the right lung may be due to the greater directness and size of the right bronchus.

These conclusions are very interesting, and can be accounted for.

First, the fact of the frequent non-expansion of the apices shows that the distance from the trachea does not explain the phenomena. Again, no doubt plugs of mucus will account for some of the unexpanded patches, but they will not explain the greater frequency of their occurrence in certain regions. Moreover the very distribution of many of these expanded and unexpanded patches disproves such cause, inasmuch as patches due to the patency or closure of a tube would be *limited to a lobule or lobe*.

Now we have seen that these patches are distributed

irrespective of fissures and lobes; therefore some other cause must be found.

This cause is, we think, to be found in the mobility of various parts of the chest walls.

The contents of the thorax are not under the conditions of fluid in a vessel, and the laws of equal pressure do not apply. If the chest walls are elevated in one part the external pressure opposite that spot is diminished, and the air will tend to expand the subjacent lung by preference.

On the other hand, the least mobile parts of the chest walls should overlay the least expanded parts of the lungs.

To apply these principles to the matter in hand. The most efficient methods of artificial respiration (*viz.* the Silvester group and the method of Schultze) act principally by elevating the ribs, clavicles, and sternum.

In a new-born child the upper ribs are hardly at all mobile, and the lower ribs are by far the most mobile. It is beneath the lower ribs, then, that the lungs should be most expanded, and this is the case; the action will be less at the diaphragm than a little remote from it, as the diaphragm acts little in Schultze's methods, and not at all in the Silvester group; and this is also the case. In one instructive case, L. (19) the situation selected for a solitary patch of subpleural emphysema was the anterior internal part of the middle lobe of the right lung.

Again the "indifference-point," or centre of motion for each rib is near its angle, and these very points form a vertical line along the spine which we have shown to very usually overlay two unexpanded vertical strips of lung.

How far these observations agree with the appearances in children which have breathed naturally we shall hereafter try to show; meanwhile, it may be remarked that these vertical strips occupy the very same situation as collapsed lung so often does in children, and that the lower edge of the anterior surface of the lungs, occupying as it does the sulcus between the ribs anteriorly and the diaphragm inferiorly, is dependent for its expansion on a consentaneous

action of the diaphragm and muscles moving the chest walls, and is often unexpanded. It has been elsewhere remarked that the mode of respiration by any of the efficient methods (Schultze's and the Silvester group), acting as it does by elevating the anterior thoracic walls, differs essentially from the natural mode of respiration in a new-born child, which is all but purely diaphragmatic.

The only considerable collections of the post-mortem appearances of the lungs of new-born children which I have been able to find are those of Joerg and Schmitt.

Out of Schmitt's 101 cases, 36 have been selected as bearing on the question and analysed; out of Joerg's 19 cases 16 have been selected and similarly treated.

The results are stated in the annexed tables, which have been compiled from positive statements only. The descriptions do not admit of more exact tabulation, being for the most part very brief.

The statements of Paris and Fonblanque, Bednar, Legendre, Gerhardt, Köstlin, Olshausen, Schwartz, and Böhr are either too inexact or are founded on too few cases to carry much weight.

Analysis of Schmitt's cases.

	Best expanded.	Least expanded.
Right lung	11	1
Left lung	3	4
Anterior surface	1	0
Posterior surface	0	2
Right upper lobe	9	3
Left upper lobe	7	4
Right middle lobe	9	3
Right base	2	12
Left base	3	9

Total cases=36 out of 101, no cases in which inflation was practised being included.

Analysis of Joerg's cases.

	Best expanded.	Least expanded.
Right lung	4	0
Left lung	1	3
Anterior surface	1	0
Posterior surface	0	1
Right upper lobe	1	3
Left upper lobe	2	0
Right middle lobe	1	3
Right base	1	4
Left base	1	4

16 cases selected out of 19.

Analysis of cases of Schmitt and Joerg.

	Best expanded.	Least expanded.
Right lung	15	1
Left lung	4	7
Anterior surfaces	2	0
Posterior surfaces	0	3
Right upper lobe	10	6
Left upper lobe	9	4
Right middle lobe	10	6
Right base	3	16
Left base	4	13

52 cases selected out of 120.

The results are that in *children which have died soon after birth* :

1. The right lung is usually better expanded than the left.
2. The anterior surfaces are usually better expanded than the posterior.
3. The lower lobes are the parts most often unexpanded.
4. The right middle lobe is usually well expanded.
5. The part of the left lung corresponding to the right

middle lobe is often better expanded than the rest of the left lung ; when the right middle lobe, on the other hand, is ill expanded, the corresponding part of the left lung is often unexpanded also (Joerg, No. 1, Case 5 ; No. 2, Case 6).

It is remarkable that in children who have breathed naturally the bases are so often unexpanded ; but this seems to correspond with the fact that the characteristic of feeble breathing in infants is feeble descent of the abdominal viscera, betokening feeble descent of the diaphragm.

Conclusions.

The following conclusions are offered :

In stillborn children which have been manipulated by the various efficient methods of artificial respiration :

1. The right lung is more usually and more completely expanded than the left.
2. The anterior surfaces are more usually and more completely expanded than the posterior.
3. The apices of the upper lobes are often unexpanded.
4. The anterior inferior borders the same.
5. One of the places of selection for atelectasis is a strip running vertically along the angles of the ribs on each side of the spine.
6. The patches of expansion or atelectasis, when considerable, are not confined to lobes nor bounded by fissures.
7. The last circumstance is not due to obstruction of the bronchi.
8. The spots of predilection for expansion or atelectasis underlie the regions of greatest and least movement of the chest walls.

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