

Roentgenological and Autopsy Studies on the Gas Content of the Lungs and Gastro-Intestinal Tract in Living and Stillborn Infants, and Sources of Error in Resuscitation

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Received November 4, 1968

In addition to the floating proof of the lungs, the Breslau floating test of the stomach and gut are affected in forensic pathology as valuable and informative tests for infants either stillborn, or born alive but dying shortly afterwards (cf. HOBOM, 1909). The movement of the air column to the distal parts of the gastro-intestinal tract together with other signs can be employed for determination of the lifetime of the infant. Air swallowed by the infant simultaneously with the first breaths reaches the colon within six hours, both in full-term infants and prematures (cf. PODOLSKY and JESTER, 1954). The most obvious sources of incorrect positive results are gas formation on putrefaction, and the impelling of air into the lungs and stomach during the artificial respiration of stillborns. During recent years, the mouth-to-mouth, or blowing method, has become the means of artificial respiration most frequently applied, by virtue its being more effective than the older methods. The utility of this method presents fresh difficulties from the forensic standpoint. In the literature, there is a lack of reports dealing with this apparent source of error in the interpretation of autopsy findings. Furthermore, in Finland no material has previously been compiled on the basis of studies by roentgenological methods and autopsies, the importance of this combination in all forensic cases has been emphasised (FRIMANN-DAHL et al., 1954).

Consequently, in the present series, a roentgenological method has been applied for study of the gas content of the gastrointestinal tract of living full-term and premature infants at several moments after birth; the same method was applied to stillborns after resuscitation, and before autopsy. A study was also made of the effect of resuscitation on the histological picture of the stillborn lungs.

Material and Methods

The series comprised normal full-term infants, prematures, infants born alive but dying subsequently, and stillborn, dead fetuses. The cases were taken from the Institute of Midwifery, Helsinki, where the X-ray examinations and autopsies were performed. The composition and treatment of the four groups are indicated below.

I. Normal, Full-Term Infants

Altogether, 178 normal infants with birth weights from 2,540—4,550 g were included in this control group. Most (160) of these were normal deliveries, nine cases were breech deliveries, sectio major was performed in 6, and suction cup in three cases. The infants were fed from the age of 12 hours with a sugar solution and after one day with mother's milk.

Table 1. *Normal, full-term infants. Movement of the gas column in the gastrointestinal tract from the moment of the birth. The number of infants in which the air has reached the various parts of the G-I tract at a given moment is indicated by the upper figure. The lower figure gives the percentage, calculated from the whole time group. Colon I includes the caecum and pars ascendens, Colon II pars transversa and descendens*

Age	Number	Ven- tricle	Jejunum	Ileum	Colon		Rec- tum
					I	II	
5 min	12	12	5	—	—	—	—
		92	42				
15 min	10	10	5	1	—	—	—
		100	50	10			
30 min	10	10	9	3	1	—	—
		100	90	33	10		
1 h	20	20	19	9	1	1	—
		100	95	45	5	5	
2 h	20	20	20	20	13	2	—
		100	100	100	65	10	
3 h	21	21	21	18	9	2	—
		100	100	86	43	9.5	
4 h	23	23	23	23	19	9	1
		100	100	100	83	39	4.3
5 h	21	21	21	21	21	18	2
		100	100	100	100	86	9.5
6 h	20	20	20	20	20	20	1
		100	100	100	100	100	5
12 h	21	21	21	21	21	21	13
		100	100	100	100	100	62
178							

They were in a healthy condition, except one who died at the age of one day. Each child was exposed only once to the X-ray examination, which was effected without any contrast medium. The time distribution is presented in Table 1.

II. Prematures

This second group of comparison cases comprised 8 cases, with birth weights from 2,150—2,480 g. The delivery was normal in 5 cases, and of breech type in 3 cases. Two infants were A-twins. All the prematures were in a healthy condition, and living during the course of the examinations. They were fed in the same way as the full terms. The times of X-ray examination are indicated in Table 2.

Table 2. *Prematures. Plain X-ray photograph taken of the stomach region. The Apgar-points given immediately after birth and in some cases also 15 minutes after the first rating. + = gas present, — = no gas*

No.	Sex	Birth weight (g)	Apgar-points	Kind of partus	Age on examination	Ven-tricle	Jejunum	Ileum	Colon		Rectum
									I	II	
1	♂	2,480	10	Normal	30 min	+	+	+	—	—	—
2	♀	2,250	8	Breech	2 h	+	+	+	+	—	—
3	♀	2,400	9	Normal	2 h	+	+	+	+	—	—
4	♂	2,150	5/6	Normal	3 h	+	+	—	—	—	—
5	♀	2,350	7/9	A-twin Breech	4 h	+	+	+	+	—	—
6	♂	2,460	4/7	Breech	4 h	+	+	+	+	+	—
7	♀	2,480	10	A-twin	5 h	+	+	+	+	+	—
8	♂	2,170	9	Normal	4 h	+	+	+	+	+	+
					5 h						+
					6 h						+

III. Infants Born Alive, but Dying Subsequently

Thirteen cases were included in this group. The birth weights were from 780—3,950 g; 8 foetuses were less than 2,500 g, and 6 cases over this weight. The lifetime ranged between 17 min, and 22 hours 13 min (see Table 3). Artificial respiration with intubation was administered to 6 infant before death. The infants and foetuses were first X-rayed after death; an autopsy was performed in each case, with a floating test of the lungs and a floating test of the gastro-intestinal tract according to Breslau. Furthermore, specimens were taken of the lungs for the routine histologic examination. The autopsies were made 3—5 days after death; during this period the bodies were stored at 4° C.

Table 3. *Born alive, but dying subsequently. Listed according to lifetime. The X-ray photographs were taken after death. The results of the floating test of the lungs and of the Breslau test of gut are given. In no case did the rectum contain gas. In cases 4, 5, 7, 8 and 11 the main autopsy diagnosis was immaturity, in 1, 2 and 6 pulmonary atelectasis and pneumonia, in 9, 12 and 13 intracerebral haemorrhage and in 10 syndrome Down. + = gas present, — = no gas, ± = traces of gas*

No.	Sex	Birth weight (g)	Apgar-points	Age at death	Artificial respiration	X-ray		Autopsy						
						Lungs	Ven-tricle	Jeju-num	Ileum	Colon		Lungs	Ven-tricle	Gut
										I	II			
1	♂	3,150	3/0	17 min	+	±	+	—	—	—	—	+	+	—
2	♂	3,350	2/2	22 min	+	±	+	+	+	—	—	+	+	—
3	♀	3,950	2/2	30 min	+	+	+	—	—	—	—	+	+	—
4	♀	2,150	1/1	41 min	—	—	—	—	—	—	—	—	—	—
5	♀	1,490	5/5	1½ h	+	+	+	—	—	—	—	+	+	+
6	♂	3,500	9	2 h	+	+	+	+	—	—	—	+	+	+
7	♀	1,340	4/7	5½ h	—	±	+	+	—	—	—	±	+	+
8	♀	780	8	7 h 45 min	—	+	+	+	+	—	—	±	+	+
9	♂	1,070	—	7 h 50 min	—	—	+	+	+	—	—	—	+	+
10	♀	2,560	8	8½ h	—	—	+	+	+	—	—	—	?	?
11	♂	1,340	5/5	10 h	—	—	+	+	+	—	—	+	+	+
12	♂	1,000	7	21 h 03 min	—	±	+	+	+	—	—	±	+	+
13	♀	2,100	1/1	22 h 13 min	+	+	+	+	—	—	—	+	+	+

IV. Stillborn and Dead Infants

Thirteen cases were included in this group. The birth weights ranged between 1,120 and 3,470 g, six cases weighed less than 2,500 g, and seven cases exceeded this weight (see Table 4). Seven foetuses were macerated in the uterus. Each case was subjected to X-ray examination twice. The

Table 4. *Stillborns. Listed according to weight. The first X-ray photograph was taken before resuscitation given to all cases with a mask. No-one had gas in the lungs, ventricle or gut (the first photograph is not included in the table). A comparison is made of the results of the second X-ray photograph (taken after resuscitation) and those of the autopsy with the floating tests. The main autopsy diagnosis was toxæmia of the mother in cases 2, 6, 8, 10 and 12, strangulation of the umbilical cord in 3 and 13 and obscure in 1, 4, 5, 7, 9 and 11*

No.	Sex	Birth weight (g)	Auto-lysis	II X-ray			Autopsy		
				Lungs	Ven-tricle	Gut	Lungs	Ven-tricle	Gut
1	♂	1,120	—	—	+	+	—	+	+
2	♀	1,750	—	—	—	—	—	—	—
3	♀	1,930	+	—	+	—	—	+	—
4	♂	1,950	—	+	+	—	—	+	—
5	♀	2,490	—	—	+	+	—	+	+
6	♀	2,500	—	—	—	—	—	—	—
7	♂	2,900	—	—	+	—	—	+	+
8		3,050	+	—	—	—	—	—	—
9	♀	3,250	+	±	+	+	—	+	+
10	♀	3,260	+	+	—	—	+	—	—
11	♀	3,280	+	+	+	+	+	+	+
12	♂	3,400	+	+	—	—	±	—	—
13	♂	3,470	+	—	+	—	±	+	—

first picture was taken before resuscitation, or other treatment. After the foetuses had received artificial respiration with a mask, they were X-rayed a second time and then subjected to autopsy. The floating tests and microscopic examination were effected in the same way as for the third group.

The autopsies were made 2—5 days after delivery. In the meantime, the bodies were stored at 4° C to prevent putrefaction and autolysis.

Results

I. Normal Infants

The movement of the gas column in the gastro-intestinal tract of the infants is presented in Table 1. Air was swallowed during the first breaths into the ventricle within 5 min. In most of the cases, gas was

observable in the jejunum within 15—30 minutes, within 1—2 hours in the ileum, within 4—5 hours in the colon, and in the rectum within 12 hours.

II. Prematures

The results obtained with this group are indicated in Table 2. The rapidity of the movement of the gas column is about the same as that in full-terms. In one premature, No. 1, the movement was a little slower, but this is the only exception. Nevertheless, in one case, No. 2, the movement was accelerated; this was ascertained by means of a series of X-ray examinations.

III. Infants Born Alive, but Dying Later

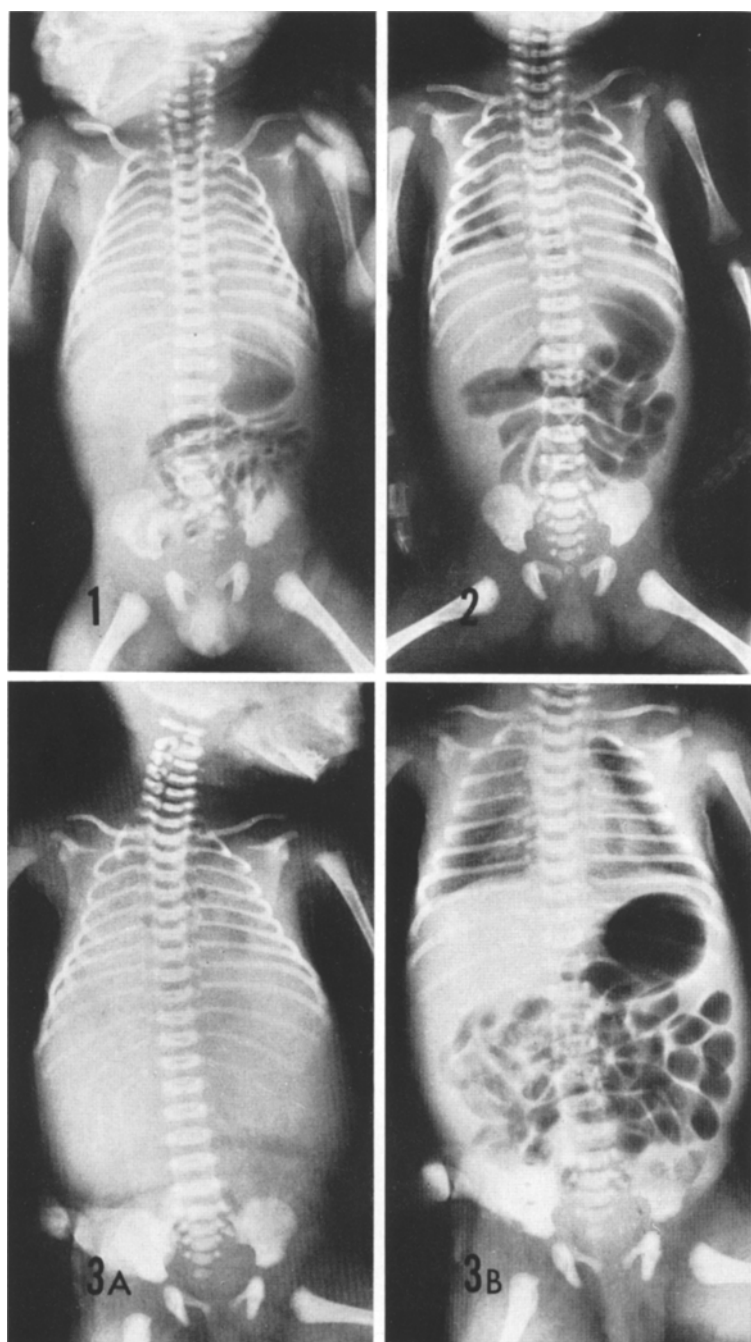
The main autopsy diagnosis, or the cause of death, was in five cases immaturity, in three cases pulmonal atelectasis and pneumonia, in three cases intracerebral haemorrhage, and in one case the syndrome Down (see Table 3). The X-ray photographs showed that all infants had gas in the ventricle, but nobody in the colon, although the longest lifetime was 22 hours 13 min (Fig. 2). Redartation of the gas movement was also demonstrated in cases who lived from 17—41 min without any gas having entered the jejunum (cases 1, 3 and 4). The X-ray examination of the lungs showed that six infants lacked gas (cases 4, 5, 8, 9, 10, 11, Fig. 1).

On autopsy, four lungs were found to be devoid of gas, and did not float (cases 4, 5, 9, 10). The other two of the six cases showed gas on autopsy notwithstanding negative results on X-ray examination. In one case (No. 4) the ventricle was empty of gas on autopsy, although the X-ray was positive. Similar discrepancies were observable between the results of the two methods also in regard to the gas content of the gut in two cases (Nos. 2 and 5). Artificial respiration seemed to increase the gas content of the lungs and gastro-intestinal tract.

Fig. 1. X-ray of case 11 in Table 3 (11/3). The infant lived 10 hours, X-ray taken just after death. The lungs are atelectatic, contain very little air. The stomach and gut are filled, but the amount of air is less than in normal infants 10 hours after birth

Fig. 2. X-ray of case 13 in Table 3 (13/3) just after death. The infant lived 22 hours. The lungs, stomach and gut contain air, but the bowel is still devoid of it due to deceleration of the moving of the gas column

Fig. 3. A, The case 11 in Table 4 just after birth (stillborn). The lungs and gastro-intestinal tract contain no gas. B, The same case after artificial respiration with over-pressure. The lungs, stomach and gut contain now great amount of air, even more than in the infant in Fig. 2. The X-ray shows the apparent source of error produced by artificial respiration



Figs. 1—3

IV. Stillborn Infants

The main findings on autopsy and concluded as the causes of death was toxæmia of the mother in five cases, strangulation of the umbilical cord in two cases, and obscure in six cases (see Table 4). Table 4 contains a summary of the results arrived at on the X-ray examination and autopsy. In no case did the lungs and gastro-intestinal tract indicate the presence of gas in the first X-ray picture taken before artificial respiration. In the second X-ray photograph, it was found that as a consequence of the resuscitation, air had escaped into the lungs of five, into the ventricle of eight, and even into the intestine of three fetuses. (Clearest example of this is in case No. 11, Fig. 3 A and B). The findings in respect of the presence of air in these organs coincided rather well, but not completely within the same case (Table 4). As a rule gas was also demonstrated on autopsy in the same fetuses as in the X-rays. However, some aberration was observable between the results in cases Nos. 4, 9 and 13.

Histological Findings in Lungs (compiled in Table 5)

Group III

Ten cases out of 12 displayed signs of aeration in the lungs. The alveoles had partly opened, but in many instances atelectatic areas were also observable. The bronchi were more open. In two cases (Nos. 4 and 12) the alveoles and bronchi had remained closed. Aspirated amnion fluid and cell debris, and haemorrhages were frequently visible. Hyaline membranes were found in two cases, and inflammation in three. In the specimen of case 6, large roundish bullas were in the lung parenchyma. The bullas were empty (gas) and could be distended terminal bronchioles (Fig. 4).

Group IV

About half of the cases in this group displayed signs of foetal asphyctic lung, such as opened alveoles and bronchi, and haemorrhages. One case had pneumonia. In three cases (Nos. 11, 12 and 13), large bullas, similar to those demonstrated in Group III, were found (Fig. 5). Bullas classified as putrefaction bullas were observed in case No. 10.

Comparison of the Reliability of the Various Methods in the Groups III and IV (from Tables 3, 4 and 5)

Group III, Born Alive, but Dying Later. The fact that the infants had lived after delivery was demonstrable by the methods applied as follows.

1. X-ray examination of the lungs showed gas in 8 cases out of 13, which implies 5 incorrect negative results.

Table 5. *Histological findings in the lungs of Group III (Part I) and Group IV (Part II). In Part II, the opened alveoles mean foetal asphyctic lung. The condition which dominated in each sample is given first if the outlook was not homogeneous. E = emphysema*

No.	Condition of alveoles	Condition of bronchi	Signs of aspiration	Haemorrhages	Hyperaemia	Morbi	Special findings	Storage time, days
Part I								
1	air	air	+	—	+	mild inflamm.	—	4
2	air/atelect.	air	+	+	+	—	—	3
3	air (E)/atelect.	air	+	+	—	inflamm.	—	5
4	atelect.	closed	—	+	—	—	—	4
5	air/atelect.	air	+	+	—	—	—	3
6	atelect/air	air	—	—	+	pneumonia	great bullas	3
7	air/atelect.	air	+	+	+	—	—	3
8	atelect/air	air/closed	+	+	—	—	—	3
9	air/atelect.	air	—	—	—	membranes	—	3
10	not investigated							
11	air (E)	air	+	—	—	—	—	3
12	atelect	closed/air	+	—	+	membranes	—	4
13	air (E)/atelect.	air	+	—	—	—	—	4
Part II								
1	closed	closed	—	—	—	—	—	4
2	open	closed/open	+	—	+	—	—	4
3	closed	closed	—	—	+	—	—	5
4	closed	closed	—	—	—	pneumonia	—	4
5	closed/open	closed	+	+	—	—	—	3
6	open	closed/open	+	+	+	—	—	2
7	open	open	+	+	—	—	—	3
8	open (E)	open	+	—	—	—	—	3
9	closed/open	closed	+	—	—	—	—	3
10	closed/open	open	+	+	—	—	putrefaction bullas	4
11	closed	closed/open	+	+	—	—	great bullas	3
12	open	closed/open	—	—	—	—	great bullas	5
13	closed	closed	—	+	+	—	great bullas	3

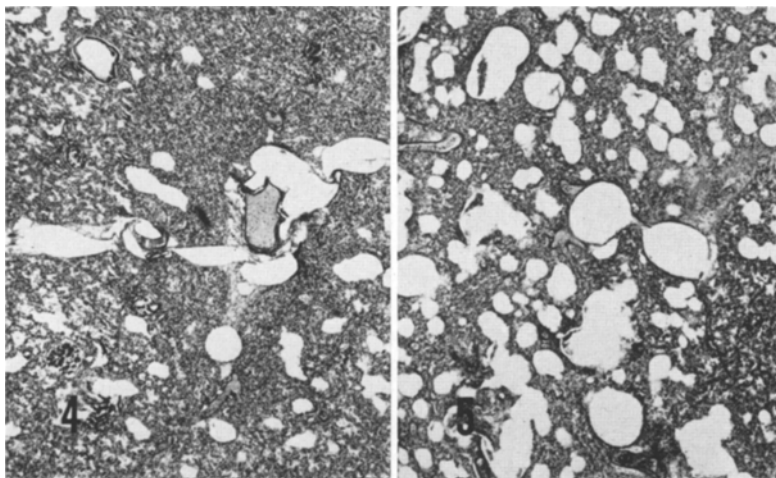


Fig. 4. Histological view of the lungs of case 6 in Table 3 living 2 hours after birth, and given artificial respiration during the life. The lungs are mostly atelectatic. In some areas (left in the microphoto) the alveoles had slightly opened. Great smooth-bordered bullas in the middle. Haematoxylin-van Gieson. $\times 40$

Fig. 5. Microphoto of the lungs of case 11 in Table 4 (the same as in Fig. 3 B). The alveoles are closed but there are great bullas in the parenchyme. These bullas are distended terminal bronchioles and are probably formed by the over-pressure artificial respiration given to the dead foetus. The histological finding is in accordance with the X-ray photo. Haematoxylin-van Gieson. $\times 40$

2. X-ray examination of the digestive tract demonstrated gas in every case (13), which means that no incorrect negative finding was made.

3. The floating test of the lungs gave 9 positive results out of 13, that is 4 negative results.

4. The floating test of the digestive tract gave 11 positive results out of 12, that is only one incorrect negative result.

5. Histological examination gave 10 positive results, and 2 incorrect negative results, which means that in two cases no signs of aeration was observable (Table 5, Nos. 4 and 12).

Group IV, Born Dead

1. X-ray examination of the lungs showed gas in 5 cases out of 13, that is, it gave 5 incorrect positive results.

2. X-ray examination of the digestive tract gave 8 incorrect positive results out of 13, that is, demonstrated gas in the ventricle or gut.

3. The floating test of the lungs demonstrated gas in 4 cases out of 13, gave 4 incorrect positive results.

4. The floating test of the digestive tract demonstrated gas in 8 cases, that is, gave 8 incorrect positive results out of 13.

5. In four cases the histological examination demonstrated large bullas, but in no case were alveoles filled with air. Thus the number of incorrect positive cases was nil.

If the incorrect results obtained by every method concerned in both groups are summed up, the following figures are derived:

1. X-ray of the lungs: 10 out of 25, = 40 per cent.
2. X-ray of the digestive tract: 8 out of 26, = 31 per cent.
3. Floating test of the lungs: 8 out of 25, = 32 per cent.
4. Floating test of the digestive tract: 9 out of 25, = 36 per cent.
5. Histological examination: 2 out of 25, = 8 per cent.

According to this list, the histological method was most reliable in the present series of experiments.

Discussion

The results obtained in the respect of the present series of normal, full-term infants tallies with those reported from previous investigations of the beginning of air swallowing, and its propulsion in the gastro-intestinal tract (BODOLSKY and JESTER, 1954; FRIMANN-DAHL et al., 1954). The filling of the ventricle within 5 min, and of the intestine within 1—2 hours, occurred slightly more rapidly than has been reported in textbooks of forensic medicine (MUELLER, 1953; UOTILA, 1961; PONSOLD, 1967).

The movement of air in the gastro-intestinal tract of prematures generally occurred at the same speed as in the full-terms. Possibly a slight tendency towards acceleration was discernible. The only distinct exception in the present series showed signs of retardation, which is partly explainable by the general weakness of this premature.

A distinct retardation of the gas movement was demonstrable in the group of infants who were born alive but died later. The phenomenon is probably related to the weak general condition of these infants. Subsequently, it was impossible to determine the condition of the child and thus estimation of the lifetime of infants known to be very weak after parturition is to some extent uncertain.

The results obtained in the group of stillborn infants illustrate that the blowing method of respiration currently applied on resuscitation attempts impairs the evidence gained on autopsy by means of the floating tests. In the present series, 11 cases out of 13 had air either in the lungs or in the gastro-intestinal tract after resuscitation with a mask. The possibility of the incorrect positive result after artificial respiration effected with over-pressure has also been emphasised by MUELLER in

his textbook. Histological examination of the lung alveoles is unavoidable in cases given artificial respiration with over-pressure, for instance with the mouth-to-mouth method, or with a mask. Maceration of the foetus did not produce gas in the lungs or in the G-I-tract to such an extent that positive results would have been achieved in the X-ray studies. The present material indicates that no gas in the X-ray of ventricle points to a stillborn infant. In general, the findings in X-ray examinations and in autopsy coincided rather well in both the third and fourth groups. More reliable evidence is obtainable if possibilities exist for X-ray examinations to be made before the autopsy in all forensic cases of infanticide.

In the present series, histological examination of the lungs proved to be the most reliable method. It gave incorrect negative results in two cases, in which the alveoles had not opened despite breathing for more than 40 min or secondary atelectasis had developed to such an extent, that it was impossible to differentiate it from the primary unopened condition of lungs. The value of histological examination became more evident in Group IV, in which the X-ray and floating tests gave incorrect positive results following artificial respiration. Over-pressure respiration was unable to open the alveoles of dead infants, and the histological examination showed foetal and foetal asphyctic lungs. Histological changes possibly induced by resuscitation seemed to be the large roundish bullas, which looked enlarged terminal bronchioles, developed by reason of the pressure. In all cases in which the bullas were found, artificial over-pressure respiration was given, although in most cases no bullas were observable despite resuscitation. The bullas resembled putrefaction bullas, but as the bodies were stored in cool places, putrefaction was minimal, and it was concluded that the bullas were formed by the pressure. The most important point is that the bullas can be differentiated from the aerated alveoles of the breathed lung. Those bullas seemed not to develop by reason of maceration. It follows that histological examination is unavoidable, and its omission can be regarded as a professional mistake.

Summary

The postnatal flow of the air column in the gastro-intestinal tract of full-term infants, prematures, and of infants born alive but dying subsequently, has been studied with special reference to the determination for forensic purposes of the lifetime. The propulsion of gas along the G-I-tract was found to proceed at the same speed in the full-terms and prematures, in the ventricle within 5—15 min, in the intestine within 1—2 hours, in the colon within 5—6 hours and in the rectum within 12 hours. The movement of the gas column was much slower in those infants, who died some hours after birth.

Furthermore, the effect of artificial respiration with a mask on the gas content of the G-I-tract of stillborn infants was investigated both roentgenologically and in autopsies with floating tests and microscopy. It became evident that during the course of resuscitation, appreciable amounts of air can be introduced into the lungs, ventricle, and even into the intestine. The air was detectable in the X-ray photographs and in the autopsies with the floating tests. Consequently the blowing method of artificial respiration introduces an obvious source of error into the interpretation of macroscopic autopsy findings.

The histological examination proved to be most reliable, since artificial respiration did not open the alveoles. It may have induced the development of large bullas, resembling distended putrefaction bullas. The foetal lungs, and foetal asphyctic lungs with bullas, could be differentiated from the aerated lungs of infants who had been alive for at least 17 min.

Zusammenfassung

Bei ausgetragenen Neugeborenen, bei Frühgeburten und bei lebendgeborenen, aber bald darauf gestorbenen Kindern, wurde der postnatale Gang der Luft im Magen-Darm-Trakt untersucht, und zwar besonders im Hinblick auf die Bestimmung der Lebensdauer für gerichtliche Zwecke. Es wurde festgestellt, daß bei den ausgetragenen und bei den prämaturnen Neugeborenen sich das Gas im Magen-Darm-Trakt mit der gleichen Geschwindigkeit vorwärtsbewegt. In den Magen gelangt es innerhalb von 15 min, in den Dünndarm in 1—2 Std, ins Colon in 5—6 Std und ins Rectum in 12 Std. Bei denjenigen Kindern, die einige Stunden nach der Geburt starben, bewegte sich das Gas erheblich langsamer.

Ferner wurde die Wirkung künstlicher Beatmung mit einer Maske auf des Gasgehalt des Magen-Darm-Traktes bei Neugeborenen sowohl röntgenologisch wie auch bei Obduktionen mit Hilfe von Schwimmproben und mikroskopisch untersucht. Es stellte sich heraus, daß im Laufe der Wiederbelebungsversuche erhebliche Mengen Luft in die Lungen, in den Magen und auch in den Darm gelangen können. Die Luft war auf den Röntgenaufnahmen zu sehen und konnte bei der Obduktion mit der Schwimmprobe nachgewiesen werden. Die Beatmungsmethode stellt also ganz offenbar eine Fehlerquelle beim Deuten der makroskopischen Obduktionsbefunde dar.

Am besten bewährte sich die histologische Untersuchung, da die künstliche Atmung die Alveolen nicht zur Entfaltung brachte. Sie kann möglicherweise zur Entstehung großer Blasen geführt haben, die an große Fäulnisblasen erinnern. Die fetalen Lungen und die fetalen, asphyktischen, blasigen Lungen waren von den belüfteten Lungen der

Kinder, die mindestens 17 min lang gelebt hatten, deutlich zu unterscheiden.

Acknowledgement. This work has been supported by an institutional grant from the Sigrid Juselius Foundation, Helsinki, to the Department of Forensic Medicine, University of Helsinki, Finland.

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