THE FACTOR OF THE POSITION OF THE DIAPHRAGM IN ROENTGEN-RAY DIAG- NOSIS OF ENLARGED THYMUS *

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The diagnosis of the presence of an enlarged thymus by percussion, I believe, has been considered by most physicians to be a difficult and uncertain performance. Therefore, the advent of roentgen ray was hailed and is generally still believed to be a safe and dependable diagnostic method as applied to the thymus.

An experience during the past winter has convinced me that the diagnosis of an enlarged thymus with the aid of the roentgen ray is also liable frequently to be very uncertain and to be a source of erroneous interpretations and findings.

A brief recapitulation of this experience will bring out the interesting points.

REPORT OF CASE

In July, 1919, in the absence of the family physician in the army, I was called to attend the child of a colleague, whose skin was scaly and itchy and who was breathing with difficulty. The boy, 12 months old, was quite well developed and nourished, showed a mild rickets, a distinct but slight eczema of the face, chest and arms, causing a great deal of itching, and a decided emphysema, accompanied by wheezing and a somewhat labored expiration. The spleen was not palpable and the posterior cervical lymph nodes were somewhat increased in size and in number, as is usually the case in exudative children.

The child had since his third week received a Walker-Gordon mixture, and recently has been given straight cow's milk and vegetables.

The condition was considered to be due either to a hypersensitiveness to some food constituent or to an exudative diathesis.

A skimmed milk diet, atropin sulphate in increasing drop doses, to physiologic limit, and 10 per cent. tricalcium phosphate in cod liver oil were ordered, and were followed by a decided improvement.

During August, 1919, the family physician returned, found an increased thymic dulness, and requested a roentgenogram, which showed a wide shadow, especially to the right but also to the left of the sternum, and which the roentgenologist stated was caused by an enlarged thymus (Fig. 1). Consequently the family physician stopped the atropin and had the thymus exposed every three to four weeks for a total of five exposures.

The condition of the child, however, grew slightly worse instead of better, and the thymic shadow remained the same, so that the roentgenologist advised against further exposures. The family physician then reordered the atropin in the form of belladonna in small doses. The child improved again and breathed in a nearly normal manner during the latter half of November, 1919.

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During the first days of December he contracted a cold and in the night of December 3 he became severely asthmatic and somewhat cyanotic. I saw him with the family physician December 4 and he was then taken to Lakeside Hospital for diagnosis and treatment.

Nov. 10, 1919, the family physician had his assistant make cutaneous scratch tests with different proteins in simple saline solution, which were all negative. The proteins used were as follows: wheat, cow's milk, rice, potatoes, egg white, beef, oats, tomato, horse hair, pneumococci, staphylococci and ragweed.

December 4 at the hospital the diet and therapy of July, 1919, were reordered and the child improved.

December 5 a roentgenogram was taken, which showed a much smaller shadow than had ever been seen in this case before and really one that was practically normal (Fig. 2). This finding convinced the family physician that after all the improvement noticed in the latter half of November, 1919, was due to a reduction in the size of the thymus, which had occurred since the last picture had been taken in October.

Fig. 1.—Roentgenogram made Aug. 5, 1919, showing decided shadow in thymic region, especially on right side. Note sharp, angular projection at right lower end of shadow.

Intracutaneous sensitization tests were carried out at the hospital from December 8 to 13 and showed the child to be negative to cow's milk casein, cow's milk albumin, strawberry, orange and tomato, questionably positive to cow's milk allergen and enormously sensitive to egg yolk allergen and egg yolk albumin. The latter two tests were accompanied by a severe anaphylactic shock that was relieved by the administration of adrenalin subcutaneously.

December 16 two roentgenograms were taken, both of which showed an abnormally large shadow in the thymic region, in other words, just the opposite from the last findings in the plates of December 5.

The improvement of the child, that was still getting atropin in increasing doses, cod liver oil with tri-calcium phosphate and skimmed milk, continued, and did not correspond with the decided reversal in the shadow in the roentgenogram.

A fluoroscopic examination was immediately made and succeeded in establishing the interesting fact that the two extremes of normal narrow shadow, on the one hand, and a markedly wide and seemingly abnormal thymic shadow on the other, corresponded in the former with the end of a deep inspiration and in the latter with the end of a deep and forceful expiration.

The development of the shadow in its most marked form under the fluoroscope may well be compared with the filling of miniature lungs which paradoxically decrease in size with inspiration and collapse entirely with a deep taking in of air. In order, however, to get this markedly increased shadow which in this patient was always greater on the right than on the left and frequently present only on the right side, especially if the expiration had not been of the extreme type, it was necessary to have the child cry vigorously and establish a prolonged and forceful expiration.

It is especially significant to note that the expiration had to be forceful, for at times I saw a prolonged expiration produce an increase in the shadow of the thymic area without presenting the beautifully clear picture to either side of the vertebral column, simulating as stated above the filling to capacity of a miniature pair of lungs with distinct outlines, definite and sharp borders. Whenever I have seen this picture produced under the fluoroscope it has seemed to me that the diaphragm moved distinctly upward and was directly or indirectly

Fig. 2.—Roentgenogram made Dec. 5, 1919, after repeated exposures (from four to five). Shadow in thymic region decidedly less and practically normal.

responsible for it. Likewise, I have always seen a distinct descent of the diaphragm, accompanied by a very deep and very voluminous taking in of air, precede the rapid and complete disappearance of the abnormal shadow.

Unless this deep inspiration and distinct drop in the position of the diaphragm occurred, the shadow would only get smaller and indistinct as it partially receded toward the middle line.

Whenever a clear and marked shadow was seen under the fluoroscope one could note the outlines of the lobelike shadow on either side, but again always more distinctly on the right than on the left, and a definite and sharp but slightly rounded angle at the extreme outer and lower pole, separated by a clear rather straight space from the heart and distinctly away from it and pointing out into the area of the lungs.

At no time was any pulsation noticed in any of the shadows or in any part of a shadow, when seen under the fluoroscope in this patient.

It is further significant that only when a forceful expiration was established could a lobelike shadow be seen to the left of the middle line and then never as clearly as on the right side. When the shadow on the right side was medium in degree no definitely outlined form could be seen on the left side. All of these pictures were seen much better in the fluoroscope than in the roentgenogram. However, on three of the pictures a less intensive, lobelike somewhat hazy shadow can be seen to the left of the middle line, which together with the shadow on the right side sits over the heart in the form of a blunted cone with a distinct lower border *separated at the side*, especially on the right side of the heart, *by a clear sharp space as described above, and forming a distinct angle, pointing outward and away from the heart.*

The child went home for the Christmas holidays and returned to the hospital January 7, where it remained for ten days. During this time four attempts were made to register on plates in prompt and, if possible, in immediate succession pictures of the two extremes seen with the fluoroscope, so as to be able to present to those interested in the roentgen-ray diagnosis and therapy of the thymic gland, the customary before treatment and after treatment pictures only obtained, however, in this child both on the same day and at the same sitting.

Fig. 3.—Roentgenogram made Jan. 17, 1920, showing return of decided shadow in thymic region, especially on right side, and practically identical with shadow shown in Figure 1. Note again the presence of the same sharp, angular projection at the right lower end of shadow.

January 8 both plates showed wide shadows to the left as well as to the right, but much more distinctly on the latter side.

January 12 it was again impossible to obtain photographs during the height of inspiration and both plates showed in consequence decided shadows to the right.

The pictures taken January 15 were out of focus and could not be utilized.

Finally January 17 we were able to get first a markedly wide shadow involving both sides (Fig. 3) and immediately afterward a narrow shadow that was practically normal (Fig. 4) and just like the two obtained December 5. In other words, we did obtain in the same child at the same sitting both a normal and an abnormal shadow in the thymic region, certainly a difficult finding to interpret.

COMMENT

Numerous questions difficult to answer immediately arise. Is this shadow due to the thymic gland or to something else as the superior vena cava or the right auricle? Is the thymus really abnormally large or is its size actually within the variable normal limits, and is it brought into the plate in the form of an abnormal shadow simply as a result of the operation of some abnormal factor such as an abnormally increased intrathoracic pressure especially in this child, whose lungs, owing to a possibly at times still existing constriction of the bronchioles, might retain more air than those of a normal child at a given stage of respiration and so might enable the production of an intrathoracic pressure in forced expiration that would be greater than that found in a normal child?

Fig. 4.—Roentgenogram made Jan. 17, 1920, five minutes after obtaining Figure 3, and showing just the opposite finding, namely, a practically normal shadow in the thymic region, and corresponding to Figure 2 obtained Dec. 5, 1919.

Or are the intrathoracic factors causing the thymus to stand out in this so-called abnormal manner really normal and simply abnormally utilized in the sense of hypereffectiveness?

For instance, is it possible that one normal child can push his diaphragm up more effectively or increase his intrathoracic pressure more decidedly than another normal child of the same age and weight? Again, if it is the thymus are its lobes mechanically pushed upward and outward by the ascent of the diaphragm or are they enlarged by a sudden filling with blood as a result of the establishment of an abnormal disproportion between the outflow and the inflow of blood into the gland? Or is its coming out into view due only slightly to the possible effect of the vascular supply on the thymus and mainly due to a following of a mechanical path of least resistance, as a result of a markedly increased intrathoracic pressure produced by various factors, but

recorded best by the ascent of the diaphragm? Does the varying topographical relation of the lungs to the thymus play a part?

Why is the shadow more often present on the right side, and when also present on the left, less distinct than on the right? Is this shadow on the right side really due to the thymus or is it produced by the superior vena cava and right auricle? If it is produced by the thymus is it caused by its close proximity to the just mentioned venous structures? Or is it due to possibly more rapid enlargement of the right lobe than of the left lobe of the thymus, or is it mechanically advantageous under an increased intrathoracic pressure for the right lobe to move out before the left?

Is such a freedom of mechanical mobility of the lobes within the sac of the thymus possible, or is it necessary that a force from within such as would be represented by the filling of the thymus with blood be developed to force the lobe outward in the manner observed?

These questions are all of importance, and I do not see how we can answer them with positiveness until further data are at hand. Definite contradictions exist in the literature regarding most of these points. I have been unable to find satisfactory data regarding the blood supply of the thymus, especially regarding the proportion existing between the inflow and outflow.

Rehn,¹ Hotz² and Hart all think that the exit venous channels are Gesellsch. f. Chir., April, 1906, 35th Congress, p. 364. relatively better developed than arterial inflow vessels, and yet Klose,³ notwithstanding the fact that he quotes Hotz and Hart as his authorities, expresses just the opposite view, based mainly on the findings of Siegel,⁴ who reported in one case the presence of a net work of fine veins on the circumference of the gland and the absence of larger venous channels. Siegel, however, does not attach the same generalization and significance to this individual observation.

Rehn, in 1906, observed at operations on the thymus a regular downward movement of the thymus with inspiration and an ascent with expiration. He makes the further comment that the more forceful the inspiration or expiration the greater the descent of the thymus in the one instance and the ascent in the other, and with deep inspiration the thymic gland is aspirated as it were into the thorax, whereas by severe expiration as during crying, coughing, the gland is forced up out of the chest.

Rehn claims that this physiologic up and down movement of the thymus is responsible, when it is enlarged, for the difficulty in breathing

1. Rehn, L.: Die Thymusstenose unter der Thymustod, Verhandl. d. Deutsch. Gesellsch. f. Chir., April, 1906, 35th Congress, p. 364.
2. Hotz, G.: Die Ursachen des Thymustodes, Beitr. z. klin. Chir. **55**:515, 1907.
3. Klose, H.: Beiträge zur Pathologie und Klinik der Thymusdrüse, Jahrb. f. Kinderh. **78**:653, 1913.
4. Siegel: Berl. klin. Wchnschr., No. 40, 1896.

that is noticed in some cases at beginning of inspiration, by fitting better and more snugly in the upper opening of the chest at the end of expiration and so acting as a more tightly fitting valve.

Benjamin and Goett,⁵ in presenting their experiences at Pfaundler's clinic with roentgen-ray studies of the thymic gland in infants, report an exactly similar observation as the one made by me in this patient, with this difference, however, that the shadow, as observed under the fluoroscope, increased with the descent of the diaphragm and decreased with the ascent. They come to the provisional conclusion that the abnormal picture was produced by the distention of the vena cava and not by the thymus. Later on in their article, however, they modify this conclusion by stating that, according to their recollection, the child cried at the time when the picture of the abnormal shadow was obtained, and was quiet when the good shadow was procured.

If their provisional conclusion is the right one, then the interpretation given by them would seem to be correct from a physiologic point of view. But, as they remark, there is no uniformity of opinion in the literature as to whether the heart in adults during inspiration is wider or smaller than it is during expiration, or vice versa.

Grödel⁶ and Dietlen⁷ are of the opinion that the descent of the diaphragm produces an inspiratory narrowing of the cardiac shadow, and that the ascent produces an expiratory widening, while Holzknecht and Hafbauer (quoted by Benjamin and Goett) find a widening of the shadow during the entire inspiration.

Dietlen bridges the two contradictory views by admitting a widening of the cardiac shadow in early inspiration due to the sudden filling of the superior vena cava and right auricle as the result of the suction effect during the early part of inspiration.

Benjamin and Goett also quote d'Oelsnitz and Paschetta⁸ as having called attention to the part played in infants by the large vessels in the widening of the shadow at the base of the heart and to the fact that this widening is influenced by respiration in the sense that the shadow becomes wider in expiration and narrower in inspiration.

In addition these authors further claim that an enlarged thymus appears mainly to the left of the vertebral column. So one can readily agree with Benjamin and Goett that a subject that at first glance seems

5. Benjamin, E., and Goett, T.: *Zur Deutung des Thoraxradiogramms beim Säugling*, Deutsch. Arch. f. klin. Med. **107**:509, 1912.

6. Grödel, F. M.: *Röntgenkinematographische Studien über Herzgrösse und Herzlage*, Ztschr. f. klin. Med. **72**:310, 1911.

7. Dietlen, H.: *Ergebnisse des medizinischen Röntgenverfahrens für die Physiologie*, Ergebn. d. Physiol. **10**: 1910.

8. d'Oelsnitz and Paschetta: *Bull. de la Soc. de Pediat*, Paris, 457, 1911. Quoted by Benjamin and Goett: *Deutsch. Arch. f. klin. Med.* **107**:514, 516, 1912.

simple and clear, when viewed from the standpoint of opinions as written down in the literature, is complicated and difficult.

Benjamin and Goett were checking Hochsinger's⁹ claim that the stridor congenitus was caused by the presence of an enlarged thymus, and that this enlarged thymus could be found in the roentgenogram. They had occasion to perform a necropsy on a 7-month-old infant killed in an accident and who also had a congenital stridor and of whose thymic area a roentgenogram had been made. A 20 gm. thymus was found and neither was it nor any other gland in the place where a shadow had been obtained in the plate. This fact, of course, does not prove that the thymus was not concerned in producing the shadow during life.

Again in another infant, the child of a wet nurse, who had never had a congenital stridor but who had frequently showed in the roentgenogram the presence of Hochsinger's shadow and on whom a necropsy was made after an acute illness of six days' duration they found only a very small thymus weighing hardly 3 gm., and concluded that it could not have been a factor in the production of the shadow in this child.

It is well to remember in this connection that Benjamin and Goett found their shadow, as observed under the fluoroscope, during inspiration and not during expiration, and therefore they could hardly expect the thymus to be a factor unless it be of enormous size.

Benjamin and Lange¹⁰ state "that the breadth of the upper mediastinal shadow varies normally with the age and general condition of the patient," and since it may vary from time to time in the same patient the roentgen-ray diagnosis is not always easy or free from error." They continue further, "in one case not included in this series an apparently normal shadow was obtained when the child was quiet or sleeping, but during a restless crying spell the thymic shadow became greatly enlarged."

"The roentgen-ray shadows of congenital heart enlargements are often confused with thymic enlargements. In all cases in which the roentgen-ray diagnosis seemed doubtful, a roentgen-ray exposure was given as a therapeutic test and this test has proven very reliable."

In other words, Benjamin and Lange have made an observation similar to mine by getting a wide shadow in a crying child—picture in all probability taken in decided expiration—and a normal shadow while the child was quiet and sleeping—picture probably taken in inspiration or in very superficial expiration.

9. Hochsinger: Stridor thymic infant, *Wien. med. Wchnschr.*, No. 45, 1903; No. 33, 1910.

10. Benjamin, J. E., and Lange, S.: Report of Nineteen Cases of Hyperphasia of the Thymus Gland, Treated by the Roentgen Rays, *Arch. Pediat.* **35**:71, 1918.

These authors do not, however, indicate how they decided in this case, by therapeutic tests or otherwise, whether the infant had an abnormal thymus or not as this child was not a part of the series which they were reporting. Nor do they go into the possible rôle that respiration or the diaphragm might play in the production of this shadow picture.

It would seem as if the therapeutic roentgen-ray tests based on finding a normal shadow would be valueless unless checked by observations made at two different respiratory phases and especially with the aid of the fluoroscope.

The patient forming the basis of this contribution is an excellent example of the case in point. Here we have a boy who has a history of difficult breathing, especially during expiration, accompanied by slight cyanosis, symptoms which very well fit into the picture of a case of so-called thymic asthma, just as they also may be just as well a part of the clinical picture of a child sensitive to proteins, or of an exudative child with asthma. Although he has received sufficient exposures to the roentgen ray, this boy can show, just as you wish, either a normal or an abnormal shadow of the thymic region, corresponding with marked inspiration in the former, and with deep and forced expiration in the latter, but not running parallel to his general condition.

This patient has a definitely abnormal shadow that, in all probability, is produced by forcing the thymus upward and outward, and yet it is also most probable that this thymus is not mechanically concerned in giving him his respiratory difficulty. And in the face of a marked protein hypersensitiveness, accompanied by a mild eczema and expiratory asthma, it is impossible to claim that this boy is one of the thymic cases that are refractory to roentgen-ray therapy and that for this reason his thymus gland has not decreased in size. In other words, unless we find in this boy what, at the present time is considered to be a normal shadow, both in expiration as well as in inspiration, under the fluoroscope, as well as in the roentgen-ray plate, we will not be able to give credit for his improvement to the effect of the roentgen ray on the thymus gland.

Of course seemingly definite cases of clinical thymic asthma in the newly-born have been rapidly and definitely relieved of their symptoms by exposure to the roentgen ray. Usually their improvement has been accompanied by decided narrowing of the shadows, so that the conclusion has been drawn that the betterment was due to the reduction in size of the thymic gland. But in the light of the present case under discussion we cannot be sure that the roentgen ray actually reduced the size of the gland and still it really may have accomplished just that. Further observation on the basis of the experience attained with this patient will help to settle that question. It may be that as a result of the exposure to the roentgen ray the child's condition was improved,

and as a result he was more quiet when later pictures were taken, so that normal shadow may have been produced because the child was more comfortable and did not cry and squirm when the pictures were being taken, rather than because the thymic gland had been decreased in size. It is conceivable that the roentgen ray might influence an internal secretion of the thymus and as a result remove the agent that is responsible for the asthma without at the same time causing any change in the actual size of the gland.

It is necessary to call attention to one of the arguments used by Benjamin and Goett in favor of their opinion that the abnormally wide shadow found in normal children varies according to their condition; the well nourished showing a wide shadow, the poorly nourished a normal shadow. They attributed the variations to the difference in blood volume between the two types of children. While this difference does exist, it is equally true that the size of the thymus gland seems to follow the same rule, being small in the skinny child and large in the well nourished, so that this argument can be applied to one theory with no greater justification than it can to the other. However, one can see how in the well nourished child both factors could operate together to the advantage of a wide shadow, whether it be thymic or nonthymic.

SUMMARY

1. The case of a patient, 17 months old, is presented who under the fluoroscope and in the roentgenogram shows a wide shadow in the thymic region which, according to present conception, is considered abnormal.

2. This shadow in its most marked form extends both to the right and to the left of the vertebral column, while in its mediumly severe form it projects out only to the right.

3. This wide shadow is sharp in outline and has a definite shape, similar to that of a miniature lung, *with an angle at the lower, outer, right side which seemingly cannot be produced by the vena cava, nor by the auricle, as it extends clearly separated from the heart out into the lung area*, and not toward the middle line, as would be the case if a distended auricle were responsible for it. No pulsations were ever seen in the shadow or any part of it, and until contradictory evidence is advanced the shadow is accepted as of thymic origin.

4. *The abnormal shadow can be replaced by one of normal size if the patient takes a deep inspiration.*

5. *The abnormal shadow can be brought out in its most marked form by having the patient expire deeply and forcefully. Both observations can clearly be seen with the aid of a fluoroscope.*

6. The diaphragm, as observed under the fluoroscope, rises with the development of the abnormal shadow and descends with the development of the normal.

7. Frequent exposures to the roentgen ray for a period of over five months have not changed the size of the thymus, nor have they influenced in a dependable manner the general condition of the patient. As a matter of fact, the patient has improved, while his thymic shadow has remained the same. The general improvement can well be explained by the dietetic changes instituted and the administration of atropin.

8. In producing the abnormal shadow in expiration the diaphragm seems to be the most important individual factor, either directly and mechanically by pushing the heart upward and so forcing the thymus in the same direction and also outward when ascending markedly, or indirectly by increasing the intrathoracic pressure to a sufficient degree to move the thymus upward in a mechanical manner, or by retarding decidedly and in forced extreme expiration nearly entirely the venous outflow from the thymus, while still permitting its arterial inflow, and by so creating an acute engorgement and enlargement of the gland, which would cause the above factors to operate even more advantageously, and which would explain better than anything else the miniature lung-like development of the shadow under the fluoroscope.

9. In establishing the return to a normal picture the descent of the diaphragm would seem to operate by relieving the causative factors indicated above, and so allowing the thymus to descend down toward and over the middle of the heart and to empty itself rapidly following the suction effect of inspiration, especially when deep.

10. The wide shadows in their most marked form appeared on both sides, especially when viewed under the fluoroscope, but more on the right than on the left. In mediumly wide shadows only the right side was represented. Consequently, it is not justifiable to conclude that a picture showing a shadow limited to the right side comes from a patient who is unable to develop a shadow on the left side as well, if given the proper conditions, nor can we conclude on the same basis that this shadow on the right side has nothing to do with the thymus gland and has been produced by some other factor such as an enlargement of the vena cava or auricle.

CONCLUSIONS

1. In order to have accurate knowledge as to the actual size of the thymus it is necessary to examine the gland under the fluoroscope and watch its position and condition at the various phases of respiration, especially in the development and at the end of a somewhat

prolonged and forceful expiration, and again during a deep inspiration following the type of expiration just described.

2. If roentgenograms are made, an attempt should be made to get pictures both in deep inspiration and deep expiration. It may be well likewise to first attempt to get a picture while the child is breathing quietly and normally. It must, however, be realized that to procure roentgenograms of the thymus in the different respiratory phases is most difficult, uncertain and time consuming, and, therefore, it is suggested that the fluoroscope be always used to check the findings of the roentgenogram.

3. That unless the thymic shadow is observed as suggested above, a normal shadow obtained following a previous abnormal one does not mean an actual reduction in size of the gland.

4. The findings reported might explain the contradiction of reports according to which clinical improvement was obtained by exposure to the roentgen ray in cases where the thymic shadow was normal. It is possible that these cases really had an enlarged thymus, and that the picture just happened to have been taken during deep inspiration or very superficial expiration. It is, of course, also possible that in such cases the enlargement of the thymus is in the anteroposterior direction.

5. In all probability the position of the diaphragm directly and mechanically, or indirectly by influencing the intrathoracic pressure is more responsible than any other one factor for the difference observed in the pictures taken on the one hand in extreme inspiration and on the other at the end of a marked and forceful expiration.¹¹

6. So called improvement in thymic shadow, as presented in Figures 2 and 4, was demonstrated by the fluoroscope to be due not to a reduction in the size of the thymus, but to a change of local conditions in this region, causing, at the end of forced expiration a wide, seemingly abnormal shadow, and at the end of deep inspiration, a narrow, seemingly normal shadow.

11. Von Reuss, A.: *Die Krankheiten des Neugeborenen*, 1914, p. 263; Friedlander, A.: *Enlargement of the Thymus Treated by the Roentgen Ray*, *Tr. Am. Pediat. Soc.* **29**:80, 81, 1917.