Keating (J. M.) & Edwards (W. A.)

CLINICAL STUDIES

ON

THE PULSE IN CHILDHOOD.

Read by title before the College of Physicians of Philadelphia, November 7, 1888.

BY

JOHN M. KEATING, M.D.,

Obstetrician to the Philadelphia Hospital, and Lecturer on Diseases of Women and Children; Surgeon to the Maternity Hospital; Physician to St. Joseph's and St. Agnes's Hospitals; Fellow of the College of Physicians; Councilman American Pediatric Society, etc., etc.

AND

WILLIAM A. EDWARDS, M.D.,

Instructor in Clinical Medicine and Physician to the Medical Dispensary in the University of Pennsylvania; Physician to St. Joseph's Hospital; Fellow of the College of Physicians and of American Pediatric Society; formerly Assistant Pathologist to the Philadelphia Hospital, etc., etc.

[*Reprinted from Archives of Pediatrics for December, 1888.*]

CLINICAL STUDIES

ON

THE PULSE IN CHILDHOOD.

A CAREFUL and systematic study of the conjoint action of the heart and arteries—the pulse—in childhood is as yet an uncultivated field in pediatric literature; that, however, it has not been wholly neglected is evidenced by the fact that as early as 1822, Mayor, of Geneva, endeavored to derive practical benefit from the already ascertained knowledge of the fœtal heart-beats, which he had accidentally discovered in 1818. Frankenhäuser, somewhat later, further tried to utilize this knowledge in diagnosing the sex of the fœtus by the rapidity of the heart-beats, a diagnostic guide which has recently received the sanction of Jacobi, who states that he was seldom mistaken in predicting the sex when based on Frankenhäuser's principle. It is necessary, however, to make the examination when the pulse is not disturbed by causes due to change in either the mother or the fœtus; the field opened by the earlier observers has not received much further attention, and to those engaged in the study of the maladies of infancy it is particularly noteworthy that, notwithstanding the importance which is attached to the pulse in adult life, its characteristics in infancy are almost unrecorded. Trousseau and Valleix have recorded their observations in relation to the pulse of the healthy infant, but, unfortunately, these gentlemen do not agree in their statistics.

The pulse in health.—To collect and collate a series of observations upon the pulse of the healthy infant from the moment of birth to the end of the first year is a task beset with difficulties; it is frequently most difficult to correctly

record the pulse for the first hour after birth; indeed, it is often impossible, for at least the first ten days of the infant's life, to count the pulse at the wrist at all in most cases, or locate the pulsations at the præcordia; indeed, Lederbérder was only able to count the radial pulsations in six infants during the first minute of life.

Immediately after birth the pulse becomes much less frequent than during fœtal life, when it ranges between 124 to 150 or more. Our own observations in the main agree with Smith and Jacobi, that within an hour after birth the heart's action becomes more regular and settles down to about an average beat of 136 per minute. Other observers do not agree with these figures. Valleix estimates the number of pulsations per minute, between ten days and twenty-one days, at 87; Trousseau places the figures for the first week of life as between 78 and 150, Gorham in the main agreeing with him. These figures, to us, seem too low, especially if we consider their disproportion to the fœtal beat, and, furthermore, the fact that the new-born babe's heart must now carry on its independent circulation and, per consequence, must find exacting demands upon its contractile power, so that we can but conclude that the higher figures are more nearly correct. During the first eighth- to quarter-minute after birth the heart pulsations are not discernible, then they commence slowly, so that by the first half-minute they are probably not more than 10 or 12 per minute, in the second half-minute a vigorous child will cry and the pulse will become rapidly accelerated, even as high as 160, to shortly settle down to between 136 and 140. Immediately after birth the pulsations are alone to be ascertained by placing the hand over the præcordia; as the child becomes a little older,—one week,—the femoral or carotid is reliable to estimate the pulse-beats, or we may observe the basilar through the open fontanelle. Jacobi states that the beats of the fontanelle or the carotid can be distinguished and counted easily, up to a frequency of 240 per minute. The following table is prepared in order to present the relative frequency of the pulse at different ages and under different conditions.

It will be noted that sleep has the most remarkable effect in reducing the number of pulse-beats; it will also be noted that

the figures in the main agree with Trousseau and Smith. The former states that the average pulse of the healthy infant between the first and second months is 137 per minute, from the third to the sixth month 128, and from the sixth to the twelfth month 120. (See Table, page 4.)

We also learn from these observations that the pulse is more rapid while awake,* particularly if sitting or standing, and that muscular exertion or mental excitement may cause the pulse to become as rapid as in disease. In feeble children this acceleration is more marked; as the child grows the pulse is much less susceptible to all these influences, and we find the child of six years with an average pulse of 100, which at thirteen has become reduced to 88, closely approximating the adult rate of 72.

The frequency of the child's pulse is, however, not its sole difference from that of the adult, but it has certain other characteristics which are worthy of study.

Irregularity.—The pulse of the young child is very apt to be irregular; this occurs whether the child is at rest, asleep, or undergoing active movements; hence the results furnished by an examination of the pulse do not offer any very definite characteristics and are not as pathognomonic as they are in the adult. With growth, this irregularity becomes less marked; it is, however, noticeable throughout the entire period of childhood. Conditions which will hardly perceptibly affect the pulse of the adult render the infant's pulse very irregular. Particularly will derangements of the digestive system, so common in infancy, show marked effect upon the pulse-rhythm. Constipation, diarrhœa, intestinal worms, dentition, meningitis, and anæmia all produce irregularity in the pulse-wave. Jacobi remarks that this irregularity becomes a puzzling factor in the differential diagnosis of incipient meningitis, with its pneumogastric irritation and anæmia.

Much may be learned by the graphic study of the pulse, notwithstanding the comparatively feeble beat, small volume,

---

* Although Goodhart recently (third edition, London, September, 1888, p. 583) stated that in several cases Newnham noted it to be three or four beats quicker during sleep.

Infantile Pulse in Health—Asleep and Awake.

	AGE.										
	First week.		From close of 1st week to close of 4th week.		From close of 4th week to close of 12th week.		From close of 12th week to close of 6th month.		From close of 6th month to close of 12th month.		Total.
	Awake but quiet.	Asleep.	Awake but quiet.	Asleep.	Awake but quiet.	Asleep.	Awake but quiet.	Asleep.	Awake but quiet.	Asleep.	
Number of observations	20	20	12	12	16	18	20	14	15	10	157
Extremes	100–150	106–138	126–156	108–140	110–150	100–132	110–140	106–118	114–142	108–120	
Mean	125	122	141	124	130	116	125	112	128	114	

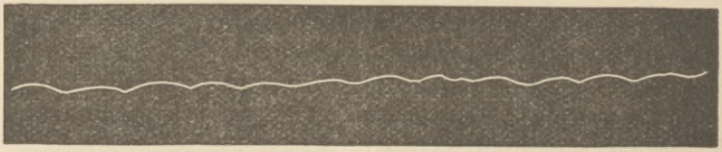
Pulse during Active Muscular Movement or Mental Excitement.

	AGE.					
	During 1st week. No child younger than two days.	From close of 1st week to close of 4th week.	From close of 4th week to close of 3d month.	From close of 3d month to close of 6th month.	From close of 6th month to close of 12th month.	Total.
Number of observations	5	10	6	9	4	34
Extremes	146–162	146–162	142–176	140–160	138–188	
Mean	154	154	159	150	163	

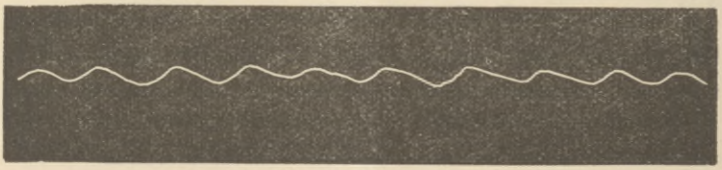
and less amplitude of the child's pulse; the cardiograph and sphygmograph present many interesting points worthy of study, although occasionally the sphygmograph will be very unsatisfactory. Goodhart goes so far as to state that with the sphygmograph he has met with little but disappointment in children. The most important peculiarity of the child's pulse revealed by tracings is that *dicrotism is absent*, and does not appear until the age of ten or fourteen years is reached. This peculiarity is well illustrated in the accompanying sphygmographic tracings taken from the thesis of Blache, which show these transitions in the pulse-wave and the age at which dicrotism commences to appear. In endeavoring to account for this absence of dicrotism we must remember that in a child there is not the same relation existing between blood-tension and arterial resistance; the child's pulse has not the same recoil,—that is, the expansion—the systolic wave—is more marked and perceptible than the contraction.

To Hofmann belongs the credit of establishing the fact that the blood-pressure in the newly-born animal is very small; for example, in the dog at birth it is but ninety millimetres, whereas in the grown dog it has risen to one hundred and sixty or one hundred and eighty millimetres. It has also been stated by way of explanation that the young child presents greater strength of the vessels to a relatively less strong heart, with a much shorter arterial circuit; for example, the common carotid in the newly-born is half the length of the descending aorta, but much less later in life, when the individual has attained its growth. Under these circumstances the blood is unable to distend the arteries sufficiently to allow a good recoil, hence the absence of dicrotism. In confirmation of the fact that the short arterial circuit is an element in reducing the dicrotic wave we have but to remember that Marey has shown that the longer the vessel the greater the dicrotism. We now know that dicrotism of the pulse is produced by the elasticity of the great vessels, especially when combined with low tension of the peripheral circulation and a sharp contraction of the heart, conditions which we also know do not exist in the young child. For example, it has been experimentally demonstrated that the adult kidney is much more permeable than that of the child;

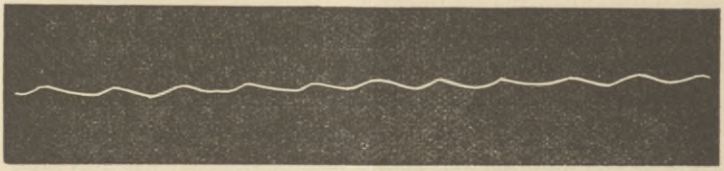
so we at once see that here is a decided interference to low tension of the peripheral circulation, as a marked resistance is offered to the arterial current.



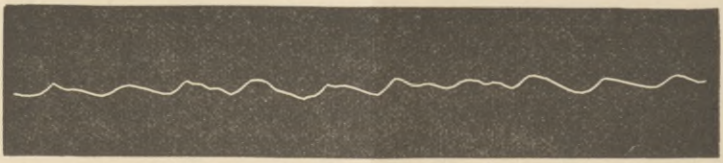
Normal pulse, child æt. three. Pulse 120.



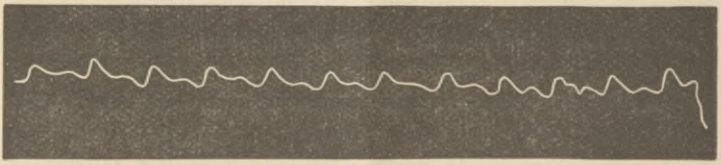
Normal pulse, child æt. four. Pulse 92.



Normal pulse, child æt. seven. Pulse 80.



Normal pulse, child æt. eleven. Pulse 90.



Normal pulse, child æt. fourteen. Pulse 88.

In some of the so-called diatheses the relation of heart to blood-vessels is much altered; in rickets we find large arteries and a normal-sized heart. Under these conditions blood-

pressure will be reduced—large arteries always have this effect—and low tension will be present.

Having now considered the two most marked characteristics of the pulse in early childhood—irregularity and absence of dicrotism—and thus established our text, we will now proceed to study the pulse in *health* and *disease*. In order to do this systematically we may adopt the classification of Broadbent, somewhat modified to suit the character of the cases under consideration.

1. *The number of beats per minute, their regularity and equality.*—This we have already fully considered in the opening pages of our paper.

2. *The size of the artery,*—an important consideration in childhood.—The size of the artery is very variable in different children. All things being equal, a large artery will present a more decided impulse, but at the same time it is more compressible; in a smaller artery compression frequently renders the pulse-wave much stronger. Undue smallness of the arteries is among the recorded abnormalities of the arterial system. Particular attention has been called to this condition by Virchow, to which we have already referred;* Meckel, Morgagni, Rokitansky, Lanceraux, and Bamberger record similar conditions. Cases of congenital smallness of the arteries often reach adult life; Gowers and Jacobi have so recorded them, and very recently Fraentzel† reports several cases of congenital narrowness of the aortic system, in two cases confirmed by autopsy.

The subjective symptoms are those of heart-disease, but the heart-sounds are clear, the second sound often accentuated, and the heart exhibits some dilatation. The symptoms are especially like those of cardiac overstrain, but develop in persons who have undergone no, or but slight, exercise. The hypertrophy of the heart begins in youth, is followed by dilatation, and finally by the signs of insufficient compensation. The arteries of the body are small, their tension high, and the face often strikingly pale.

---

* "Diseases of Heart in Infancy," Keating and Edwards, 1888.

† Deutsche Medicin. Wochenschr., 589, 1888.

3. *Tension.*—A healthy pulse of average tension stands out during the systolic wave and subsides gradually during diastole; should the tension be decreased, it is only at the apex of the systolic wave that we are able to feel the pulse in a young child. On the other hand, should the tension be increased, the pulse-wave is almost as marked as in the adult.

4. *Character of the pulse.*—The character of the pulse cannot be better described than by quoting from two Greek physicians,* Rufus, who considered it small and yielding, no perceptible difference between systole and diastole, and Herophilus, who states that it is deprived of sense or rule or proportion; they also in a very realistic manner illustrated its characteristics by metric measurements. Those who desire to pursue this subject further will find Duremberg's "History of Medicine," Paris, 1879, i. p. 224, worthy of perusal, and will be convinced of the fact that we have made but few advances in the study of the character of the pulse in childhood.

5. *The strength of the pulse* in childhood is never a constant quantity until about the age of fourteen is reached; before that time it has not established its equilibrium and is easily affected by the most trivial departure from health,—even a slight accumulation of flatus, for example, will convert the perfectly normal pulse of the infant into a rapid-running pulse that at an older period of life would be indicative of grave disease.

We may, in an off-hand manner, estimate the strength of the pulse by placing several fingers on the radial artery and one or two nearer the heart, and thus estimate the degree of pressure that will be required to obliterate the radial pulsation.

6. *The state of the arterial walls.*—Insomuch that atheromatous arteries are rare in children, it is hardly necessary to study the pulse as affected by atheromatous changes in the arteries. When atheroma does occur in children it is apt to be localized in the cerebral vessels, and does not extend to the entire arterial system, consequently it cannot have the same effect on the pulse as it does in the adult. The extent to which the child's vessels

* "Heart and Blood-Vessels in the Young," Jacobi; Brooklyn Medical Journal, March, 1888.

are liable to atheroma has been already fully elaborated by us, and space forbids a repetition.

The pulse in disease.—The pulse of the young is affected to a marked degree by the so-called functional disorders, and of these abnormalities in its action alterations in the rhythm are by far the most frequent. As we have before remarked, functional disorders of the heart's action, irrespective of inflammation or structural lesion of any kind whatever, constitute a frequent and an important class of cardiac diseases in the growing child.

Alterations in the rhythm.—A persistent frequency of the pulse is usually due to cardiac overstrain from continuous exertion; it is also a concomitant of neurasthenia and the abuse of certain articles, as tobacco, tea, coffee, or alcohol,—the so-called toxic cases. A fruitful source of palpitation or irritable heart in young boys is masturbation; persistent frequency is seen in anæmic and leukæmic cases, also in malarial poisoning. Alterations in the blood crasis, anæmia, leucocythæmia, melanæmia, and pernicious anæmia have as a constant attendant great irregularity of the heart and pulse; the younger the child the greater the irregularity.

Paroxysmal palpitation may occur and the pulse be very irregular,—from 75 to 200 within a few minutes. During the remissions of a paroxysm the heart may regain its normal rate. Position will exert a most decided influence upon the pulse-rate; while recumbent it will be much slower. Some of these cases present a peculiar flushing of the skin, due to vaso-motor change or innervation. Most typical examples of paroxysmal palpitation occur in Graves's disease and tachycardia: it is not at all unusual to meet a pulse-rate of 180 or 200, although the former condition rarely occurs in the young. We have recorded cases of exophthalmic goitre in young girls at puberty in whom paroxysmal palpitation was a distressing attendant manifestation of the disorder. We must, however, always bear in mind that a child may present extreme rapidity of the pulse and circulation, either constantly or paroxysmally, almost independently of organic disease, and that we must not attach too much importance to acceleration of the pulse-rate unassociated with conditions that in themselves merit careful study.

Neurotic influences often produce extreme palpitation of the heart, with a pulse-rate far above the normal; the pulse under these influences gives one the impression of but little onward movement of the blood; it seems more to vibrate than to pulsate. At a later period of life this condition is alarming, and sometimes is the precursor of death.

We do not find in children the same intense lividity and general capillary congestion of the face and extremities as we do in adults, but, on the contrary, intense pallor of the skin and mucous membrane exists; for a short time preceding death the pallor may become a light violet hue.

Palpitation in childhood sometimes produces angina pectoris, but it is not of the same variety as in the adult. It perhaps should be called pseudo-angina; but as the nervous system of the child is so easily impressed, we sometimes note the association of encephalic troubles and cardiac irregularity. We also note anæmia of the nerve-centres as a result of this irregularity, lowered arterial tension, engorgement of the venous circulation, sleeplessness, somnolence, sometimes torpor or even coma.

Infrequent, intermittent, and irregular pulse, reduplication or doubling of the heart-beats.—The former condition may be congenital. We have now under our care a lad, aged sixteen, whose normal pulse is but 40 to the minute; during an attack of typhoid fever one year ago, the highest pulse-rate recorded in this case was but 60. Individuals with infrequent pulse enjoy robust health; indeed, infrequent pulse is perfectly compatible with the most vigorous health. Jaundice, renal disease, and some nervous disorders occasionally present an infrequent pulse. The literature presents cases of diminished frequency in which the children presented normal pulse-rates of 60, 40, and 32 per minute. Children who are the subjects of infrequent pulse are apt to present some form of cerebral disturbance; these may be of the nature of epileptiform or syncopal seizures or great mental excitability.

As we have before remarked, Flint calls attention to a curious form of functional disorder which would lead to the error of inferring infrequency of the heart's action from the pulse alone. This condition is characterized by the regular alternation of a ventricular systole, giving rise to a radial pulse,

with one too feeble to be appreciated at the wrist. For example, Flint assumes the number of the ventricular systoles to be 70 per minute; in such a case the radial pulse would be 35 per minute. He has met with several cases of this disorder; the carotid pulse, however, accurately represents the heart's systole,—so that with auscultation we would note four sounds to each radial pulse. In this wise we may fall into the mistake of considering the case as one of reduplication of both the first and second sound. We have not as yet met such a case in young children, but have noted them in patients of eighteen years or over.

The *bigeminal pulse*—that is, a pulse in which the heart-beats and pulse-waves are in couples, a strong beat being followed by a weaker one—never, in our experience, occurs in childhood, although we have noted it several times in adults.

Dropped beat is rare except in association with organic valvular disease; its most frequent association is with mitral stenosis. Broadbent agrees with the now generally accepted statement that there is never want of synchronous action of the ventricles, but that in these cases of dropped beat the right heart contracts effectually in both beats, while the left heart succeeds in raising the aortic valves in the first beat only. One can readily appreciate the value of this additional right ventricular action in mitral stenosis.

Intermittent pulse does not occur as frequently in childhood as it does in later years, principally because its main cause—fatty degeneration of the heart-muscle—does not often arise during the early periods of life; however, we will sometimes meet an intermittent pulse in a child of apparently perfect health; it also occurs after exhausting diseases. This very day we have examined a child, aged ten, convalescing from typhoid fever, in whom the pulse is markedly intermittent.

Irregularity may almost be said to be one of the normal characteristics of the infant's pulse, giving place to the regular rhythm as the child grows. Mitral regurgitation, affections of the respiratory apparatus, as bronchitis, pertussis, and emphysema, all produce great irregularity of the pulse. Nervous influences play a marked rôle in its causation, as do also certain toxic agents, as tea, coffee, and tobacco. In conclusion, we

would draw attention to the fact that the irregularity of the pulse that accompanies mitral regurgitation is more marked than at any period of life, probably due to the fact that irregularity is so common at this early period of life.

Reduplication or doubling of the heart-sounds.—Reduplication of the first or ventricular sound may be heard in a perfectly healthy individual; it is, however, under these circumstances not constant, heard to-day and inaudible to-morrow.

It is also noticed in connection with heart-disease, though here, again, it may not be constant. Doubling of the second sound—arterial sound—is met with as the next most frequent abnormality of this kind.

Various explanations have been advanced in explanation of reduplicated sounds; some considering, as Da Costa does, that they are caused by an arrest of synchronous action in the right and left hearts; others that it originates in non-synchronous tension of the individual segments of the auriculo-ventricular valves.

In a few instances in children, with thin thoracic walls, we have been enabled to note a double impulse accompanying each systole. Bamberger, Leyden, and Skoda give similar testimony; also endorsed by Malbrane, Gerhardt, Friedrich, Rosenstein, and Roy. One of our cases was far advanced in the sequential lesions of mitral insufficiency. It is interesting to note the fact that with the abnormal beat there is no pulsation in the arteries. Paul, who believes in the theory of want of synchronous action of the two ventricles, endeavors to explain their non-simultaneous action by stating that when the mitral valve is markedly incompetent, the overfilled right ventricle is unable to empty itself completely during the systole, and the next instant, during the diastole, is again distended with blood, and so excited to renewed contraction; on the other hand, he states that the left ventricle takes no part in this second or abnormal contraction of the right heart,—that is, at least none that is appreciable to our hearing or our sense of touch.

Stearn,* however, takes exception to the statement that both ventricles act simultaneously with the first of the double

* Deutsches Arch. für Klinische Med., October 15, 1884; also Edinburgh Medical Journal, December, 1884.

sounds, while the right acts alone with the second; he states that neither anatomical structure nor nervous supply will allow such a theory to be accepted, citing against it also the fact that there is no hemi-systole in the dying heart.

Further, in one of his cases there was a pulsation with each of the systolic sounds in the carotid artery, although there was none in the radial, and he is therefore obliged to conclude with Bozzolo that there are two complete systoles, one following the other very rapidly, as the cause of the phenomena. He explains the absence of the radial pulsation with the second beat by the fact that systole recurs so rapidly that there is no time for the left ventricle to refill, this being the more difficult as there was in his two cases—which he believes to be always present in such—tricuspid regurgitation; this would still further diminish the quantity of blood going to the left side, while the systemic veins and right auricle would be surcharged and ready to pour their contents into the right ventricle. A further point militating against the statement that reduplication of the first sound is due to a want of simultaneous contraction of the ventricles, is the fact that the second arterial sound is not also doubled, for if the ventricles do not act together, the diastolic closure of the semilunar valves—aortic and pulmonary—should also be non-synchronous.

A rare form of reduplication is that in which the first sound is split into three parts, the *trommelschlag*, or drum-beat, of the Germans.

Potain has reported in cases of cardiac hypertrophy dependent upon "granular atrophy of the kidneys" a variety of reduplication of the first sound which he has designated *bruit de galop*, in which besides the normal sounds an additional sound preceding the first was noted; this was considered to be due to contraction of the hypertrophied auricles.*

As we have already stated, reduplication of the first sound may occur entirely independent of any appreciable disease, so also may we meet *reduplication of the second sound;* most

* Those who desire to pursue this subject further are referred to a recent article by Cuffer and Barbillion, in the Gaz. des Hôp., No. 36, March 24, 1887, p. 284.

usually, however, it is an evidence of some cardiac disorder. Its cause seems to be alone want of synchronous closure of the aortic and pulmonary valves, consequently the two sounds do not correspond with each other. It seems possible to us, however, that the tension of the leaflets might occur in two separate and distinct movements, and thus occasion division of the second sound. We have met cases in which the division occurred over but one of the arterial orifices, most usually the aortic, which we are totally unable to explain except upon this hypothesis. We have the notes of two cases in which reduplication of the second sound was associated with organic mitral disease; we have also been enabled to verify its association with adherent pericardium, a condition that is met with even in the very young, as Behier* noted an infant of eleven months with an adherent pericardium, the result of chronic pericarditis.

THE PULSE IN VALVULAR DISEASE.

Mitral regurgitation.—Great irregularity of pulse is almost diagnostic.

Mitral stenosis.—Until heart-failure arises the pulse is small and regular, but as soon as compensation fails irregularity at the wrist arises. Although for a time the præcordial pulsations may continue to be regular, eventually extreme irregularity both in cardiac and arterial action arises, as Broadbent most aptly remarks; finally, the irregularity of the pulse and its lack of correspondence with the irregular heart defy description.

Aortic stenosis.—Should a child present this pulse in its typical form it is most characteristic, the wave is gradual in onset and long in duration, due to the narrowed condition of the valves; it is also small, and at once gives to the observer the impression of want of impact or strength. But rarely, however, do we meet this pulse in its purity, as aortic stenosis is so apt to be complicated by regurgitation at the same valve. We have elsewhere presented a case of pure aortic stenosis with pulse-tracing in a child, aged six, on whom an autopsy was held.

---

* J. M. Da Costa, "Amer. System Med.," vol. iii. p. 786; from Constantin Paul, "Mal. des Cœur," Paris, 1883.

Aortic insufficiency.—If we exclude cases of congenital origin, primary regurgitation at the aortic valve is rare in childhood. Corrigan has made this pulse almost historic in medicine, and it is not necessary for us to dwell upon its characteristics now, particularly as we have fully elaborated its peculiarities in another publication.