SINO-ATRIAL HEART BLOCK IN A CHILD

WITH OBSERVATIONS ON THE EFFECTS OF ATROPIN AND VAGUS
STIMULATION *

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The cardiac arrhythmias of childhood are largely confined to those alterations in rhythm which are governed by the rate of stimulus production in the sino-atrial node. This function is stimulated or depressed by the influence of extracardiac nerves, the vagus and the sympathetic, which in the young are especially active. Of the arrhythmias arising in the sino-atrial node, the simple respiratory arrhythmia which characterizes Mackenzie's "youthful heart" is the most common. There is another type of sinus arrhythmia which is independent of the respiration, but which still has a peculiar phasic character. The cardiac cycles increase progressively in length until the rate is notably retarded, then become shorter until the more rapid rhythm is again established. The rhythm of the sinus node may be interrupted by excitation waves arising at some lower point in the primitive cardiac tissue and retrograde stimulation disturb the fundamental rhythm, or the focus of stimulus production may be shifted within the node from one group of cells to another possessing a different inherent rate of impulse production. The function of pacemaker may also be temporarily assumed by specialized tissues elsewhere in the heart, often in the atrial wall or in the atrioventricular node, which, if possessed of a rapid rate of impulse production, will result in a paroxysmal tachycardia or an atrial flutter.

It is known from experimental and clinical evidence that many of these variations in rhythm may be produced by direct or indirect stimulation of the vagus or of the vagus center. The cardiac response of hypervagotonic individuals to reflex stimulation is characterized by marked changes in the pulse rate. Fear, anger, hunger, deepened respiration, the act of swallowing or defecation are accompanied by transient arrhythmia. Direct stimulation by pressure on the vagus, especially that of the right side, will retard the production of excitation waves at the sinus node in hearts susceptible to vagus influence. The oculocardiac reflex, elicited by pressure over the eyeballs, will also cause a retardation of the pulse rate and a lengthening of the cardiac cycle. Susceptibility to vagal influence is often marked during convalescence from fevers. At such times the response to vagal

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stimulation by a slowing of the pulse and a slight arrhythmia is considered by Mackenzie to be evidence of improvement in myocardial tone. In all these conditions there is a delicate balance between the influences of the sympathetic and the vagus. When this balance is disturbed the rate of impulse production varies from beat to beat and a true sinus arrhythmia exists.

It is customary to classify interferences with impulse conduction according to the locality of the obstruction as determined by the interpretation of the electrocardiographic or polygraphic record. The most common example, that to which the term "heart block" is generally applied, consists of a defect in the mechanism of impulse conduction between the atrium and the ventricle. The excitation wave may, however, be interrupted at any point in its course. If the impulse is blocked in the sino-atrial node, the atrioventricular node or in the bundle of His, where only one path is available, the result is a "dropped beat." In other areas an excitation wave blocked in its normal path will traverse an unusual route, and the electrocardiographic picture gives evidence of the irregular course of such an impulse. Sino-atrial block is due to a structural or functional defect or to some neurogenic influence that effectively blocks an excitation wave within the sinus node or between the node and the atrial musculature. There is, therefore, no evidence of atrial activity, and the whole heart comes to a standstill for a period of one or more cardiac cycles. Measurement of graphic records show that in sino-atrial block a regular rhythm underlies the apparent arrhythmia. This fundamental rhythm is maintained at some focus within the sino-atrial node and is represented by atrial contractions whenever excitation waves are released. Each interruption is, therefore, approximately equal to two or more cardiac cycles of normal duration. Sinus arrhythmia of a respiratory or phasic type may complicate a sinus block and at times still further modify the rhythm.

Both complete and partial sino-atrial block have been produced experimentally in animals. By gradual isolation of the sinus node in dogs and by clamping lower portions of the node, Eyster and Meek¹ have been able to reproduce and demonstrate, under electrocardiographic control, the rhythm which characterizes sino-atrial block in man. That which they secured as a result of these manipulations was a functional block due to artificial structural defects, a condition comparable to that usually found in atrioventricular block. Sino-atrial block is sometimes associated with the administration of digitalis. Ten out of eighteen cases collected by Levine² were, at the time of

1. Eyster, J. A. E., and Meek, W. J.: *Arch. Int. Med.* **19**:117 (Jan.) 1917.

2. Levine, S. A.: *Arch. Int. Med.* **17**:153 (Feb.) 1916.

observation, under digitalis. White³ and Parkinson⁴ report cases in which this form of block was present only during the periods of digitalis administration. Cushny⁵ has produced a two-to-one sino-atrial block with aconitine. Eyster and Meek⁶ and Cohn⁷ have shown that the condition will follow the administration of morphin in large doses.

Sino-atrial block is not a common clinical finding. Of 2,000 electrocardiographic records taken in the Johns Hopkins Hospital only four show this type of arrhythmia. The condition has been clinically studied by Levine² who collected the fourteen cases reported in the medical literature and added to this series four which have come under his own observation. The youngest patient whose case is reported is one seen by Joachim.⁸ The patient was a boy, aged 15, with a previous history of rheumatism, mitral insufficiency and acute pericarditis. The only graphic records obtained were from the radial artery. Wilson,⁹ in reviewing the circulatory disturbances of childhood, calls attention to the fact that up to that time (1915) no cases of sino-atrial block in childhood had been reported.

The case here presented is one of sino-atrial heart block occurring in a boy, aged 11 years, a patient from the Harriet Lane Hospital in the service of Dr. John Howland, who has kindly furnished the clinical data for this report.

CLINICAL REPORT

H. N., a boy, aged 11, was admitted to the hospital June 26, 1917. He is the younger of two children. The mother is of a nervous temperament. The father had rheumatic fever five years ago.

Past History.—During infancy the patient had frequent digestive disturbances. Breast feeding was supplemented from the age of six months by various milk modifications. Dentition began at six months. He walked when one year of age and began to talk at the age of 15 months. He is now in the fourth grade at school.

In early childhood he had measles and chickenpox; no mumps, scarlet fever or chorea. He caught cold easily, and frequently had sore throat with fever. The mother states that when the boy was 2 years old she was told that he had a weak heart. His playing was often interrupted because of shortness of breath.

One month ago he was sick with sore throat, headache, fever and vomiting. There was no eruption. He returned to school but complained of headache and pains in the arms. June 19 prostration was marked. He was feverish and the headache increased. The following day his right hip and left ankle became painful. Since then both ankles have alternately been painful and swollen.

Present Illness.—On admission his temperature was 101.6 F., pulse 88, respiration 24. His general appearance was that of a rather delicate child, small for his age, resting comfortably in bed and complaining of pain only

3. White, P. D.: Boston M. & S. J. **175**:233 (Aug. 17) 1916.

4. Parkinson, J.: Heart **6**:335, 1917.

5. Cushny, A. R.: Heart **1**:1, 1910.

6. Eyster, J. A. E., and Meek, W. J.: Heart **5**:137, 1914.

7. Cohn, A. E.: J. Exper. Med. **18**:715, 1913.

8. Joachim, G.: Deutsch. Arch. f. klin. med. **85**:373, 1905.

9. Wilson, F. N.: Am. J. Dis. Child. **10**:376 (Oct.) 1915.

Figs. 1, 2 and 3.—Derivations I, II and III. June 30, 1917. Sino-atrial block. Atrial cycles are measured from P to P. One cm. deflection equals 1 millivolt. Time recorded in fifths of a second.

when moved. He answered questions and cooperated intelligently. On examination the cervical glands were found somewhat enlarged, the inguinal lymph nodes small but palpable. The teeth were in poor condition; there was pyorrhea; the gums bled easily. Both tonsils were markedly enlarged, red and ragged, but without follicular exudate. The lungs were negative. Cardiac dullness was increased to the right. The apical impulse was in the fifth interspace, three and three-fourth inches from the midsternal line. On auscultation the first aortic sound was weak; the second aortic sound was clear, the second pul-

Fig 4.—Derivation II. July 3, 1917. Atropin observation. Control. Sino-atrial block. Ventricular rate 64.

Fig. 5.—Ten minutes after hypodermic administration of $\frac{1}{150}$ grain of atropin. No block. Slight sinus arrhythmia. Rate 68.

Fig. 6.—Twenty-three minutes after atropin. No block. Regular rhythm. Rate 58.

monic sound was rough and accentuated. A soft, blowing murmur was heard over the precordium but was only faintly transmitted beyond the apex. Occasional "dropped beats" were noted. The liver was not enlarged; the spleen was not palpable. There was slight tenderness in the region of the left shoulder; the left ankle was swollen, reddened and tender. Other joints were negative. Reflexes normal. The urine showed albumin in small quantities but there were no pus cells, casts or red blood cells, no sugar and no acetone. The von Pirquet reaction was negative. The white blood count was 18,400.

On admission sodium salicylate and sodium bicarbonate were prescribed in suitable doses. No digitalis was administered.

Clinical Course.—June 27, 1917: Pain in ankle subsided. Patient's condition improved; no change in heart findings. Temperature 100 F.

June 30: An electrocardiographic examination was made.

July 2: Cardiac dulness extends only three inches from the midsternal line. The systolic murmur is the same. The second pulmonic sound is sometimes reduplicated. Temperature 99 F.; pulse during sleep is 50 and fairly regular.

Fig. 7.—Thirty minutes after atropin. No block. Regular rhythm. Rate 55.

Fig. 8.—Forty-three minutes after atropin. Sinus arrhythmia. Rate 68.

Fig. 9.—Fifty-five minutes after atropin. Sino-atrial block returns.

July 3: An electrocardiographic examination was made. Atropin, 1/150 grain, was administered.

July 4: The patient had gastrointestinal disturbances, and his pulse was very irregular.

July 5: The pulse was irregular, with pauses of different lengths. The rate was about 48.

July 9: An electrocardiographic examination was made and atropin, 1/100 grain, was administered.

July 11: An electrocardiographic examination was made.

July 13: Final note. The general condition of the patient was good. The apical impulse was two and three-fourths inches from the midsternal line. The pulse was irregular, about 60 per minute. The temperature was normal. The patient was discharged improved.

Feb. 15, 1918: The patient returned for examination. He has been attending school. His general health was good. There was no recurrence of any pains, but there was slight shortness of breath on exertion. The apical impulse was well within the mammary line. The systolic murmur at the apex was not transmitted to the axilla. The pulse showed the same type of arrhythmia as on previous examinations. An electrocardiographic examination was made. Atropin, 1/75 grain, was administered.

Fig. 10.—Derivation II. July 9, 1917. Control with respiratory curve. Sino-atrial block. Slow film.

Fig. 11.—Before atropin. Pressure on right vagus. Applied at (1), released at (2). Block is increased.

ELECTROCARDIOGRAPHIC STUDY

June 30, 1917.—The principal waves of the electrocardiogram (Figs. 1, 2 and 3) are normal for a child of this age. The R waves are low in all three leads; the S deflection is prominent in the first and second leads. P waves are normal. T is upright in all leads. The sequence is normal. Conduction time is slightly prolonged and measures from 0.18 to 0.21 second. Arrhythmia of an unusual type is present in which the normal rhythm is interrupted by frequent pauses approximately equal to two normal cycles. There is no evidence of auricular activity during these intermissions. The P-R interval is slightly longer in the cycles just preceding the pause. Measurement of the individual atrial cycles (P-P) shows that the atrial intervals preceding the intermissions are usually longer than those which immediately follow them. The long cycles are either equal to, or slightly longer than, the period occupied by two short cycles. The short atrial cycles which represent the fundamental sinus rhythm measure

on the average 0.67 second, indicating a production rate of 90 or 92 excitation waves per minute. The long pauses average 1.45 seconds. The diagnosis is sino-atrial block.

July 3, 1917. Controls were taken which showed (Fig. 4) the same arrhythmia as on June 30. There are frequent pauses equal to two or four normal beats. The average length of the normal cycle is 0.65 second; the average length of the pause is 1.4 seconds. The fundamental rate of sinus is 92. The ventricular rate is 64. Atropin, $\frac{1}{150}$ grain, was given hypodermically.

Fig. 12.—Before atropin. Pressure on left vagus. Applied at (1), released at (2). No appreciable effect on rhythm.

Fig. 13.—Before atropin. Oculocardiac reflex. Pressure applied at (1), released at (2). Block is increased.

Fig. 14.—After atropin. Pressure on right vagus. Applied at (1), released at (2). No change in rhythm.

Ten minutes after atropin was given the sinus block disappeared (Fig. 5), but a slight sinus arrhythmia persisted. The cardiac cycles measured from 0.70 to 0.98 second. The rate was 68; the P-R interval was 0.18 second.

Twenty-three minutes after atropin was given the rhythm (Fig. 6) was regular; the rate was 58; the cardiac cycles measured 1.02 to 1.08 seconds; the P-R interval was 0.18 second.

Fig. 15.—Derivation II. July 11, 1917. Sino-atrial block. During the long three-cycle intermissions nodal extra-systoles appear (R'P'T').

Fig. 16.—Derivation II. Feb. 15, 1918. Sinus block disappears while breath is held in full inspiration. Sinus rate is retarded.

Fig 17.—Continuation of record shown in Fig. 16. There is an intermission of twelve seconds between Figs. 16 and 17. On expiration the characteristic sinus block returns.

Thirty minutes after atropin was given the rhythm was regular (Fig. 7); the rate was 55; the cardiac cycles measured 1.08 seconds; the P-R interval was 0.17 second.

Forty-three minutes after atropin was given there was (Fig. 8) slight sinus arrhythmia; the rate was 68; the cardiac cycles measured 0.71 to 1.06 seconds.

Fifty-five minutes after atropin was given the sino-atrial block (Fig. 9) had returned. There were pauses after three to six normal cycles. The short cycles measured 0.56 to 0.60 second; the pauses measured 1.12 to 1.24 seconds.

July 9, 1917. Controls show sinus block as before (Fig. 10). The short cycles measure 0.60 to 0.66 second; the pauses measure 1.32 to 1.40 seconds. The ventricular rate is 60. The P-R interval is from 0.17 to 0.19 second. A respiratory curve taken with the electrocardiogram shows the relation of the respiration to the arrhythmia. The long pauses occur usually, but not always, during the inspiratory phase. On holding the breath the block entirely disappears, the rate is 57 per minute. Pressure on the right vagus increases the block and eliminates the short cycles; four blocks occur in succession. Pressure on the left vagus produces no appreciable change (Fig. 11). Firm ocular pressure definitely increases the number of blocked impulses (Fig. 12). Atropin, $\frac{1}{100}$ grain, was given hypodermically. Ten minutes afterward there was no block. Sinus arrhythmia was present with cycles measuring from 0.63 to 1.15 seconds; the ventricular rate was 66. Sixteen minutes after the injection of the atropin the rhythm was regular. Twenty-two minutes after the injection the rhythm was regular, the rate was 73 and the cardiac cycles measured from 0.72 to 0.88 second.

Twenty-six minutes after atropin injection the rate was 82. Pressure at this time on the right vagus produced no effect (Fig. 13). Deep pressure on the eyeballs produced a brief return of the sinus block showing that the vagus was still partially active. Sixty minutes after atropin was given the sinus block type of arrhythmia returned; the fundamental rhythm became more rapid; the short cycles measured from 0.56 to 0.60 second; the pauses measured from 1.08 to 1.14 seconds; the ventricular rate was 68.

July 11, 1917. A sino-atrial block was present, but electrocardiograms also showed frequent nodal extrasystoles (Fig. 14). The short cycles measure 0.64 to 0.68 second. After one or two normal beats there is an interval of from 2.22 to 2.30 seconds before another normal excitation wave appears. This interval is greater than those previously found and is approximately equal to the period occupied by three normal cycles. In the middle of this interval there appears, each time, a nodal extrasystole. The atrium and ventricle contract simultaneously; a small diphasic P wave appears between the R and the T, following the R wave by 0.08 second. The extrasystole is always the same distance, 1.12 to 1.16 seconds from the preceding R wave. The ventricular rate is 58. Holding the breath in full inspiration eliminates the extrasystoles and the arrhythmia. While the breath is held the cardiac cycles measure from 0.78 to 0.86 second with a ventricular rate of 80.

Feb. 15, 1918. Electrocardiograms show sino-atrial block of the same type as existed in July, 1917. The short cycles are somewhat more numerous. No extrasystoles were found. Right vagus and ocular pressure, as on former occasions, produced an increase in the number of dropper beats. The arrhythmia again disappeared when the breath was held in full inspiration (Figs. 15 and 16). Atropin, $\frac{1}{75}$ grain, was given hypodermically. Five minutes later the arrhythmia was still present. In ten minutes it had disappeared; the rate was 80. Twenty minutes after atropin administration the rate had increased to 115. One hour later it was 120, the rhythm still being regular. Two hours after the atropin injection the heart had resumed its characteristic arrhythmia.

DISCUSSION

The arrhythmia found in this case is that usually referred to as "sino-auricular block." There is a complete standstill of the entire

heart for one or more beats, the intermissions being separated by one to six normal cardiac cycles. The blocks which characterize the records from this patient may hypothetically result from a failure of the sino-atrial node to generate an excitation wave, from a failure of the atrial musculature to respond to the excitation or from interference with the impulse in its passage to the atrium. The persistence of a fundamental rhythm underlying this arrhythmia is evidence of the maintenance of rhythmic impulse production. There is no evidence of diminished atrial excitability and the atrium responds to every excitation wave when the rate is much augmented.

The arrhythmia is best explained by the existence of some factor which interferes with the transmission of correctly timed excitation waves. Such a functional defect may be dependent either on structural changes or the influence of depressor nerves. The sino-atrial block produced experimentally by Eyster and Meek¹ is essentially a functional block due to structural changes. Our records from this case present some of the same characteristics. After several normal contractions an impulse fails to pass. In the series of normal beats the atrial cycles preceding an intermission are slightly longer than those which follow it, suggesting an increasing delay in impulse transmission prior to the appearance of the block. Such an observation was used by Levine² as a basis for the hypothesis that sinus arrhythmias associated with sino-atrial block are due to a progressive delay in impulse transmission. Were this hypothesis applicable in the explanation of this arrhythmia, a retardation in the rate of impulse production would eliminate, and an acceleration would increase, the block. The rate was reduced and the block eliminated in this case by holding the breath after deep inspiration, but when stronger vagus stimulation was employed, directly by pressure on the right vagus, or indirectly by ocular pressure, the intermissions increased in frequency. The administration of $\frac{1}{75}$ grain of atropin increased the rate to 120 per minute, but with the acceleration the blocks disappeared. It is evident that if there be in this case any structural defect, it is a minor factor, and that the abnormal rhythm is due chiefly to vagus influence. The electrocardiograms taken on July 11 (Fig. 14) in which there occur three cycle pauses broken by a nodal extrasystole, bear a striking resemblance to those taken by Cohn⁷ after the administration of morphin to "right vagus dogs," those in which the left vagus had been severed.

It is known that structures in various parts of the heart have the power, under certain conditions, of initiating excitation waves, and that these areas have different rates of impulse production. Meek and Eyster¹⁰ have shown that even within the sino-atrial node the

10. Meek, W. J., and Eyster, J. A. E.: *Am. J. Physiol.* **34**:368, 1914.

location of the pacemaker may be changed by moderate vagus stimulation. It is possible that different portions of the node have different rates of stimulus production, and that by a shifting of the pacemaker within the node the rhythm is changed. Macleod¹¹ suggests that varying degrees of vagus stimulation may have a selective action on the strength, rate, impulse transmission and excitability of the heart muscle. Varying the degree of vagus paralysis in a hypervagotonic individual would inversely modify the strength of vagal stimulation.

The primary action of atropin is to stimulate the vagus center in common with other medullary centers. A preliminary slowing of the pulse is sometimes observed, but this is quickly replaced by the tachycardia which accompanies the atropin action on the vagus endings. To modify the action of the vagus, atropin was given hypodermically. A small dose, $\frac{1}{150}$ grain, produced a slowing of the pulse and an elimination of the arrhythmia. This effect appeared in ten minutes and persisted for almost an hour without the acceleration which usually follows atropin administration. On another occasion the same result followed the injection of $\frac{1}{100}$ grain of atropin. The arrhythmia disappeared and a regular rhythm, slower than the fundamental rhythm, was maintained for an hour. The administration of $\frac{1}{75}$ grain produced a rapid increase in the rate of the heart to thirty beats above the fundamental rhythm. The arrhythmia was eliminated. The larger dose produced a simple tachycardia, the usual result of atropin administration. Wilson¹² concludes, from observations on patients in whom he produces a temporary atrioventricular rhythm, that there is a selective action of atropin by which the vagus terminations in the atrioventricular node are affected before those in the sinus node. In a similar manner it appears that in the instance here recorded atropin acts first on the vagus terminations in and about the sinus node which control conductivity and later on those which control the rate of impulse production.

A prominent feature of these electrocardiograms is the persistence under normal conditions of a fundamental sinus rhythm. The portion of the sinus node which acts as pacemaker has, it is evident, a rate of stimulus production which results in the formation of excitation waves at the rate of 90 per minute. This has been referred to as the fundamental rhythm. The demands of the circulation only call for 58 to 66 ventricular contractions per minute. The adjustment of the sinus rate to the circulatory demand is largely dependent upon the balance established between the opposing influences of the vagus and the sympathetic nerves. While occasionally this heart shows beats of intermediate

11. Macleod, J. J.: *Physiology and Biochemistry in Modern Medicine*, 1918, p. 227.

12. Wilson, F. N.: *Arch. Int. Med.* **16**:989 (Dec.) 1915.

length, nearly all cardiac cycles fall into two groups; those which measure approximately 0.66 seconds, a rate of 90 per minute, and those which occupy 1.20 to 1.40 seconds. The pacemaker is adjusted to the 90 per minute rate, and the vagus, instead of depressing stimulus production and thereby reducing the rate, affects first the conductivity and produces a sufficient number of intermissions to bring the rate to about 60 contractions per minute, the number required to properly maintain the circulation. In Figure 14 is shown a block of three cycles. This delay permits a ventricular release, the excitation wave originating in or near the atrioventricular node and resulting in the simultaneous contraction of auricles and ventricles. By means of this nodal extrasystole introduced in each three cycle intermission, the heart maintains the requisite number of contractions per minute.

The action of small doses of atropin in eliminating the arrhythmia without producing sufficient vagal inhibition to permit the acceleration of impulse production, and the persistence of this slow, regular rhythm are of clinical interest. They indicate a prolonged primary atropin effect which moderately stimulates the vagus center and retards impulse production, while coincident with this is a selective peripheral action of atropin on the vagus endings which control impulse transmission, thus facilitating the passage of excitation waves to the atrium.

SUMMARY

A case is reported of a child, 11 years old, with acute arthritis, who presents a typical sino-atrial block. Changes in heart rate and rhythm by vagus stimulation and by the administration of atropin are demonstrated. It is found that atropin in small doses will eliminate the arrhythmia without producing an acceleration of the heart rate. Electrocardiographic records accompany the report and illustrate the observations.

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