The Carotid Sinus
Clinical Value of Its Stimulation
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STRETCH OR BARORECEPTORS on the arterial and venous side of the circulation play an integral role in regulating certain key cardiovascular functions. The only receptors that can readily be affected from the outside are the carotid sinuses, situated at the bifurcation of the common carotid arteries. Massage or pressure over these areas may change significantly heart rate, heart rhythm, and systemic blood pressure.

Manipulation of the carotid sinus can be accomplished at the bedside. When done properly the maneuver carries little risk. It frequently serves as an important diagnostic aid and may be a definitive therapeutic measure. At times it constitutes the only means of correctly diagnosing the underlying cardiac disturbance. In recent years insufficient attention has been given to the carotid sinus test. The object of the present report is to summarize current physiologic knowledge of the carotid sinus, to indicate the effects of stimulation of this area in normal man, to emphasize its prompt therapeutic value in some cardiovascular conditions, to delineate the valuable clinical information, which such stimulation may provide, and to point out certain hitherto unreported insights that this test affords.

Historical Considerations
The Greeks may have been aware that compression of the carotid artery affected cerebral function, for the term carotid derives from karos, a Greek word meaning heavy sleep. The earliest medical report is that of Parry in 1799, who noted that pressure on the bifurcation of the common carotid artery produced dizziness and slowing of the heart. A similar observation was made by Czermack in 1866. He found that pressure upon the carotid swelling at the level of the upper margin of the sternocleidomastoid muscle induced temporary bradycardia. He ascribed this to mechanical stimulation of the adjoining vagus trunk by the carotid bulb. In 1870 Coneato pointed out that bradycardia occurred only if the bifurcation of the common carotid was compressed while pressure on the cervical vagus alone was without such effect. This finding was ignored, and Czermak’s view prevailed for many years and was known as the “vagus pressure test” (Vagusdruckversuch) of Czermak.

Animal experiments in the nineteenth century demonstrated that lowering arterial pressure in the head and neck produced tachycardia, whereas elevation of pressure in these vessels was followed by bradycardia and a fall in systemic pressure. This led to the conclusion that cardiac and vasomotor centers in the medulla were directly sensitive to pressure changes in the nutrient arteries. Siciliano and Pagano however demonstrated that ligation of all branches of the internal and external carotid arteries supplying the medullary centers did not change heart rate or vasomotor tone. Sollman and Brown further demonstrated that traction of the carotid arteries in the absence of stimulation of the vagus nerve reduced arterial pressure and
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slowed the heart rate. Notwithstanding the definite nature of these findings, the hypothesis that a cardioregulatory and vasomotor center in the medulla was directly sensitive to pressure was entertained until recently.8

The painstaking work of Hering16 in the early 1920's brought general recognition of the reflex nature of carotid sinus stimulation. When the vagus nerve was separated from the adjoining vessels, mechanical pressure upon the bifurcation of the common carotid artery continued to produce the same degree of bradycardia. He and his co-workers11,12 further demonstrated that the bifurcation of the common carotid is richly supplied with sensory nerves. These nerves emerge from the adventitia as spiral fibers to form the sinus nerve of Hering, which joins the glossopharyngeal nerve. Thus, a direct afferent nerve connection was shown to exist between the carotid sinus and the medullary centers. When the sinus nerve was divided or cocainized, raising or lowering pressure in the common carotids resulted in no reflex changes in the heart. The conclusions of Hering were confirmed by the detailed anatomic studies of De Castro,13 who showed profuse arborization of sensory receptors lying among the collagen fibers of the adventitia of the carotid sinus. The physiologic significance of the carotid sinus as a part of the baroreceptor system of the body was documented by the meticulous experimentations of Heymans and Neil.14 Wassermann was the first to observe that stimulation of the carotid sinus was effective in terminating some episodes of acute pulmonary edema15 and relieving angina pectoris.16 Clinical attention to the carotid sinus as an area responsible for syncopal attacks was high-lighted by the work of Weiss and Baker.17

Physiology of the Carotid Sinus Pressoreceptors

The most extensively studied and best known set of pressor reflexes in the circulation are those originating from the carotid sinuses. These pressoreceptors are anatomically and functionally distinct from the chemoreceptors situated in the adjoining carotid bodies.18 While the carotid artery possesses other baroreceptors, those in the carotid sinus play a key role. The afferent impulses generated in the sinus reach the glossopharyngeal nerve by the nerve of Hering. This nerve carries impulses not only from pressoreceptors located in the carotid sinus and in the region of the carotid bifurcation, but also from the chemoreceptors of the carotid body. Cutting the nerve of Hering thus inactivates both the carotid sinus and the carotid body.

Bradycardia, hypotension, and apnea result when electrical stimulation is limited to the pressoreceptor fibers of the nerve of Hering. These baroreceptors are activated by stretching or deformation of the wall of the carotid sinus in which the nerve endings are embedded. Hauss and co-workers19 showed convincingly that when deformation of the sinus wall was prevented, a rise in endosinus pressure was without effect.

Under physiologic conditions, stretching of the sinus is initiated by a rise in carotid artery blood pressure, whether the rise in pressure is static12 or is generated by pulsatile flow.20 Pulsatile stimuli are far more effective than sustained pressure in arousing baroreceptor activity.21,22 The carotid sinus reflex is initiated at a pressure of 60 mm. Hg. With each systole there is a burst of activity in the sinus nerve. As carotid pressure rises, the frequency and duration of firing are increased with progressive recruitment of discharging units.23,24

Changes in the carotid sinus wall itself may affect the sensitivity of the baroreceptor. Application of epinephrine to the wall of the carotid sinus caused reflex hypotension.25 A large variety of drugs that induce smooth muscle contraction have a similar effect.14 When all arterial branches to the carotid sinus were ligated and the common carotid arteries were opened just proximal to the bifurcation, topical application of norepinephrine induced reflex hypotension, which was abolished by section of the sinus nerve.26 These effects can be blocked by adrenolytic agents.14 Actual contraction of the sinus wall has been observed upon addition of epineph-
rine to Tyrode's solution bathing the excised suspended structure. When, however, the carotid sinus is perfused with blood containing increased concentration of epinephrine, baroreceptor sensitivity is not enhanced. These observations suggest that responsiveness of the baroreceptor mechanism depends upon the state of tension in the wall itself.

Stimulation of the carotid sinus also induces changes in the sympathetic nervous system. When endovascular pressure in the sinus is increased, the persistent tonic discharge traversing sympathetic nerves from the stellate ganglion to the heart is diminished. If the increased pressure within the sinus is maintained, complete inhibition continues for some seconds, after which there is escape and return of sympathetic discharge. The duration of inhibition and the speed of escape are a function of the pressure level. Reflex inhibition is bilateral. When one side is stimulated, discharge decreases from both stellate ganglia. When the carotid sinus is suddenly distended, vagal activity accounts for the initial slowing; however, decreased sympathetic activity, which emerges more gradually, becomes the major restraining influence with continued stimulation.

The effector reflex pathway resulting from an increase in endosinus pressure has been extensively studied. The bradycardia is due to activation of cardio-inhibitory innervation and inactivation of the cardio-accelerators. The hypotension results from decreased activity of the vasococontractor sympathetic center. There are also respiratory inhibition, bronchoconstriction, and pulmonary hypotension. The picture, therefore, is that of massive inhibition of medullary centers. An exception is the increased performance of cardio-inhibitory nerves. This may be due to release of their inhibition by the depression of the cardio-accelerators. In addition to hypotension, the circulatory consequences consist of pooling of blood in the periphery due to venous dilatation and reduction in the cardiac output.

When the carotid sinus is inactivated by sectioning the nerve of Hering, changes opposite to those described above follow. Tachycardia, hypertension, and some hyperpnea develop. The hypertension is due both to increased vascular resistance brought about by augmented activity of the vasomotor center and to an increase in the cardiac output. An increased discharge in all sympathetic nerves to the heart and an enhanced liberation of catecholamines by the adrenal glands also occur.

Current concepts of the physiologic significance of the carotid sinus pressoreceptors remain essentially those outlined by Hering, the discoverer of the reflex. The two carotid sinuses, together with the receptors in the aortic arch, form a unified depressor system. These baroreceptors are stimulated by the systolic surges of intravascular pressure to emit inhibitory impulses that continuously restrain the cardio-accelerator and vasocostrictor centers within the medulla. When intravascular pressure rises, these receptors become more active. Conversely, with reduction of systemic blood pressure, the centers become inactive. The reflex originating from these pressoreceptors is depressed or paralyzed by hypopaleaemia, anoxemia, high spinal anesthesia, narcotics, and pulmonary hyperventilation.

Reduced activity of the carotid and aortic baroreceptors that occurs with a fall in systemic pressure also plays a vital role in homeostasis. Venocostriction is probably the most important consequence of such inactivity. Since the veins contain about 60 per cent of the blood volume, a reduction of the venous capacity by only 1 or 2 per cent will increase diastolic inflow to the heart. The decrease in venous capacity is associated with reflex tachycardia. This combination of adjustments is effective in sustaining the cardiac output. The simultaneous increase in peripheral arteriolar resistance in the skin and splanchnic areas that accompanies diminished baroreceptor activity aids in distributing blood to cerebral and coronary circulations, which are themselves independent of the reflex vasoconstriction.
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Carotid Sinus Stimulation in Normal Man

In the normal person, carotid sinus stimulation results in respiratory and cardiovascular changes. Hyperpnea usually follows digital pressure to the carotid sinus area with an increase in depth but not in rate of respiration. This response is independent of the subject's age or sex and appears unrelated to simultaneously induced cardiovascular changes. Once pressure is applied, the depth of the respiratory excursion begins to increase within 5 to 20 seconds and continues until a peak is reached within 45 to 90 seconds. Prolonged stimulation may result in a phasic type of breathing simulating Cheyne-Stokes respiration. Painful stimuli in the neck region or compression of the carotid artery below or above the carotid sinus area do not evoke this change in ventilation. The respiratory reflex persists during barbiturate anesthesia.

Galdston and co-workers have shown that proacinations of the carotid sinus area that prevents the respiratory reflex also abolishes hyperventilation from injection of sodium cyanide. The cyanide ion in low concentration stimulates respiration through action on chemoreceptors of the carotid and aortic bodies. These workers have suggested that the respiratory reflex is due to interference with blood supply to the carotid body which lies adjacent to the carotid sinus. In support of a different mechanism for the respiratory and cardiovascular reflexes is the observation that when the carotid sinus is stimulated, as a local anesthetic effect wears off, the respiratory response returns before the cardiac response. Furthermore, in animal experiments apnea rather than hyperpnea occurs when stimulation is limited to the baroreceptor fibers of the carotid sinus.

The cardiovascular effects are upon the sinoatrial pacemaker, the atiroventricular (A-V) conduction system, and the blood pressure. Cohn and Lewis first reported upon the electrocardiographic effects of vagal stimulation. The changes, in order of their frequency, are the following: sinoatrial slowing, atrial conduction defects with changes in amplitude, duration and morphology of the P wave, sinoatrial bradycardia with rates ranging from 30 to 50 per minute, prolongation of P-R interval, A-V block, sinoatrial arrest, nodal escape, complete asystole, and ventricular ectopic beats. No changes have been observed in the QRS complex. The effects upon the sinoatrial pacemaker and the conduction system are mutually independent.

In a study of the effect of carotid sinus stimulation in 67 subjects without heart disease, Purns noted slowing of the sinus rate in 75 per cent, A-V conduction defects in 10 per cent, ventricular standstill in 4 per cent, and atrial standstill in 3 per cent. A response was elicited in 82 per cent of those over 40 years of age, but in only 18 per cent under 40. In a recent study of 40 normal men, the carotid sinus was compressed for 30 seconds. The age range of this group was 25 to 58, with a mean age of 38. Interatrial block occurred in 30 instances, sinoatrial bradycardia in 14, and P-R prolongation in 12. Ventricular asystole, varying from 2.0 to 5.7 seconds in duration, was produced in nine subjects. Pressure on either side was equally productive of electrocardiographic alterations. Subjective manifestations including syncope, nausea, and light headedness were found in 25 per cent.

When constant pressure is exerted on the carotid sinuses, maximum prolongation of the P-P interval is often observed promptly with the first cardiac cycle after the onset of stimulation. When such pressure is applied for 30 seconds or more, the sinoatrial rate often returns to its control level within 10 to 15 seconds. With release of pressure the heart rate may accelerate slightly. This is probably due to sympathetic rebound, since there is a reduction in impulse conduction in the sympathetic chain during carotid sinus stimulation.

A depressor vasomotor reflex occurs in man upon stimulation of carotid sinus. Mandelstamm and Lifschitz induced a fall in systolic pressure of at least 10 mm. Hg in 60 per cent of 335 subjects. This was particularly marked in patients having either arteriosclerosis or hypertension. In 103 aged and
retired workers the average fall in systolic pressure was 37 mm. Hg, whereas in 106 healthy soldiers it was only only 5 mm. Hg. The fall in blood pressure generally lasted several minutes and usually persisted longer than the bradycardia. There appeared to be no correlation between the degree of cardiac slowing and the extent of hypotension.

The basis for the fall in systemic pressure in man is probably vasodilatation in the splanchnic, renal, muscular, and cutaneous arterial circulations. Barcroft and Edholm found considerable vasodilatation in the muscles of the forearm in a patient with vasodepressor syncope. The vasodilatation was annulled by sympathectomy of the limb, but not by a dose of atropine that prevented bradycardia.

The reflex effects upon the heart and peripheral vessels are independent of each other although they generally occur together. Atropinization abolishes rate changes but does not prevent reduction in blood pressure.

The Technic and Hazards of Carotid Sinus Stimulation

There are certain points of importance in the technic of stimulating the carotid sinus. With the exception of patients who are being tested for relief of anginal pain it seems best to have the patient recumbent in order to reduce the likelihood of syncope. The head is tilted either forward or backward, to one side or the other, until the expansile body is readily palpated. If the neck muscles are too taut or too slack, it is difficult to feel the appropriate part of the vessel. The sinus is usually situated just below the angle of the jaw at the upper level of the thyroid cartilage. The carotid bulb is massaged with pressure directed posteriorly and medially, the artery and sinus being compressed against the vertebral spine. Massage is applied for not more than 5 seconds at a time. Carotid blood flow is interrupted only transiently. The procedure may be repeated after several seconds.

The dangers of carotid sinus stimulation are believed to be due either to production of prolonged cardiac asystole or interference with cerebral circulation. Transient ventricular fibrillation has also been reported during carotid sinus pressure. Review of the electrocardiograms in the one published case shows the ventricular fibrillation to have been a misinterpretation. The presumed arrhythm-
Paroxysmal atrial tachycardia with block (PAT with block) reverted to normal sinus rhythm by CSS (note signal). Stimulation probably started before signal and continued longer than generally advisable. Upper strip shows PAT with 1:1 and later with 2:1 response. Lower two strips show sinus rhythm.

A number of reports document the potentially harmful cerebral consequences of carotid sinus pressure. Askey described seven patients who developed hemiplegia with the cerebral lesion homolateral to the side of stimulation. In two patients no cardiac slowing developed. Two other instances of paresis or death are recorded. One is led to the conclusion that arrest of the carotid circulation resulting from prolonged compression of this vessel probably injured a portion of the brain already vulnerable. This view is supported by the fact that several of the patients had carotid artery insufficiency. On careful consideration it is evident that these complications were not an inherent part of the carotid sinus reflex. They were in fact the consequence of prolonged compression of the carotid artery and mechanical interference with cerebral blood flow.

In the light of the frequency of this maneuver and the few untoward reactions reported, risk of carotid sinus manipulation must be regarded as extremely small. A number of observers who have employed this test...
extensively over many years have encountered no serious complications.17, 49, 50 The present authors in an experience of several thousand such tests have noted but one brief episode of facial weakness which cleared in several minutes.

It has been our practice to limit the duration of each gentle massage to a time not exceeding 5 seconds. Bilateral occlusion is never carried out. Prior to the maneuver the carotid arteries should be auscultated for murmurs. Elderly patients, over 75 years of age, are generally not tested. Similarly in the presence of cerebral vascular disease, unless there are very pertinent indications, this maneuver is avoided. In such individuals there is not only the hazard of sclerosed and narrowed cerebral vessels but the reflex may be unduly sensitive with resultant prolonged asystole. This is especially prone to occur when carotid sinus stimulation abolishes a paroxysm of rapid heart action. In such an instance the tachycardia has depressed the sinus as well as subsidiary cardiac pacemakers. In the elderly individual, as was true in the experience cited above, it may lead to fatality. Ideally an electric cardiac pacemaker should be at hand, especially when the carotid sinus is stimulated in older patients.

During the carotid test the heart is listened to or the electrocardiogram is continuously observed. In patients with coronary artery disease or angina pectoris initial pressure is especially brief and gentle. As soon as the desired effect is obtained, the manipulation is stopped. Patients are generally in a sitting or recumbent position. If the above enumerated safeguards are followed the procedure is reasonably safe.

Clinical Applications

Arrhythmias and Carotid Sinus Pressure

Probably the greatest clinical value of carotid sinus stimulation is in the deciphering of cardiac arrhythmias. This procedure frequently enables the physician to make a definitive bedside diagnosis of the underlying mechanism. At times even after recording the electrocardiogram the nature of the disordered rhythm remains unclear until the heart rate or rhythm has been upset by this vagal maneuver. Carotid sinus stimulation is also an effective therapeutic tool in reverting both atrial and nodal tachycardia to a normal mechanism.

The carotid sinus test may be helpful at the bedside at all heart rates. When the rate is slow (between 30 and 50) and regular, one of three rhythms may be present: sinus bradycardia, 2:1 A-V heart block, and complete heart block. Carotid sinus massage permits differentiation among them. If the slow rate is unaffected by the carotid sinus test, the mechanism is likely to be complete heart block. If a smooth slowing results followed by a gradual resumption of the original rate, the rhythm is sinus bradycardia. When the slowing or reacceleration is irregular or jerky, the mechanism is partial heart block. Bedside confirmation of the presence of block, partial or complete, is provided by the detection of atrial sounds and the presence of a jugular "a" wave during diastole. An additional clue to 2:1 block is paradoxic acceleration of the ventricular rate during carotid sinus stimulation (fig. 1). With the vagal-induced slowing in atrial rate, the previously blocked impulse reaches the A-V node when it is no longer refractory to conduction, so that 1:1 atrioventricular response is established at a faster ventricular rate.

Ordinarily when the heart rate is found to be about 70 and regular, it is naturally assumed that a normal sinus mechanism is present. If for any reason one suspects an abnormality, however, carotid sinus stimulation may uncover the arrhythmia. If this test results in an abrupt slowing or halving of the rate with a jerky return to 70, the mechanism is not sinus rhythm but rather atrial flutter or paroxysmal atrial tachycardia with block. This suspicion may then be quickly confirmed if a brief effort exactly doubles the heart rate. Differentiation between the two can then be made by additional clinical study.

When the heart rate is rapid, between 120 and 300, and regular, the possible mechanisms
are sinus tachycardia, paroxysmal atrial or nodal tachycardia, paroxysmal atrial tachycardia with block, atrial flutter, and ventricular tachycardia. Carotid sinus stimulation is often decisive in establishing a diagnosis. If this maneuver abruptly stops the tachycardia and the rhythm remains slow and regular, one is dealing in the great majority of instances with paroxysmal atrial or nodal tachycardia. If carotid stimulation temporarily slows the ventricular rate, one can be quite certain that the arrhythmia is not classical atrial tachycardia or ventricular tachycardia. If the slowing is smooth and gradual with a similar return to the original rate, the mechanism is sinus tachycardia. If recovery from the temporary slowing is jerky with variation in duration of consecutive cycles, the mechanism is either atrial flutter or paroxysmal atrial tachycardia (PAT) with block. If the rate is unaltered, no decision can be reached concerning the rhythm. As a most unusual occurrence, carotid sinus stimulation may actually arrest such arrhythmias as PAT with block, atrial flutter or fibrillation and restore a sinus mechanism either temporarily or permanently (figs. 2 to 4).

When the rate is rapid and irregular, the common mechanisms one has to consider are multiple premature beats (especially atrial) with varying coupling, atrial fibrillation, atrial flutter, paroxysmal atrial tachycardia with block, and ventricular tachycardia. Slowing of the heart rate by the carotid sinus excludes ventricular tachycardia. If the slowed heart rate is regular, atrial fibrillation is excluded. If the heart slows, but the rhythm is irregular and exercise accelerates and regularizes it, one is dealing with atrial flutter, frequent premature beats or PAT with block.

Apart from these simple auscultatory observations at the bedside, electrocardiographic data can be obtained during carotid sinus manipulation, which establishes the presence or the nature of an arrhythmia that cannot be otherwise diagnosed.

Occasionally, with a slow ventricular rate and apparent 2:1 heart block, carotid sinus massage may slow the atrial rate without affecting the ventricular response. This would establish the presence of complete heart block and synchronization of atrial and ventricular pacemakers. The presence of an arrhythmia may be overlooked when the electrocardiogram reveals only one P wave before each QRS complex with a heart rate of 70 to 80. Suspicion of the presence of an arrhythmia is aroused under certain circumstances. One may detect a difference in the appearance of the P wave compared with its form in previous tracings, or the T wave may exhibit a small deformity not previously present, raising the possibility of a nonconducted P wave. Carotid sinus stimulation, by slowing the ventricular rate may dislodge a nonconducted P wave from its concealed location within the ventricular complex (fig. 5). This may provide the first and only proof of the
existence of PAT with block, a commonly overlooked arrhythmia, generally resulting from serious digitalis intoxication.

It is quite common to see tracings in which the ventricular rate is rapid, from 120 to 180, regular and with only one P wave evident. These electrocardiograms are often interpreted as instances of either normal sinus tachycardia or paroxysmal atrial tachycardia. The sharp and triangular P wave in lead II should, however, suggest atrial flutter. This is confirmed when carotid sinus massage increases the A-V block and reveals the typical saw-toothed undulation of atrial flutter. If, however, this procedure reveals an isoelectric baseline between P waves discharging at a rate of 120 to 220 while the ventricular rate is slowed, one is dealing with PAT with block (figs. 6 and 7).

At times, one encounters an arrhythmia with an atrial rate in the vicinity of 240 with atrioventricular block. The question then arises whether this is due to atrial flutter or PAT with block. If carotid sinus stimulation results in acceleration of atrial rate, the underlying mechanism is atrial flutter; such a response is, however, not the rule in flutter.

If one observes a regular or irregular rapid ventricular rate with a prolonged and deformed QRS complex, identification of the arrhythmia is difficult. The relation between atrial and ventricular activity must be established. Such a mechanism may be the result of a ventricular or supraventricular pacemaker, the latter complicated either by bundle-branch or intraventricular block. Carotid sinus stimulation is helpful, if atrial activity can be detected. If the atrial rate is slowed, but the ventricular rate is unaffected, A-V dissociation is present (fig. 8). One is then dealing with ventricular tachycardia, though rarely the mechanism may be nodal tachycardia complicated by retrograde block and impaired ventricular conduction.

Carotid sinus stimulation is also useful in the analysis of various symptoms. For example, if a patient complains of fluttering in the neck or chest and the electrocardiogram is normal, the physician can only guess the basis for these complaints. However, if carotid sinus pressure brings out anomalous A-V conduction, the symptoms probably are due to paroxysmal rapid heart action. In the patient with Wolff-Parkinson-White syndrome, reflex vagus stimulation impairs conduction in the normal A-V pathways, thus favoring impulse propagation through the accessory bundle. Still another problem is posed by the patient who complains of palpitation when the electrocardiogram shows no arrhythmia. It is then uncertain whether the difficulty is psychologic or due to an arrhythmia. If there

Figure 4
Temporary reversion from coarse fibrillation or impure flutter to normal sinus rhythm by CSS. This phenomenon could be reproduced repeatedly.
is an arrhythmia, is it due to A-V block or ectopic beats; if ectopic beats are present, do they originate in the atrium, node, or ventricles? Carotid sinus stimulation frequently provides otherwise unobtainable information. In the patient with sporadic partial heart block, this vagal maneuver may reproduce the conduction defect. In the patient with recurring extrasystoles carotid sinus stimulation may bring the ectopic pacemaker to the fore (fig. 9).

It is clear from this discussion that an electrocardiogram obtained during carotid sinus stimulation is often the only means for identifying the mechanism of a cardiac arrhythmia. When a patient shows a rhythm disorder that is not readily deciphered, complete investigation requires determination of the response of the heart to vagal stimulation. Carotid sinus massage is usually the simplest and safest way of achieving this.

Angina Pectoris and Carotid Sinus Pressure

Angina pectoris is a distinct clinical entity. It is a painful subjective manifestation of a diseased coronary arterial system. The recognition of angina pectoris depends entirely upon the proper interpretation of symptoms. Frequently anginal pain is the only indication of ischemic heart disease. While the story is distinctive in the majority of patients, there are many with atypical aspects to this subjective experience. Furthermore, chest pain that simulates the anginal episode in one or more respects may not be due to coronary artery insufficiency, or for that matter, to any sort of heart disease. Any simple procedure that helps in distinguishing anginal pain from other chest discomforts is obviously of great value. Carotid sinus massage frequently provides critical information about the nature of the chest pain. At times this procedure affords relief that cannot readily be obtained by other means.

Wassermann, in 1928, was the first to point out that carotid sinus pressure may relieve anginal pain. This observation has been amply confirmed. The diagnostic and therapeutic implications of Wassermann's observation have been ignored by clinicians. Three of the leading current textbooks in cardiology do not even mention this subject. Over the past 15 years, we have employed this technic in many hundreds of patients. Our continuing experience confirms the value of carotid sinus stimulation in the diagnosis of angina pectoris.

When a patient has chest pain, the physician should promptly listen to the heart. The stethoscope is best held in place by an attendant or by the patient when no one else is
available. Both hands are then free to perform the test. This maneuver is more effective if carried out with the patient in the sitting position. Coronary artery pain is usually less pronounced in the sitting than recumbent position. Just before the test, it is important to establish that the pain is still present. The right carotid sinus is first massaged; if this does not produce appreciable cardiac slowing, the left side is tried. The patient is then asked whether the pain has become worse. If the heart has been slowed, the patient with angina pectoris behaves frequently in a characteristic fashion: there is a pause before the answer is given, frequently with a look of uncertainty and puzzlement, “No, doctor, the pain is all gone”; or “it is letting up.” Disappearance or lessening of the pain occurs almost instantly, within several seconds after the onset of slowing of the heart. Though the heart may promptly reaccelerate, generally the pain does not recur.

Of importance in the proper performance of the test is the exact wording of the question. The objective is to mislead the patient by suggesting that this maneuver has aggravated the chest discomfort. If, despite this deliberate misdirection, the patient says the pain is lessened or has disappeared, one can be certain that the subjective change is real and has not been suggested by the examiner. Pressure on the common carotid artery, below
the carotid bulb, at the angle of the mandible, or upon the sternomcleidomastoid muscle, is without effect on the duration or character of the anginal attack. The lessening or control of angina pectoris is therefore not due to distraction by the introduction of another painful stimulus.

Our experience indicates that abolition of angina pectoris is almost invariably associated with slowing of the heart rate. In only one patient out of many hundreds was there relief of pain without slowing. This patient was experiencing a prolonged episode of substernal pain during an episode of supraventricular tachycardia. Carotid sinus pressure consistently relieved the pain though the rate was unaltered. When the pressure was stopped the pain returned. Freedberg and Riseman have reported relief from pain in three of 13 patients without apparent change in heart rate. They found no relationship between the degree of cardiac slowing and the relief of cardiac pain. In one patient the heart rate was reduced from 115 to 56, yet there was no effect upon the anginal discomfort. These observers studied patients whose anginal pain was brought on by exercise in a cold room. Our observations have been made exclusively in patients with spontaneously occurring attacks.

We interpret this test in the following way: if an attack of chest pain is relieved by carotid sinus stimulation, we conclude that angina pectoris is present. If there is no relief or the pain is made worse, though the heart rate is slowed, the discomfort is not anginal in nature. The pain may still be due to coronary artery disease; however, in such an instance coronary insufficiency or thrombosis is the likely pathogenic factor. If heart rate does not slow, the test is regarded as inconclusive. In patients with functional chest discomforts, carotid sinus stimulation will frequently make the pain worse because of the suggestion by the physician. Occasionally the pain lessens transiently when good slowing is obtained during an actual acute myocardial infarction. Pain derived from gallbladder disease, hiatus hernia, cervical arthritis, or various other chest conditions generally is not relieved by this maneuver. Carotid sinus pressure is therefore a helpful diagnostic procedure in the analysis of chest pain.

Carotid sinus stimulation carried out during an episode of angina pectoris does not alter the ischemic electrocardiographic pattern nor does it abbreviate the duration of such S-T and T-wave changes even though the pain is relieved (fig. 10). During an exercise test the anginal pain may be totally prevented by massage of the carotid sinus, though S-T depression nonetheless occurs.

At present the mechanism of the relief of angina by carotid sinus massage is not clear. Acetylcholine in all concentrations dilates...
the coronary arteries. However, in the presence of coronary atherosclerosis it has been suggested that coronary artery blood flow is fixed. The facts that the electrocardiogram is not improved, that there may not be any slowing, and that the report of the relief of pain is only on the stimulated side have led some to the view that the effect is due to an interruption of a homolateral sympathetic reflex arc or sensory pathway from the heart. Bronk and co-workers have found that increase in carotid endosinus pressure diminishes tonic sympathetic discharge from the stellate ganglion. In extensive experience we have observed that pressure on the carotid sinus on one side is effective in relieving pain on both sides of the body. Left-sided arm pain is readily ameliorated by right-sided carotid sinus stimulation as well as the converse. Indeed, Bronk noted that distention of either carotid sinus produced inhibition of cardiac sympathetic impulses from both stellate ganglia. If the mechanism were indeed transient sympathetic block in the sensory sympathetic pathways, i.e., in the perception of pain, it would be hard to account for the increased exercise capacity following such stimulation. Since slowing of the heart is so constantly associated with relief, one is tempted to ascribe the relief to the bradycardia. Is it not possible that with slowing in rate, there is less production and increased "washing out" of an irritating catabolite responsible for the pain? An alternate explanation is that this reflex by its enhanced vagal and diminished sympathetic nerve action alters myocardial or vascular metabolism, diminishing the discrepancy between blood flow and requirement.

**Coronary Artery Disease**

A majority of patients with coronary artery disease exhibit increased carotid sinus sensitivity. Such enhanced responsiveness is more likely to be present during an acute myocardial infarction. About half the patients who experience angina pectoris have increased responsiveness, which is more marked during an episode of pain. Braun and Samet have shown experimentally in cats that the effect of carotid sinus pressure was greatly increased when branches of the left coronary arterial system were tied.

In our experience the patient with coronary artery disease is especially prone to develop asystole after brief carotid sinus massage. This results from several factors: depression of the sinoatrial node, atrioventricular block, and delayed nodal or ventricular escape. Advanced degrees of heart block are prominent manifestations. Generally carotid sinus sensitivity varies directly with the degree of coronary artery disease and with the individual's age. We have diagnosed coronary artery disease in patients in their late thirties and early forties who complained of atypical chest pain, exhibited nonspecific alterations in S-T and T-wave complex but responded to mild and brief carotid sinus stimulation with partial or complete heart block.
The carotid sinus test may be helpful in yet another way in establishing the diagnosis of coronary artery disease. When an electrocardiogram is recorded during this maneuver and slowing occurs, it is important to examine the T waves for a change in contour. If in the complex immediately following the longest pause, the T wave has become inverted but the QRS complex remains unaltered, myocardial disease is present. It has the same clinical significance as the postextrasystolic T-wave change, which has been ascribed to myocardial ischemia, generally the result of underlying coronary artery disease. The similarity in T-wave alteration following an ectopic beat and brief carotid sinus massage in a patient with coronary artery disease is illustrated in figure 11.

Carotid Sinus Stimulation in Acute Pulmonary Edema

Massage of the carotid sinus may relieve acute pulmonary edema in patients with hypertensive and coronary artery disease. This phenomenon was first noted by Wassermann, Alzamora-Castro and co-workers found the maneuver to be effective in 80 per cent of patients with pulmonary edema. Relief is immediate and coincides with the onset of bradycardia. In the majority it is associated with a drop in blood pressure. The patient is promptly able to lie flat. Fear, dyspnea, and chest oppression disappear, perspiration lessens, and pallor vanishes. Pulmonary rales decrease or clear entirely, respirations become less labored, heart sounds diminish in intensity, and the apex impulse becomes less forceful. The episode frequently is completely reversed. If it recurs, it may be controlled for as long as carotid sinus stimulation is continued. When the reflex becomes exhausted on one side, a good response may be achieved by stimulating the opposite side. Such massage has been carried out for as long as 30 minutes. A great advantage of the procedure is that the physician can control the changes in heart rate and blood pressure by varying the duration and intensity of stimulation. In the presence of atrial fibrillation or aortic valvular disease this maneuver has been unsuccessful in controlling acute pulmonary edema.

Carotid sinus stimulation will reduce the period of fatigue and the objective manifestations of cardiac overload in patients with heart disease undergoing exercise tests. Slowing of the heart rate with improved left ventricular efficiency as well as lowered peripheral resistance with reduced myocardial pressure work has been offered as the explanation for the salutary effects of carotid sinus massage in the presence of acute left ventricular failure. Wassermann, however, believed that acute pulmonary edema is not due to backward failure of the left ventricle, but represents a reflex syndrome involving the cardiopulmonary segments of the autonomic nervous system. The prompt relief provided a morphine, a powerful depressant of the central nervous system with affinities for the respiratory and vasomotor centers, supports
this view. Acute pulmonary edema begins with tachycardia, elevation of blood pressure, cutaneous vasoconstriction, and other sympathetic manifestations. These may be due to decreased baroreceptor activity that would be reversed by carotid sinus stimulation. Wassermann has suggested that angina pectoris and paroxysmal pulmonary edema are initiated by a common afferent reflex pathway residing in the coronary artery nervi vasorum. A number of clinical observations may be pertinent in this context. Both angina pectoris and acute pulmonary edema are helped by carotid sinus massage and nitroglycerin. Angina pectoris and chronic atrial fibrillation infrequently coexist. Similarly, acute paroxysmal pulmonary edema is rare in the presence of established atrial fibrillation; when it does occur, carotid sinus stimulation is without effect.

These observations are of considerable theoretical and practical importance. The effectiveness of carotid sinus stimulation in the treatment of pulmonary edema needs further clinical elaboration.

**Carotid Sinus Pressure and Bundle-Branch Block**

Left bundle-branch block makes the electrocardiographic recognition of fresh or even old myocardial infarction difficult or impossible. Slowing of the ventricular rate with carotid sinus massage may temporarily abolish the block and permit analysis of the basic ventricular complex. The presence or absence of an infarction pattern can then be readily observed. It is reasonable to assume that in the evolution of bundle-branch block, there exists a phase of conduction impairment that will be affected by a change in heart rate. Rate-conditioned variability in conduction is especially likely to be present at the onset of bundle-branch block. At such times carotid sinus induced slowing of the heart proves helpful in determining whether or not bundle-branch block is associated with other electrocardiographic abnormalities. Reflex vagal stimulation may temporarily restore normal intraventricular conduction even without a change in heart rate.

The following brief case report—one of a number of similar experiences—illustrates this problem.

The patient, a 53-year-old woman with rheumatic aortic valvar disease and heart failure, was found to have left bundle-branch block. The possibility of an acute myocardial infarction could not be ruled out. It was noted, however, that normal conduction for one or more beats occurred when the heart rate was slowed by means of carotid sinus stimulation. Brief massage was therefore carried out as each lead was recorded. The normally conducted complexes were found to be essentially unaltered when compared with earlier tracings taken prior to this episode (fig. 12).

Carotid sinus stimulation during auscultation of the heart occasionally helps in the recognition of unsuspected left bundle-branch block. When this vagal maneuver results in an abrupt increase in the intensity of a muffled and reduplicated first heart sound with but slight reduction in heart rate, bundle-branch block may be considered. The explanation for this auscultatory phenomenon is...
that with development of left bundle-branch block, the interval between atrial and left ventricular systole is lengthened, resulting in a decreased first sound at the apex. With the temporary establishment of normal conduction, the interval between atrial and left ventricular systole becomes shorter, with a resultant louder first heart sound. This is comparable to the well-known alteration of the first sound that follows changes in the P-R interval.

**Digitalis and the Carotid Sinus Reflex**

It is well established that digitalization may sensitize the heart to carotid sinus stimulation. The enhanced vagal response to carotid sinus massage results in greater slowing, cardiac standstill, or complex arrhythmias (fig. 13). As little as 0.2 Gm. of digitalis leaf has been reported to produce increased carotid sinus sensitivity in man. At times such sensitivity occasions bizarre problems. For example, one patient complained of being periodically "abstracted." He found it difficult to elaborate upon this symptom, and despite much questioning no further light could be shed on the meaning of this term. This very sensation of "abstractness" as well as prolonged cardiac standstill was reproduced by brief massage of the carotid sinus. After digitalis therapy was stopped, carotid sinus stimulation no longer induced symptoms or cardiac standstill.

The increased cardiac response to carotid sinus massage that follows digitalization can be utilized in the treatment of supraventricular tachycardia. When this vagal maneuver fails to arrest classical atrial tachycardia, it may still be effective if performed after digitalis administration. Our practice has been to massage the carotid sinus before each additional increment of digitalis is administered. A smaller dose of drug is then required for restoration of normal rhythm. The likelihood of digitalis intoxication is thereby diminished.

Carotid sinus stimulation occasionally provides the earliest evidence of digitalis intoxication and clarifies unusual and hitherto unexplained symptoms. The following experience is illustrative. A patient was bedridden with intractable vertigo. He had no other complaints. Neurologic examination was essentially negative. He denied taking digitalis. When carotid sinus stimulation was carried out, he exhibited Wenckebach type of A-V conduction disturbance. He was therefore advised to bring in all of his medications. It was found that he was taking 0.2 mg. of digitoxin daily, though he was unaware of the name or the nature of this medicine. Symptoms promptly disappeared on stopping the digitoxin.

The possibility of digitalis intoxication needs to be considered in any digitalized patient who develops advanced degrees of heart block during carotid sinus stimulation, especially when this response was absent previously. The emergence of rapid and regular ventricular response in the patient with atrial fibrillation after carotid sinus stimulation has similar implications. Likewise the development of ectopic beats or fixed coupling during this test provides the earliest evidence of digitalis overdose (fig. 14). In fact, carotid sinus massage will permit the recognition of disorders of rhythm due to overdigitalization before they occur spontaneously. In these patients without objective stigmata of digitalis overdose, straining, excitement, or sudden cardiac overloads by either pressure, volume, or rate work may precipitate serious digitalis arrhythmias or even death. The lengthening of the cardiac cycle by carotid sinus stimulation favors discharge of a ventricular ectopic focus. The compensatory pause after a premature systole predisposes to fixed coupling. Langendorf and co-workers have termed this phenomenon the "rule of bigeminny." Once bigeminny is initiated, it may persist for many minutes. The longer pause after each premature beat tends to sustain the mechanism. Furthermore, Scherf has demonstrated that stimulating the vagus caused many ventricular extrasystoles and other ventricular arrhythmias in dogs who had received a cardiac irritant such as aconitine.

These experiences lead to the conclusion that carotid sinus stimulation should be em-
ployed more frequently in the process of digitalization. It is indicated in the patient who experiences symptoms suggestive of digitalis overdosage in the absence of any objective evidence of such a disorder. It is also of value during digitalization of patients suspected of having a low threshold to the toxic action of the cardiac glycosides. The maneuver may prove helpful in digitalized patients with heart failure presenting unexplained symptoms or signs.

**Carotid Sinus Syndrome**

Since Weiss and co-workers\(^ {17, 75, 76} \) first emphasized that a hypersensitive carotid sinus may be responsible for syncopal episodes, an extensive literature has accumulated on the so-called carotid sinus syndrome.\(^ {77-87} \)

The syndrome may be defined as the spontaneous occurrence of faintness or loss of consciousness that is reproducible by stimulation of the carotid sinus on either right or left side, but not by pressure upon the carotid vessels below the sinus. To make certain that the cerebral manifestations are not the result of obstruction of the carotid circulation, it is worthwhile to palpate the ipsilateral superficial temporal artery just in front of the ear during manipulation of the carotid sinus.\(^ {88, 89} \) Continued pulsation of this vessel would indicate that cerebral blood flow has not been critically obstructed. The syndrome is more readily produced with the patient either sitting or standing. The episode, whether occurring spontaneously or indeed deliberately, depends upon marked slowing of the heart rate, reduction in blood pressure, or both. Loss of consciousness usually lasts no more than several seconds and is usually preceded by such auras as blurred vision, vertigo, tinnitus, faintness, visual hallucinations, and at times weakness, paresthesias, and even epigastric distress. Objectively the patient exhibits facial pallor, hyperpnea, and increased perspiration. The unconsciousness may be accompanied by convulsive phenomena, either focal motor or psychomotor. Abdominal cramps, diarrhea, and even angina pectoris have been ascribed to hyperactivity of the carotid sinus.\(^ {78, 90} \) Syncopal attacks due to carotid sinus sensitivity may be distinguished from seizures of other etiology by their predominant occurrence when the patient is standing, by their rapid onset and short duration, by the usually clear postictal sensorium, and by their reproduction on brief carotid sinus massage.\(^ {89, 91} \)

Attacks may be precipitated by any factor that exerts direct pressure or tension on the carotid sinus. The following have been implicated: tight collar, cervical gland, pressure over the area while shaving, sudden turning

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**Figure 12**

CSS (at arrow) by slowing the heart transiently permits normal conduction in each lead. This thereby reveals no evidence of myocardial infarction.
Figure 13

CSS produces prolonged asystole (5 seconds) and syncope in over-digitalized patient; this was followed by nodal and reciprocal rhythm. The entire arrhythmia lasted 58 seconds (continuous tracing). After discontinuation of digitalis, repetition of CSS was entirely negative.

of the head, coughing, straining at stool, or abrupt change from the supine to the erect position. A positive history of such associated factors is reported in only a quarter of the patients with this syndrome. When carotid sinus sensitivity exists, it can usually be elicited on both sides, albeit to an unequal degree. It must be borne in mind that there are individuals in whom the carotid sinus is quite sensitive, even to the degree that massage will precipitate actual unconsciousness and yet no spontaneous symptoms may be present.

Syncopal attacks occur predominantly in men, and older age groups are favored. In 150 patients with carotid sinus-induced fainting spells, all were over 30 years of age and 70 per cent were between the ages of 50 and 70 years. The majority of patients are afflicted with cardiovascular disease. This syndrome, however, is not due to sensitization of the efferent outflow of the vagus as it enters the heart muscle. Stimulation of the distal end of the vagus does not reproduce the observed changes. Procainization of the vagus does not block this reflex. Furthermore, in careful studies by Weiss and Baker of 15 patients with the cardio-inhibitory syndrome, nine had local pathology in the region of the sinus. In six it was due to aneurysmal dilatation of the carotid sinus, and in three to an adjoining tumor impinging upon the wall of the sinus. No gross pathologic findings were detected in the remaining six patients. In a later study, of 52 patients, 31 had abnormalities in the region of the sinus wall. Thus sensitization of the afferent nerve endings within the carotid sinus accounts for the increased sensitivity to external pressure or internal tension.

Weiss and co-workers distinguished three types of mechanism underlying this syndrome:

1. A cardio-inhibitory reflex consisting of prolonged ventricular asystole due either to complete A-V block or sinoatrial standstill without prompt ventricular escape. The mechanisms are prevented by atropine or epinephrine. This was observed in 34 per cent of 56 patients.

2. A vasodepressor reflex occurring independent of changes in heart rate and resulting from generalized vasodilatation with a
fall in blood pressure. It can be prevented by epinephrine or other sympathomimetic agents. Five per cent of patients with carotid sinus sensitivity exhibit this mechanism.

3. A "cerebral" reflex presumed to be due to vasoconstriction of cerebral blood vessels without changes in heart rate or blood pressure and not prevented by atropine or epinephrine. Loss of consciousness was ascribed to this mechanism in 60 per cent of the patients.93

We have never observed the cerebral type of this syndrome; our technic consists of transient massage of the carotid bulb. Ask-Upmark94 first suggested that mechanical interference with blood flow in the carotid artery during sinus stimulation was responsible for the so-called cerebral type. In a study of 100 patients with hemiplegia or hemiparesis who reacted with syncope upon carotid compression, it was found that all those who did not develop bradycardia or a fall in blood pressure had occlusive vascular disease either in the opposite carotid, the anterior cerebral, or the basilar arteries demonstrable by angiography.92

A recent study by Toole88 is instructive. In 17 patients who developed cerebral manifest-
tations upon compression of the carotid sinus, this syndrome could not be reproduced when the pressure was insufficient to obliterate pulsation in the ipsilateral distal temporal artery. In all but four of these reactors, a response identical with that obtained over the carotid sinus was elicited by similar compression of the common carotid artery, i.e., the effect was not specific for the sinus. Furthermore, when procaine was infiltrated into the sinus adventitia and the cervical sympathetics on the same side were blocked, carotid sinus compression was still effective in provoking cerebral manifestation. Arteriography or carotid surgery in 12 of the 17 demonstrated a markedly stenosed or occluded carotid on the side opposite to the sensitive vessel. It has been shown\textsuperscript{65} that if one carotid is diseased, digital compression of the opposite vessel can produce a cerebral response simulating that occurring with the carotid sinus reflex. The evidence therefore suggests that a cerebral reflex is not elicited by carotid sinus stimulation. Syncope attacks may be considered to be due to the depressor reflex when they are produced by massage requiring no more than 5 seconds of stimulation; however, when mechanical compression lasting 10 to 40 seconds produces these attacks the mechanism is due to occlusion of the underlying carotid artery.

Miscellaneous Considerations

The carotid sinus test may prove helpful during auscultation of the heart. There are times when it is difficult to distinguish the first from the second sound and to decide which is systole and which is diastole. This is most likely to occur when the rate is 120 or over and the two sounds are of equal intensity. Carotid sinus stimulation by slowing the heart rate, lengthens the diastolic interval. The sound following the longer diastolic pause is then easily identified as the first sound. A diastolic rumble of mitral stenosis may be heard only after slowing of the heart rate induced by carotid sinus effect.

A number of disease states are associated with altered sensitivity to carotid sinus stimulation. Conditions predisposing to sinus tachycardia are generally associated with diminished sensitivity or complete unresponsiveness. Most noteworthy are febrile states, anemia, thyrotoxicosis, acute cor pulmonale, and pneumonia. Increased sensitivity occurs in the elderly, in the presence of coronary artery disease, and in angina pectoris. Syncope attacks and even convulsive episodes have been long known to occur with biliary colic. These may be due to the increase in carotid sinus sensitivity associated with gallbladder disease. In 23 patients with symptoms of acute biliary obstruction, 18, or 78 per cent, showed cardiac standstill lasting 3 or more seconds during massage of the carotid sinus.\textsuperscript{66, 67} Following operation carotid sinus sensitivity disappeared in seven of 10 patients with liver disease in the absence of jaundice or common duct obstruction. It has been reported that sodium taurocholate or sodium glycocholate when injected into the common carotid artery or around the carotid sinus of dogs predisposes to bradycardia and hypotension.\textsuperscript{98, 99} No such reaction resulted when the carotid sinuses were denervated or the vagi were sectioned. The bradycardia that accompanies jaundice may therefore be due to increased baroreceptor activity resulting from receptor sensitization by the retained bile pigments.

Increased carotid sinus responsiveness follows various drugs. In addition to the digitalis glycosides, cholinergic drugs may similarly increase the reactivity of this reflex. An important group of drugs that significantly increases carotid sinus sensitivity are the ranolaza derivatives. Serious reaction may occur when large doses are employed in the digitalized patient. Unappreciated is the fact that potassium may enhance vagus action\textsuperscript{100} and therefore increase responsiveness to carotid sinus stimulation. An example of this interaction is illustrated in figure 15.

Summary and Conclusion

The carotid sinuses, situated at the bifurcation of the common carotid arteries, are important pressoreceptors. They are activated by changes in pulsatile intravascular pressure, thereby initiating reflexes that modify heart
rate, cardiac output, blood pressure, peripheral resistance, and venomotor tone, as well as pulmonary blood flow and ventilation. Their superficial location in the neck permits ready manipulation and influence upon the heart and peripheral vessels.

Massage of the carotid sinus, when a few simple precautions are heeded, is a procedure devoid of serious hazard. This procedure had been much neglected. At times it affords the only means of establishing a definite diagnosis. Often it provides invaluable clues for diagnosis of various heart conditions and frequently serves as a definite therapeutic procedure. Carotid sinus stimulation is of value in diagnosis, treatment, or analysis of the following: arrhythmias of the heart, angina pectoris, coronary artery disease, acute pulmonary edema, bundle-branch block, and the state of digitalization. Increased sensitivity of the carotid sinuses may evoke reflexes that seriously impair heart rate, peripheral resistance, or both, and may thereby precipitate syncopal episodes.

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Each period of human achievement has its phases of spring, culmination, and decline, ... If we believe ourselves at last to have found the only thoroughfare, we owe this knowledge to those who before us travelled the uncharted seas. If we have inherited a great commerce and dominion of science it is because their argosies had been on the ocean, and their camels on the desert.—THOMAS CLIFFORD ALLBUTT, M.A., M.D. Science and Medieval Thought, London, C. J. Clay and Sons, 1901, p. 15.
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