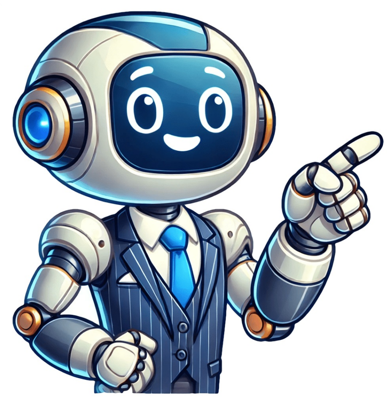

The heart is mainly composed of muscle tissue, with well-defined sheets of connective tissue giving it some shape, as well as providing electrical insulation between the main sections of the heart (upper atria and lower ventricles, left and right sides). It is important that the atria and ventricles have distinct phases of diastole (relaxation, allowing the chamber to fill with blood) followed by systole (contraction, moving blood onwards and out), and that each contraction is synchronised. Muscle tissue is electrically polarised like neurones (negative membrane potential). Its contraction is stimulated by the opening of 'fast' ion channels which allow the entry of sodium ions, which depolarise the membrane. Then potassium ion channels open, causing efflux of potassium ions as well as opening of calcium ion channels which allow calcium ions in. This causes the internal release of calcium ions from the sarcoplasmic reticulum which starts the interaction of proteins causing muscle fibres to shorten. As in neurones, potassium ion channels close but small amounts of potassium ions continue to leak out, resulting in repolarisation of the membrane. Cardiac muscle cells are in contact with one another by means of structures called gap junctions which ensure that contractions are co-ordinated. Certain bodies within the heart are composed of specialised cells which generate impulses but do not really contract. Each has a different frequency but this can be overridden by other impulses. These make up the heart's electrical conduction system, shown in yellow on the diagram on the right. The sinoatrial node (SAN) is the main pacemaker of the heart, and it is located in the wall of the right atrium, between the superior and inferior vena cavae (upper and lower main veins of the body). Extending out from this are a series of specialised muscle fibres [not nerve fibres] - the 'electrical conduction system' - which carry action potentials to various sections of the heart. These waves of electrical activity spread across the atria. Distinct fibres ('Bachman's bundle') extend straight across the left atrium, and others loop around the right atrium, so the atria contract together. However the impulses do not pass directly from the atria to the ventricles, and the atria are able to empty their contents smoothly into the ventricles. The action potentials reach another section of specialised tissue - the atrioventricular node (AVN) in the centre of the heart between the atria and the ventricles. This sends the action potentials onwards via bundles of His which pass down on either side of the septum between the ventricles and continue into much-branching Purkyne fibres or tissue which spread out over the ventricles. These cause contraction of the ventricles, beginning at the base and extending upwards, so that blood is effectively pushed upwards and out. The right ventricle sends deoxygenated blood towards the lungs, and the left ventricle sends blood out via the aorta to all parts of the body. In addition to increased heart rate, exercise will cause the heart to beat more deeply. In other words each heartbeat will cause a greater volume of blood to flow. The stroke volume is the the volume of blood pumped out (from the left ventricle) per beat. Stroke volume cannot usually be directly measured, but it may be calculated from difference in the volume of blood before and after the heart beats - usually obtained using an echocardiogram - output from a (3-D) scanner using ultrasound. These values are also called the end-systolic volume and the end-diastolic volume. A typical value for stroke volume is 70 cm3 in a healthy man (70kg). With a normal heart rate of 70 beats per minute this gives the volume of blood pumped per minute as 4900 cm3, which is quite close to the total amount of blood in the body. Cardiac output (CO) may be calculated using the formula CO = R � V, where R= heart rate and V= stroke volume. Starling's law states that the stroke volume of the heart will increase in response to an increase in the volume of blood in the ventricles, before contraction (the end-diastolic volume) - sometimes known as preload. Effectively the inflow of extra blood stretches the cardiac muscle fibres, leading to an increase in the force of contraction. The electrical conduction system of the heart The electrocardiogram trace is typically labelled PQRS. It can be used to monitor the process of electrical stimulation of the heart chambers. This is achieved by attaching electrodes to the skin of the chest, arms, and legs. The waveform is not like membrane potential, and it does not cross over (much) from negative to positive. The regularity and timings of the peaks of the waveform can give insight into the condition of the heart, and it is also expressed as a number of strangely labelled sections such as the PR segment and PR interval. The P wave is caused by depolarisation of the atria, as initiated by the sino-atrial node. The QRS section is caused by depolarisation of the ventricles, as a result of electrical activity passing down from the atrioventricular node, and it shows as a long sharp spike at R. This shows that ventricular contraction is strong and quick. The T wave represents ventricular repolarisation. Atrial repolarisation is hidden by QRS. This topic leads on fairly logically to a series of related topics (none of them exactly trivial): cardiac arrhythmias artificial pacemakers defibrillators cardioversion heart attacks myocardial infarctions beta blockers cardioactive drugs Heart rate is one of the two factors (the other being stroke volume) that determines cardiac output. Heart rate (also called chronotropy) normally falls in the range of 60-100 beats per minute (bpm). However in special circumstances, such as during exercise, the heart needs to be able to change this rate to either increase or decrease cardiac output accordingly. In this article, we will discuss how hormones and nerve impulses work to control the heart rate and the baroreceptor reflex, which can change the heart rate. Heart rate (or chronotrophy) is established by the sinoatrial node (SAN) – this is a cluster of pacemaker cells which sits in the right atrium. In the absence of any external influences, the SAN pacing rate is about 100 beats per minute (bpm). However, heart rate and cardiac output must be able to vary in response to the needs of the body. By influencing cells in the SAN, nerve impulses and hormones can affect the speed at which the SAN generates an electrical impulse. This affects the heart rate, which in turn affects cardiac output. The atrioventricular node (AVN) sits above the ventricular septum at the junction between the atria and the ventricles. Its function is to pass on the impulse from the atria to the ventricles. However, as the conduction velocity of the AVN is much slower than the SAN, this creates a delay of about 0.15 seconds. This 0.15s delay is what allows the atria to finish contracting and the atrioventricular valves to close before the ventricles start to contract – this prevents blood from regurgitating back into the atria during ventricular contraction. This delay is also one of the reasons why despite the SAN having a pacing rate of 100bpm, the actual heart rate is usually lower, at around 70bpm. The autonomic nervous system (ANS) is responsible for controlling many physiological functions. It induces the force of contraction of the heart and its heart rate. In addition, it controls the peripheral resistance of blood vessels. The ANS has both sympathetic and parasympathetic divisions that work together to maintain balance. Parasympathetic Parasympathetic input to the heart is via the vagus nerve (CN X). The vagus nerve synapses with postganglionic cells in the SAN and atrioventricular node (AVN). When stimulated, acetylcholine binds on to M2 receptors, which act to decrease the slope of the pacemaker potential. This leads to a decrease in heart rate (a negative chronotropic effect). Sympathetic Sympathetic input to the heart is via the postganglionic fibres from the superficial and deep cardiac plexuses, which innervate the SAN and AVN. The postganglionic fibres release noradrenaline, which acts on B1 adrenoreceptors to increase the slope of the pacemaker potential. This increases the heart rate (a positive chronotropic effect), as well as the force of contraction (positive inotropic effect). At rest, parasympathetic input to the SAN dominates, giving a normal resting heart rate of around 60bpm. A reduction in parasympathetic outflow results in an increase in heart rate, reaching over 100bpm. This is further brought about by an increase in sympathetic outflow. By OpenStax College [CC BY 3.0 ( ], via Wikimedia Commons Fig 1Diagram showing an overview of autonomic innervation to the heart. Baroreceptors are mechanoreceptors located in both the carotid sinus and aortic arch. They are sensitive to changes in stretch and tension in the arterial wall. Additionally, they detect changes in arterial pressure and communicate this to the medulla oblongata in the brainstem via the glossopharyngeal nerve (CN IX) and vagus nerve (CN X). The medullary centres in the brain are responsible for the overall output of the autonomic nervous system, and use the information fed back from baroreceptors to coordinate a response: If an increase in arterial pressure is detected by the baroreceptors, the parasympathetic pathway is activated. This impulse is carried the glossopharyngeal (CN IX) and vagus (CN X) nerves to the medulla oblongata oblongata, where they activate cardiac decelerator centre. These cardioinhibitory centres carry impulses back to the heart via the vagus nerve (CN X) to reduce the heart rate. This, along with increasing vasodilation of vessels, acts to reduce the arterial pressure. If a decrease in arterial pressure is detected by the baroreceptors, there is no parasympathetic activation. Therefore the sympathetic pathway is activated. The cardiac accelerator centre in the medulla oblongata is activatedto increase the heart rate and the contractility of the heart. This, along with increasing vasoconstriction of vessels, acts to increase the arterial pressure. By OpenStax College [CC BY 3.0 ( ], via Wikimedia Commons Fig 2Diagram showing the action of the baroreceptor reflex. Hormones also have the ability to affect heart rate. For example, adrenaline is released from the medulla of adrenal glands during times of stress. This results in a number of effects that occur during a stress response such as an increase in heart rate. Tachycardia is defined as a heart rate that exceeds the normal resting rate (over 100bpm). This can be normal in the case of exercise, however, tachycardia at rest is generally due to causes such as: Anxiety Infection Hypoglycaemia Hypovolaemia Hyperthyroidism Problems with conductance in the heart Tachycardias due to conductance within the heart can be classified as narrow or wide complex tachycardia depending on the length of the QRS complex on an ECG. Narrow complex tachycardias include sinus tachycardia, atrial fibrillation and atrial flutter. Wide complex tachycardias include ventricular tachycardia and Wolff-Parkinson-White Syndrome. In narrow complex tachycardias, vagal manoeuvres (e.g. Valsalva manoeuvre or carotid sinus massage) or IV adenosine can be used to attempt to revert to a normal rhythm. If the patient is haemodynamically unstable then DC cardioversion may be necessary. For broad complex tachycardias, amiodarone can be given if a patient is stable, however, if a patient is unstable DC cardioversion may be needed. It is important to note that in the case of Wolff-Parkinson-White syndrome with atrial fibrillation, AV node blocking drugs must not be used as they will increase conduction down the abnormal pathway. Some disorders such as atrial fibrillation can be rate controlled using drugs such as beta-blockers, with accompanying anti-coagulants. By User:MoodyGroove (en.wikipedia.org) CC BY-SA 3.0 ( ], via Wikimedia Commons Fig 3ECG showing Sinus Tachycardia with a heart rate of 150bpm. A multiscale predictive digital twin for neurocardiac modulation. Yang PC, Rose A, DeMarco KR, Dawson JRD, Han Y, Jeng MT, Harvey RD, Santana LF, Ripplinger CM, Vorobyov I, Lewis TJ, Clancy CE. Yang PC, et al. J Physiol. 2023 Sep;601(17):3789-3812. doi: 10.1113/JP284391. Epub 2023 Aug 1. J Physiol. 2023. PMID: 37528537 Free PMC article. Heart rate is one of the two factors (the other being stroke volume) that determines cardiac output. Heart rate (also called chronotropy) normally falls in the range of 60-100 beats per minute (bpm). However in special circumstances, such as during exercise, the heart needs to be able to change this rate to either increase or decrease cardiac output accordingly. In this article, we will discuss how hormones and nerve impulses work to control the heart rate and the baroreceptor reflex, which can change the heart rate. Heart rate (or chronotrophy) is established by the sinoatrial node (SAN) – this is a cluster of pacemaker cells which sits in the right atrium. In the absence of any external influences, the SAN pacing rate is about 100 beats per minute (bpm). However, heart rate and cardiac output must be able to vary in response to the needs of the body. By influencing cells in the SAN, nerve impulses and hormones can affect the speed at which the SAN generates an electrical impulse. This affects the heart rate, which in turn affects cardiac output. 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The heart’s ability to adjust its rate based on the body’s needs is controlled by the autonomic nervous system, which balances between increasing and decreasing heart activity. This regulation ensures sufficient oxygenated blood reaches tissues during exertion or stress while conserving energy during rest. Understanding how sympathetic and parasympathetic control work together provides insight into normal cardiovascular function and potential disruptions that can lead to irregularities. Autonomic Nervous System Role In Heart Regulation The autonomic nervous system (ANS) governs heart rate by modulating the sinoatrial (SA) node, the heart’s natural pacemaker. This occurs through two opposing branches: the sympathetic nervous system (SNS), which accelerates heart rate, and the parasympathetic nervous system (PNS), which slows it down. These systems continuously adjust cardiac function based on physiological demands such as exercise, stress, or rest. Their balance determines the heart’s baseline rhythm and its ability to respond dynamically to changing conditions. Sympathetic stimulation originates from the thoracic spinal cord, where preganglionic neurons synapse with postganglionic fibers that release norepinephrine onto the heart. This neurotransmitter binds to adrenergic receptors, increasing pacemaker cell depolarization and enhancing conduction velocity through the atrioventricular (AV) node. The result is a faster heart rate and stronger contractions, improving cardiac output during heightened activity, such as exercise. Parasympathetic control, mediated by the vagus nerve, reduces heart rate through acetylcholine, which binds to muscarinic receptors on pacemaker cells, slowing their firing rate and prolonging AV node conduction. This effect dominates during restful states, promoting energy conservation. In well-trained athletes, heightened parasympathetic tone often results in bradycardia, reflecting enhanced cardiovascular efficiency. Mechanisms Of Sympathetic Activation Sympathetic activation begins with neural signals from the medullary cardiovascular centers of the brainstem. These signals travel through the spinal cord to preganglionic neurons in the thoracic spinal segments (T1–T4). These neurons release acetylcholine onto nicotinic receptors in the sympathetic chain ganglia, prompting postganglionic fibers to release norepinephrine onto the heart. Norepinephrine primarily binds to beta-1 adrenergic receptors on pacemaker cells, AV node cells, and ventricular myocardium. This triggers intracellular signaling via the G-protein-coupled adenylyl cyclase pathway, increasing cyclic adenosine monophosphate (cAMP) levels. Elevated cAMP activates protein kinase A (PKA), which phosphorylates L-type calcium channels and hyperpolarization-activated cyclic nucleotide-gated (HCN) channels. The result is increased calcium and sodium ion influx, accelerating pacemaker cell depolarization and shortening conduction pathway refractory periods. These changes elevate heart rate and enhance myocardial contractility, ensuring greater cardiac output. Beyond direct effects on pacemaker activity, sympathetic activation influences vascular tone and systemic hemodynamics. Increased norepinephrine release leads to vasoconstriction in non-essential vascular beds, redirecting blood flow to skeletal muscles and vital organs. This optimizes oxygen delivery during stress or exercise. Additionally, sympathetic stimulation enhances venous return by constricting large veins, increasing preload and stroke volume through the Frank-Starling mechanism. These coordinated responses help meet metabolic demands efficiently. Mechanisms Of Parasympathetic Activation Parasympathetic control of heart rate is primarily exerted through the vagus nerve, which originates in the medulla and extends directly to the heart. The vagus nerve releases acetylcholine (ACh) onto cardiac pacemaker cells, where it binds to muscarinic M2 receptors. This interaction activates an inhibitory G-protein (Gi), reducing cAMP production and suppressing PKA activity. The downstream effect is decreased L-type calcium channel activity and increased potassium conductance through G-protein-coupled inwardly rectifying potassium (GIRK) channels, slowing pacemaker cell depolarization. The physiological outcome is a prolonged phase 4 depolarization in pacemaker cells, delaying the threshold potential necessary for action potential generation. This delay decreases heart rate (negative chronotropy). Additionally, acetylcholine’s effect on the AV node extends conduction time, limiting impulses transmitted to the ventricles. This is particularly pronounced during sleep or deep relaxation, where parasympathetic dominance maintains a lower heart rate, conserving energy. Parasympathetic activation also influences heart rate variability (HRV), a key marker of autonomic balance and cardiovascular health. Increased vagal tone is associated with greater HRV, reflecting the heart’s adaptability to physiological changes. Studies show individuals with higher vagal activity exhibit improved cardiovascular resilience and a lower risk of arrhythmias. Endurance athletes often develop enhanced parasympathetic tone, leading to resting bradycardia without pathological consequences. Receptor-Specific Effects On The Heart Autonomic regulation of heart rate is mediated by specific receptors responding to neurotransmitters from the sympathetic and parasympathetic nervous systems. Beta-adrenergic and muscarinic receptors influence cardiac excitability, conduction velocity, and contractility. Beta-Adrenergic Receptors Beta-1 adrenergic receptors are the primary mediators of sympathetic stimulation in the heart. These receptors, found in the SA node, AV node, and ventricular myocardium, activate the Gs protein when bound by norepinephrine or epinephrine. This stimulates adenylyl cyclase, increasing cAMP production. Elevated cAMP enhances PKA activity, phosphorylating L-type calcium channels and ryanodine receptors, increasing calcium influx and release from the sarcoplasmic reticulum. This accelerates depolarization and strengthens myocardial contractions. Beta-1 receptor activation increases heart rate (positive chronotropy), enhances conduction velocity (positive dromotropy), and strengthens cardiac contractions (positive inotropy). These effects are crucial during exercise or stress when increased cardiac output is required. Beta-blockers, such as metoprolol and propranolol, antagonize beta-1 receptors, reducing heart rate and contractility, making them effective for hypertension and arrhythmias. Muscarinic Receptors Muscarinic M2 receptors mediate parasympathetic regulation in the heart. These receptors, concentrated in the SA and AV nodes, engage the Gi protein when activated by acetylcholine. This inhibits adenylyl cyclase, reducing cAMP levels and suppressing PKA activity. The result is decreased calcium influx through L-type calcium channels and increased potassium efflux via GIRK channels, hyperpolarizing pacemaker cells and slowing their firing rate. M2 receptor activation reduces heart rate (negative chronotropy) and prolongs AV node conduction time (negative dromotropy). This helps maintain a low resting heart rate and prevents excessive sympathetic stimulation. Anticholinergic drugs, such as atropine, block M2 receptors, increasing heart rate, which is useful in treating bradycardia or vagally mediated syncope. Additional Receptor Types Other receptor types contribute to autonomic modulation. Alpha-1 adrenergic receptors, though primarily involved in vascular tone, influence myocardial contractility by increasing intracellular calcium levels. Beta-2 adrenergic receptors, more prevalent in vascular smooth muscle, contribute to cardiac relaxation and vasodilation, indirectly affecting heart rate by modulating afterload. Purinoceptors, such as P2X and P1 (adenosine) receptors, also play roles in autonomic regulation. Adenosine, acting through A1 receptors, inhibits adenylyl cyclase and activates potassium channels, mimicking parasympathetic effects by slowing SA node firing and AV node conduction. This mechanism is clinically relevant in treating supraventricular tachycardia, where adenosine is used to transiently block AV node conduction and restore normal rhythm. Reflex Pathways Governing Heart Rate Heart rate regulation extends beyond direct autonomic input to include reflex pathways that fine-tune cardiovascular responses. These reflexes, mediated by sensory receptors detecting changes in blood pressure, oxygen levels, and mechanical stretch, ensure cardiac output is dynamically adjusted to maintain circulatory stability. The baroreceptor reflex plays a fundamental role in short-term blood pressure regulation. Baroreceptors in the carotid sinus and aortic arch detect arterial pressure fluctuations and relay this information to the medullary cardiovascular centers. When blood pressure rises, baroreceptor firing enhances parasympathetic activity while suppressing sympathetic output, reducing heart rate and causing vasodilation. A drop in pressure triggers sympathetic activation, increasing heart rate and contractility to restore perfusion. Chemoreceptor reflexes, primarily mediated by carotid and aortic bodies, modulate heart rate by sensing blood oxygen, carbon dioxide, and pH levels. During hypoxia or hypercapnia, chemoreceptors stimulate sympathetic outflow to elevate heart rate and cardiac output, ensuring adequate oxygen delivery. The Bainbridge reflex responds to atrial stretch from increased venous return, promoting sympathetic stimulation to prevent blood pooling in the heart. Autonomic Imbalance And Heart Rate Irregularities Disruptions in sympathetic and parasympathetic balance can cause significant heart rate irregularities. Autonomic dysfunction, whether due to disease or external factors, compromises the heart’s ability to maintain a stable rhythm. Excessive sympathetic activity can lead to tachycardia, where persistent adrenergic stimulation accelerates heart rate beyond physiological needs. Conditions such as postural orthostatic tachycardia syndrome (POTS) and inappropriate sinus tachycardia (IST) illustrate how autonomic dysfunction can cause sustained heart rate elevations, often accompanied by palpitations and dizziness. Conversely, excessive parasympathetic influence can cause bradyarrhythmias, where an abnormally slow heart rate impairs cardiac output, as seen in vasovagal syncope. Heart rate is normally determined by the pacemaker activity of the sinoatrial node (SA node) in the posterior wall of the right atrium. The SA node exhibits automaticity that is determined by spontaneous changes in Ca++, Na+, and K+ conductances. This intrinsic automaticity, if left unmodified by neurohumoral factors, exhibits a spontaneous firing rate of 100-110 beats/min. This intrinsic firing rate decreases with age.Heart rate is decreased below the intrinsic rate, primarily by activation of the vagus nerve innervating the SA node. Normally, at rest, there is significant vagal tone on the SA node so that the resting heart rate is between 60 and 80 beats/min. This vagal influence can be demonstrated by administration of atropine, a muscarinic receptor antagonist, which leads to a 20-40 beats/min increase in heart rate depending upon the initial level of vagal tone.For the heart rate to increase above the intrinsic rate, there is both a withdrawal of vagal tone and an activation of sympathetic nerves innervating the SA node. This reciprocal change in sympathetic and parasympathetic activity permits the heart rate to increase during exercise, for example.Heart rate is changed by circulating catecholamines acting via β1-adrenoceptors on SA nodal cells. Heart rate is also changed by changes in circulating thyroxin (thyrotoxicosis causes tachycardia) and by changes in body core temperature (hyperthermia increases heart rate). SA nodal dysfunction can lead to sinus bradycardia, sinus tachycardia, or sick-sinus syndrome.The maximal heart rate (max HR) that can be achieved in an individual is often estimated by:Max HR = 220 beats/min − age in yearsAlthough this formula is commonly used in the US fitness health industry, many studies have shown that this simple formula underestimates max HR by 10 or more beats/min in older individuals. A study done on more than 3000 healthy men and women of a wide age range (Scand J Med Sci Sports 23:697-704, 2013), showed that max HR is better estimated by 211 – (0.64 x age). The following comparison indicates the differences in estimated max HR for 30- and 70-year-old individuals based on these two calculations:Therefore, max HR is reduced with increasing age, which also reduces maximal cardiac output during exertion. This effect is independent of gender, type of physical activity, maximal oxygen consumption, or body mass index. It is genetically determined and cannot be significantly modified by exercise training or by external factors.Additional and more detailed information on the factors controlling heart rate can be found by clicking here.Revised 11/03/2023 The heart is made up of cardiac muscle, a specialised tissue known as myogenic tissue. It is able to initiate its own contraction within the muscle cells, meaning it isn’t dependent on external signals from the nervous system. A-level Biology – Controlling Heart Rate The right atrium wall is where specialised fibres called the sinoatrial node (SAN) is located. It is also known as the ‘pacemaker of the heart’ as it is what starts the wave of electrical stimulation. The process is described below: The sinoatrial node produces a wave of electrical stimulation. The SAN sends a wave of electricity to the atrial walls which causes the atria to contract at approximately the same time. The signal passes down the atrial septum. A thin layer of collagen tissue at the base of the atria prevents the wave of electricity from reaching the ventricles. Instead, the SAN passes the electricity to the atrioventricular node (AVN), located between both the atria. The atrioventricular node (AVN) conducts the signal to the ventricles. The AVN passes the wave of electricity down the nerves of the bundle of His. There is a slight delay in this, so the muscle of the ventricles don’t contract before the atria can fully empty. The bundle of His transmits the wave to the base of the heart. The bundle is comprised of muscle fibres that extend from the AVN to the apex (bottom) of the heart, where it splits into the Purkinje fibres and branches up into each ventricle. The electricity passes up the Purkinje fibres. This allows the ventricles to contract from the base up, which allows the ventricles to fully empty, pushing the blood into the aorta and pulmonary artery. A-level Biology – Controlling Heart Rate The sinoatrial node (SAN) connects to two nerves which are located in the medulla oblongata, in the brain: The accelerator nerve is part of the sympathetic nervous system and delivers a higher than usual frequency of impulses to the SAN to increase the heart rate. The vagus nerve is opposite to the accelerator nerve as it is part of the parasympathetic nerve and works to decrease the heart rate by delivering a lower than usual frequency of impulses to the SAN. Resting heart rate is determined by the internal pacemaker (SAN). But, it can be regulated by the brain. The heart rate can increase or decrease in response to internal stimuli. There are two types of receptors to detect changes. Both are located in the aorta and carotid arteries: Chemoreceptors detect chemical changes, such as oxygen concentration, carbon dioxide levels and the pH of the blood. They are also found in the medulla. Baroreceptors detect changes in blood pressure. They are found in the carotid arteries (in the neck) and aorta. The medulla oblongata is a section of the brain that controls autonomic functions, such as digestion, heart rate and breathing. It controls the heart rate by altering the speed at which the SAN fires. The medulla is connected to the SAN by two types of neurone, parasympathetic and sympathetic. The parasympathetic neurones secrete acetylcholine – a type of neurotransmitter. This decreases heart rate. The sympathetic neurones secrete noradrenaline – another type of neurotransmitter. This increases heart rate. High blood pressure If high blood pressure is detected, impulses are sent from the baroreceptors to the medulla – this will send the impulse down parasympathetic neurones. This causes acetylcholine to be released in the cardiac muscle, binding to receptors on the SAN. The heart rate will slow to decrease the blood pressure. Low blood pressure Inversely, if low blood pressure is detected, impulses are sent down sympathetic neurones by the medulla. This causes noradrenaline to be realised in the cardiac muscle, binding to receptors on the SAN. The heart rate will speed up to increase the blood pressure. Boost your exam scores with personalised tutoring to suit your needs High blood oxygen, pH or low carbon dioxide If these changes are detected, impulses are sent from the chemoreceptors to the medulla – this will send the impulse down parasympathetic neurones. This causes acetylcholine to be released in the cardiac muscle, binding to receptors on the SAN. The heart rate will slow to return the oxygen, carbon dioxide and pH of the blood to normal levels. Low blood oxygen, pH or high carbon dioxide If these changes are detected, impulses are sent down sympathetic neurones by the medulla. This causes noradrenaline to be released in the cardiac muscle, binding to receptors on the SAN. The heart rate will speed up to return the oxygen, carbon dioxide and pH or the blood to normal levels. When the heart rate changes, there are steps taken to try and return it to a normal rhythm. Below are the steps that happens when the heart rate changes: The relevant receptors send an impulse to the cardiac control centre, located in the medulla oblongata. The impulse then gets sent to the sinoatrial node along the sympathetic neurone where depolarisation occurs. The SAN releases noradrenaline which results in an increased heart rate Conversely to the process of increasing the heart rate, decreasing the heart rate is the opposite to the steps above. When the factors that affect the heart rate return to normal, the impulses return to their usual frequency to maintain a steady heart rate. →What is heart rate and why is it important? Heart rate refers to the number of heartbeats per minute. It is an important physiological measure as it can indicate an individual’s level of physical exertion, stress, and overall cardiovascular health. →What are the factors that can affect heart rate? Heart rate can be influenced by a variety of factors, including exercise, stress, age, medications, and underlying medical conditions. →How does the autonomic nervous system control heart rate? The autonomic nervous system is responsible for controlling heart rate. The sympathetic nervous system increases heart rate, while the parasympathetic nervous system slows it down. →What is the role of the sinoatrial (SA) node in controlling heart rate? The sinoatrial (SA) node is responsible for initiating the electrical impulses that control the contraction of the heart. It acts as the natural pacemaker for the heart and determines the heart rate. →What is the role of the atrioventricular (AV) node in controlling heart rate? The atrioventricular (AV) node acts as a relay between the atria and ventricles, transmitting electrical impulses from the atria to the ventricles. It regulates the heart rate by slowing down the impulses to allow the ventricles to fill properly before contracting. →How does exercise affect heart rate? Exercise increases heart rate as it stimulates the sympathetic nervous system, causing the heart to beat faster. This increases the amount of blood being pumped and delivers oxygen and nutrients to the muscles. →How does stress affect heart rate? Stress increases heart rate as it activates the sympathetic nervous system, causing the heart to beat faster. This prepares the body for the “fight or flight” response to perceived danger. →How do medications affect heart rate? Some medications, such as beta blockers and calcium channel blockers, can slow heart rate by blocking the effects of the sympathetic nervous system. Other medications, such as stimulants, can increase heart rate by activating the sympathetic nervous system. →What are the potential health consequences of an irregular heart rate? An irregular heart rate can be a sign of an underlying health problem, such as arrhythmia or heart disease. An irregular heart rate can also lead to decreased cardiac output, decreased blood flow to the brain and other vital organs, and increased risk of heart attack or stroke. As a library, NLM provides access to scientific literature. Inclusion in an NLM database does not imply endorsement of, or agreement with, the contents by NLM or the National Institutes of Health. Learn more: PMC Disclaimer | PMC Copyright Notice . 2021 May 25;53(1):682–692. doi: 10.1080/07853890.2021.1930137 Atrial fibrillation (AF) is one of the main cardiac arrhythmias associated with higher risk of cardiovascular morbidity and mortality. AF can cause adverse symptoms and reduced quality of life. One of the strategies for the management of AF is rate control, which can modulate ventricle rate, alleviate adverse associated symptoms and improve the quality of life. As primary management of AF through rate control or rhythm is a topic under debate, the purpose of this review is to explore the rationale for the rate control approach in managing AF by considering the guidelines, recommendations and determinants for the choice of rate control drugs, including beta blockers, digoxin and non- dihydropyridine calcium channel blockers for patients with AF and other comorbidities and atrioventricular nodal ablation and pacing. Despite the limitations of rate control treatment, which may not be effective in preventing disease progression or in reducing symptoms in highly symptomatic patients, it is widely used for almost all patients with atrial fibrillation. Although rate control is one of the first line management of all patient with atrial fibrillation, several issues remain debateable. Keywords: Atrial fibrillation, Rate control strategy, Electrophysiology, arrhythmias Atrial fibrillation (AF) is the most common cardiac arrhythmia in adults [1]. It can increase the risk of stroke, heart failure (HF) and mortality [2]. The risk of developing AF increases progressively with age [3], from a prevalence of 0.1% in individuals under 55 years of age to 9.0% in individuals 80 years and older [4], and in adults, the current prevalence of AF is 2–4% [1], with estimated rise of 2.3 folds [5] due to extended longevity in general population [6]. The exact reasons for why age and certain medical disorders increase the risk of AF are not yet fully understood [7]. Although age is an independent risk factor for adverse AF outcomes [3], the increased burden of comorbidities (i.e. coronary heart disease, heart failure, diabetes mellitus, hypertension and obstructive sleep apnoea) are significant contributors to the development and progression of AF, as well as significant modifiable risk factors [8–10].It is likely that structural (e.g. dilatation and fibrosis) and electrophysiological changes of atrial myocytes, likely disturb the electrical substrate which causes AF [6],although the mechanisms vary among patients with AF. The main aim of AF treatment is to simply follow the ABC pathway, avoid strokes, better control symptoms, and reduce cardiovascular and comorbidity risks [2]. Another important aim is to recognize and manage the associated factors, whether acute (e.g. as a result of cardiac surgery and inflammatory diseases) or chronic (e.g. as a result of heart valve stenosis, coronary artery disease, hypertension or obesity) [11]. Rate control and rhythm control treatments are the two main strategies currently in use. The rate control is defined as use of any combination of β-blocker, non- dihydropyridine calcium channel blocker, and digoxin or AV nodal ablation without aiming to restore normal sinus rhythm. Rate control is an essential part of AF management. The goal of rate control treatment is to modulate the ventricular rate, with the aim of better symptom control, the reductions in thromboembolic, cardiovascular and comorbidity risks. The rhythm control strategy, which could involve pharmacological intervention, is relatively effective for the maintenance of sinus rhythm, but it can have adverse drug reactions. It reduces AF recurrences, but may not always eliminate them [12], the risk of serious adverse events in patients appears to be greater, compared to rate control strategies [13]. The AFFIRM trial [14] was a comparative study of rhythm versus rate control strategies in AF patients over five years. This demonstrated no significant difference in neither the ischemic stroke rate (7.1% vs. 5.5%; respectively; p = .79) or mortality (23.8% vs. 21.3%; respectively; p = .08). Similarly, meta-analyses of a few RCTs demonstrated no significant difference with regards to both stroke-related and general mortality, in spite of bias towards rate control [15]. Thus far, comparison of rhythm vs rate control as the superior strategy for AF management remains a controversial area in the literature; however, there is still little of evidence in the management of older patients. The superiority of rate control over rhythm control was evident in terms of cost-effectiveness [16], whereas rhythm control has demonstrated better outcomes in factors such as rates of stroke/TIA and health related QoL [17,18]. In spite of this, studies from the real world demonstrate that rate control strategies are used preferentially, and especially in the management of older patients [19], while rhythm control strategies are used primarily to reduce AF-related symptoms [20]. This can be achieved through the rate control approach, which is easier to establish and manage, and has a lower rate of hospitalization as well as major adverse events. The purpose of this review is to explore the rationale for employing the rate control approach, by considering the guidelines, recommendations and determinants for the choice of rate control drugs and atrioventricular nodal ablations. In spite of the limitations of rate control treatment, which may not be effective in preventing disease progression or in reducing symptoms insusceptible patients, it is still widely used for almost all AF patients (Figure 1). Indications of rate control treatment with the ultimate goal. AF: Atrial fibrillation [2]. During AF, stroke volume and ventricle filling time are reduced as a result of fast and irregular ventricular rates [21]. Consequently, a reduction in the cardiac output by 20–30% [22] and irregular rhythm cause symptomatic consequences and contribute to the development or worsening of heart conditions, such as HF [23]. The dramatic increase in the heart rate also leads to substantial negative inotropic effects [21]. Patients with HF in whom the left ventricle ejection fraction (LVEF) is preserved or reduced are prone to more significant deterioration if they have AF [24]. In a nationwide large-scale AF cohort study [25], it was demonstrated that patients who received rate control treatment agents such as beta blockers (BB) or non-dihydropyridine calcium channel blockers (NDCC) had a lower mortality rate than patients who did not receive these treatments. In addition, the use of BB was associated with the lowest risk of mortality (adjusted HR: 0.76; 95% CI: 0.74–0.78), while digoxin usage was associated with the highest mortality risk (adjusted HR: 1.12; 95% CI: 1.10–1.14) [25]. Rate control therapy is preferred in three situations. First, although patients with new-onset AF (less than 1 year after diagnosis) and cardiovascular conditions are more preferred to use the rhythm control management (catheter ablation and/or pharmacological) compared to the usual care (rate control) [26]; rate control remains the mainstay treatment for almost all patients with AF. This is because maintaining well-controlled ventricular rates during AF deterioration is of the utmost importance. Second, it is the drug of choice for those who do not require rhythm control, that is, those older than 80 years of age who are asymptomatic or have mild symptoms [2,27]. Currently, the main aim of using rhythm control treatment is to improve AF-related symptoms. Third, it is the only alternative treatment used if rhythm strategy (e.g. pharmacological and catheter ablation) is unsuccessful or if the risks outweigh the benefits (e.g. bradycardia-tachycardia syndrome and high pacing risk). Therefore, it would be reasonable to consider rate control strategies in these situations, but the choice of treatment should be comprehensive and tailored to the severity of the symptoms, ventricular rates, associated co-morbidities and shared decision-making strategy [28,29]. Improvement of symptoms, preservation or prevention of left ventricle function impairment and QoL improvement are the aims of rate control drugs. This treatment should prevent tachycardiomyopathy and the development of HF. In order to maintain an adequate cardiac output, lower physiological demands, and prevent consequences, an appropriate ventricular rate should be achieved. If the ventricular rate is very rapid or slow, it could cause undesired adverse effects (e.g. pacemaker implantation, impaired QoL, and higher cost) [30]. However, in response to AF, ventricular rates have to increase in order to maintain homeostasis in the cardiovascular system due to the atrial conduction system being impaired and not contracting properly. Moreover, appropriate ventricular rates may differ from patient to patient. For instance, HF preserve ejection fraction (HFpEF) often requires slower ventricular rates to allow for more diastolic filling time [22]. However, American guidelines (American Heart Association/American College of Cardiology/Heart Rhythm Society) for the management of AF are more inclined to maintain a strict rate strategy and heart rate (defined as a ventricle rate