

Physiological Changes to Blood Pressure due to Haemorrhage Caused by a Stab Wound
In A 30 Year Old Female

Homeostasis

The most fundamental concept of biology and the basis of human evolutionary adaptation is homeostasis. The key to comprehending the functioning of various organ systems of the body is understanding the process of homeostasis. Homeostasis aims to preserve the “internal milieu” (stable internal environment) of the human body concerning temperature, pressure, electrolytes and water concentrations. Homeostasis was a term coined by Walter Bradford Cannon based upon Claude Bernard’s postulate of milieu “intérieur”. Before understanding the physiological changes to blood pressure as a result of haemorrhage due to a stab wound, we must explore the homeostatic mechanism of blood pressure of the human body in general. Biochemical and physiological homeostatic mechanisms tend to stabilise blood pressure during any stress situation.

Homeostasis of Blood Pressure

It is crucial to maintain a homeostatic condition of blood pressure. If perfusion of an organ is low (ischemic) then hypoxia occurs. Excessive perfusion can damage delicate, soft tissues and fragile vessels. Homeostasis of blood pressure is maintained by the **negative feedback control mechanism**. The homeostatic mechanisms that ensure adequate blood flow, pressure, distribution and perfusion are **neural, endocrine, and autoregulatory mechanisms**. Let us begin by looking into the neural regulation mechanism of cardio-vascular homeostasis.

Baroreceptors

Baroreceptors are located in the glossopharyngeal (carotid sinus) and the vagus (aortic arch). They communicate the stretch in blood vessels due to the presence of blood. They are stretched more tightly during high blood pressure conditions thus generating action potentials at a higher rate (if the normal set point is 10 action potentials per minute, let us consider the action potentials per minute during high blood pressure conditions to be 30/min). During low blood pressure conditions, the number of action potentials per minute produced by baroreceptors are lower as the stretch in blood vessels is lower. These inputs are then received by the cardiovascular control centre in the medulla oblongata which in turn initiates a reflex that maintains homeostasis via the **autonomic nervous system**. The autonomic nervous system is sub-divided into two parts- the **sympathetic nervous system** (concerned with increasing blood pressure) and the **parasympathetic nervous system** (concerned with decreasing blood pressure).

The formula for determining the change in blood pressure is as follows:

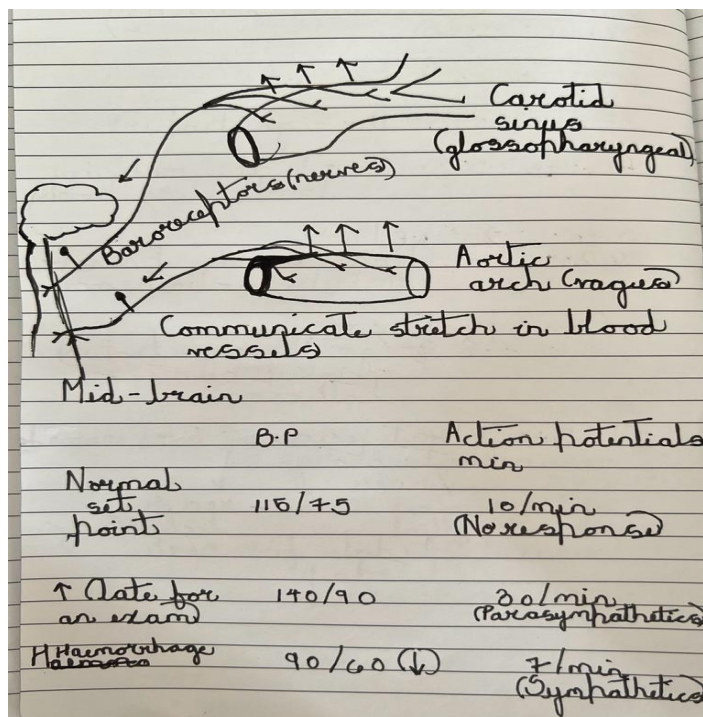
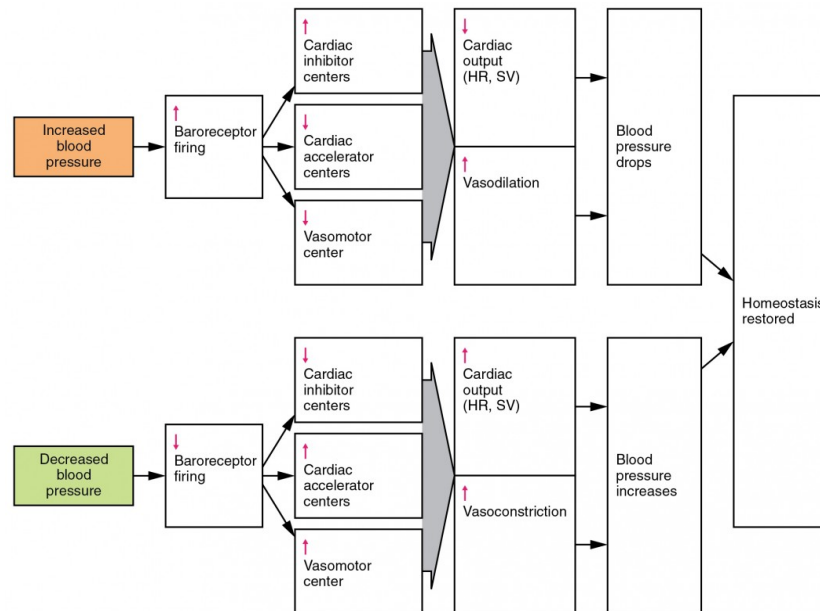
$\Delta P = Q \times R$, where ΔP is the pressure gradient, Q is the blood flow (cardiac output) and R is the resistance in the system.

Q (cardiac output) can in turn be determined by the formula:

$Q = SV \times HR$, where SV = Stroke Volume and HR = Heart Rate.

The sympathetic nervous system, when stimulated, affects the heart and the blood vessels by increasing the heart rate and the stroke volume, increasing resistance of the system, thereby bringing about vasoconstriction. This **causes an increase in blood pressure**.

The parasympathetic nervous system, on the other hand, works in an opposite manner. It decreases the heart rate and the stroke volume, decreases the resistance of the system thus bringing about vasodilation and **reducing the blood pressure**.

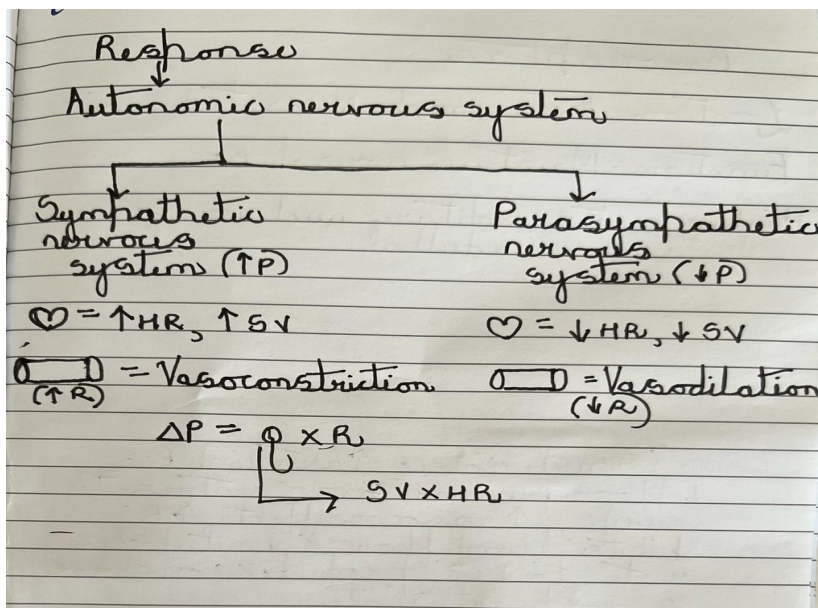


Chemoreceptors

Chemoreceptors help in keeping cardiovascular and respiratory homeostasis. They are located in the **vagus and glossopharyngeal body** and have their higher centre in the solitary nucleus of the medulla. The central and peripheral chemoreceptors are stimulated by **Pco₂ and pH** and function to maintain normal arterial blood gas analysis(ABG).

There are two cardiovascular centres in the medulla, namely the **vasomotor control centre and the cardiac control centre**. The vasomotor control centre controls the diameter of blood vessels while the cardiac control centre controls heart rate and cardiac contractility. When there is increase in arterial pCo₂(decrease in blood pH), the chemoreceptors fire and stimulate the **sympathetic** nervous system thereby, increasing the resistance of the system, limiting blood flow due to vasoconstriction, decreasing metabolic rate to reduce co₂ production and to conserve o₂.

On the pulmonary front, the **heart rate increases** so that more oxygen is taken in and more co₂ is diffused out. The airways stretch which is in turn detected by the pulmonary stretch receptors that fire and send signals through the vagus nerve to the pons and the medulla oblongata. This stimulates the cardiac accelerator centre, increasing the heart rate, sympathetic effect and cardiac contractility. This **causes the blood pressure to increase**.



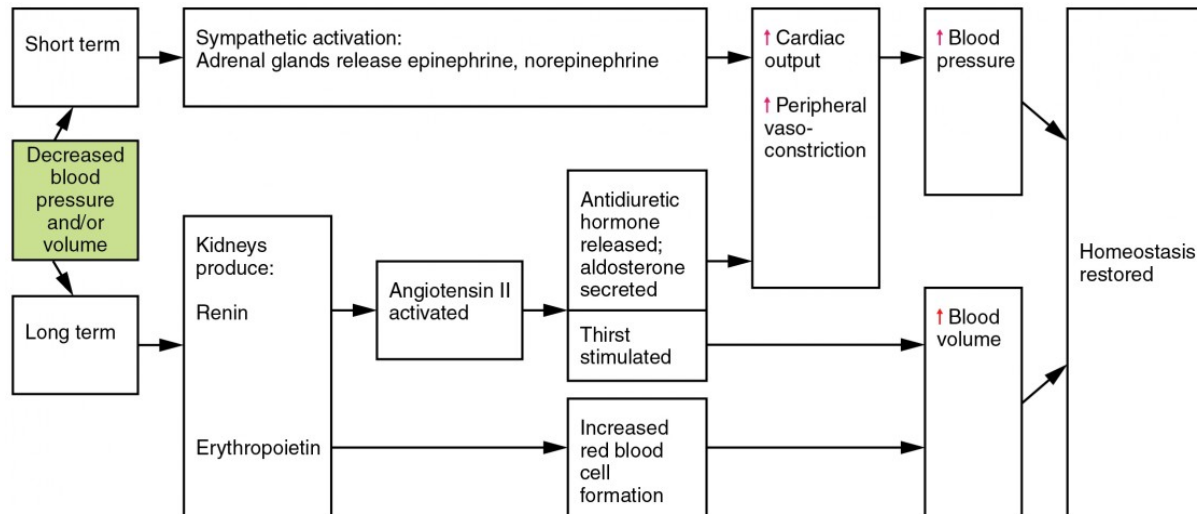
Endocrine Regulation

The endocrine catecholamines- **epinephrine, norepinephrine**, as well as hormones that interact with the kidneys in the regulation of blood volume. The catecholamines are secreted by the adrenal medulla and stimulate the body's "**flight or fight**" response via the sympathetic nervous system causing vasoconstriction and elevated blood pressure.

Vasopressin is secreted by the posterior pituitary and plays a crucial role in osmoregulation. The posterior pituitary is stimulated to secrete vasopressin especially during

cases when there is a significant loss in blood volume. Vasopressin acts on kidneys, re-absorbing more water thus preventing loss of additional fluid in urine. This plays a pivotal role in maintaining blood volume and pressure. Hypersecretion of vasopressin causes an elevation of blood pressure by constricting blood vessels.

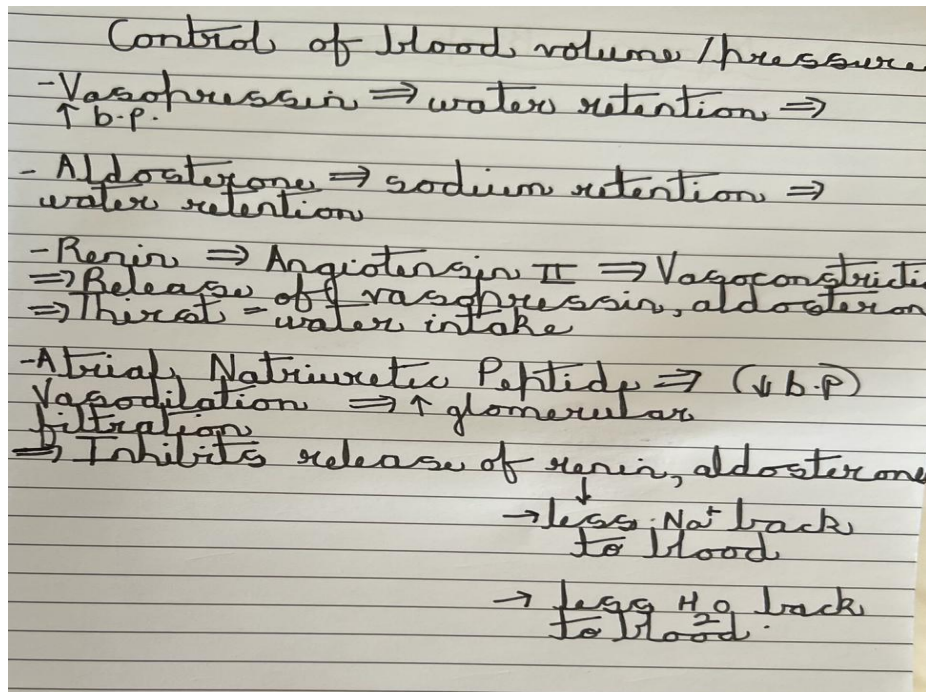
The renin-angiotensin-aldosterone(RAA) mechanism is also crucial in maintaining the homeostasis of blood pressure. Renin, an enzyme, converts plasma protein angiotensinogen(produced by the liver) into angiotensin I which gets catalysed into angiotensin II in the lungs. Angiotensin II is a powerful vasoconstrictor that greatly increases blood pressure and stimulates the release of ADH and aldosterone. It also stimulates the thirst centre in the hypothalamus causing the individual to drink more water causing the blood volume and pressure to increase. Aldosterone causes sodium retention which in turn leads to water retention in the blood thereby increasing blood volume and pressure.



Erythropoietin (EPO), released by the kidneys when blood flow decreases, is not only a powerful vasoconstrictor but also stimulates the production of erythrocytes within the bone marrow. Overproduction of EPO increases the system's viscosity, resistance, and hence, the blood pressure.

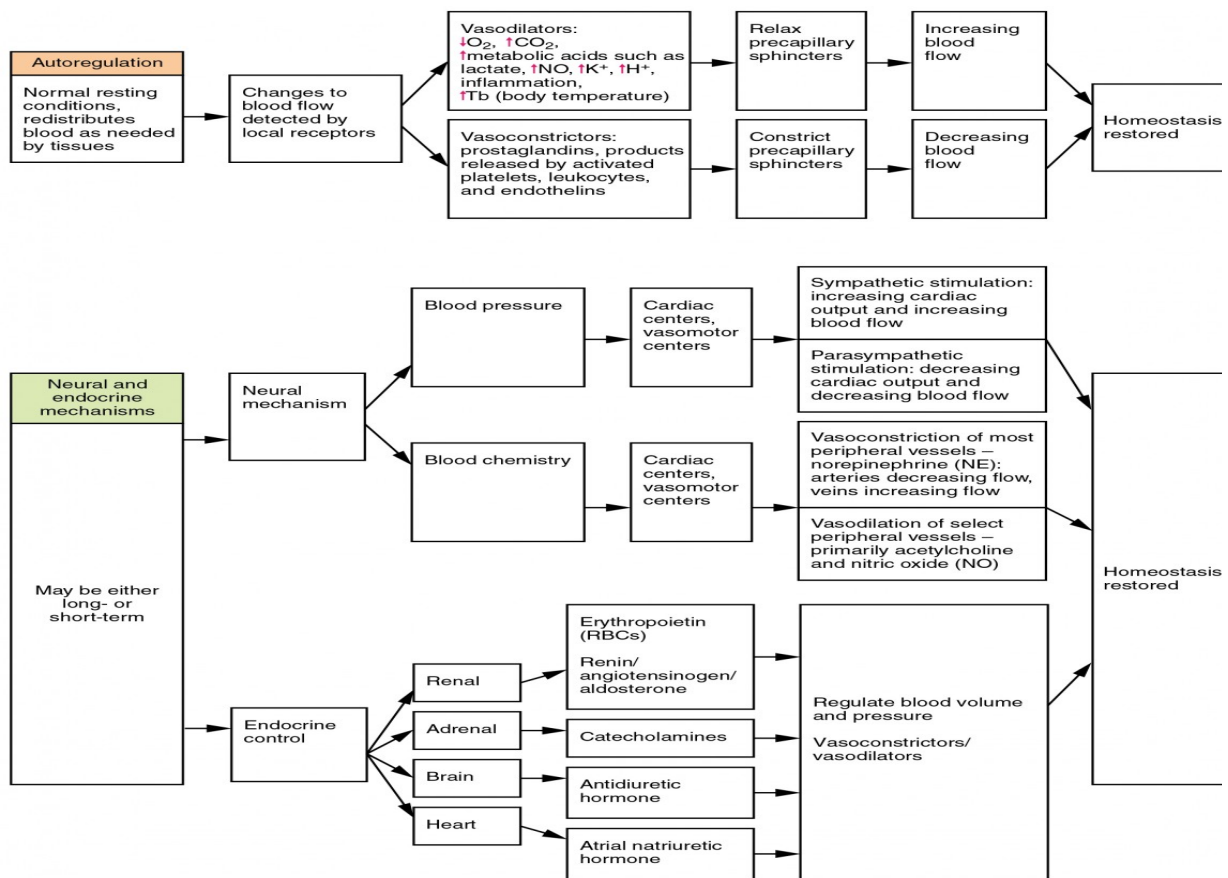
The Atrial Natriuretic Peptide brings about a decrease in blood pressure. It inhibits the secretion of renin and aldosterone hence inhibiting salt and water retention in the body. The decrease blood volume and blood pressure, increases glomerular filtration and increases

vasodilation.



Autoregulatory Mechanism

The autoregulatory mechanism of blood pressure includes **chemical signals and myogenic controls**. These are not brought about by any nervous or endocrine control. **Nitric oxide**, a powerful vasodilator secreted by endothelial cells, is released due to increased CO_2 concentrations, decreased O_2 conditions, increased levels of lactic acid, waste products of cellular metabolism, potassium ions, falling pH, increased body temperature and histamines. This causes a decrease in blood pressure. The myogenic response is also an essential autoregulatory mechanism of blood pressure.



Haemorrhage

The patient presented is a 30 year old female experiencing haemorrhage due to a stab wound.

A haemorrhage can be defined as the loss of blood from a damaged blood vessel/ abnormal bleeding and may be internal or external. The bleeding may be minor leading to petechiae or ecchymosis. Fatal external haemorrhages can be caused due significant trauma wounds which may hamper the body vitals as well as affect cognitive abilities. Blood is vital for transporting nutrients, hormones, distributing heat, maintaining body temperature, eliminating carbon dioxide and waste products. It protects the body against invaders through phagocytosis, diapedesis, secretion of antibodies (predominantly functions of leukocytes) and formation of blood clots(function of thrombocytes). Thus, haemorrhages can prove to be fatal as cells and nerves of the body do not receive adequate oxygen supply to carry out their inherent functions(hypoxia leading to coma, seizures, organ failure and death).

Physiological Changes to Blood Pressure Due To Haemorrhage

Haemorrhages cause a **drop in blood pressure** and may prove to be fatal. Hence, the homeostatic mechanism of the body works to restore normal conditions by increasing the blood pressure. In the case of the female patient, a serious haemorrhage occurs hence the stretch in the blood vessels decreases. The rate of action potentials produced per minute due to baroreceptors of the glossopharyngeal and the vagus decreases. This in turn stimulates the sympathetic nervous system that increases blood pressure since the heart rate, stroke volume and resistance of the system increases. Vasoconstriction occurs and the body is prepared to fight against the violent, abnormal conditions. Cardiac contractility and cardiac output increases. Temperature, pulse and respiration(TPR) increases.

Hypoxia caused due to haemorrhage also stimulates the chemoreceptors. This is detected by the pulmonary stretch receptors that stimulate the cardiac accelerator centre and increase the sympathetic effect, so as to take in greater oxygen and cause the carbon dioxide to diffuse out rapidly(Increases blood pressure and heart rate).

The renin-angiotensin-aldosterone(RAA) mechanism leaps into action. Angiotensin II brings about vasoconstriction, greatly increasing blood pressure and stimulates the release of ADH and aldosterone. The thirst centre in the hypothalamus is stimulated causing the water intake and therefore the blood volume to increase.

Aldosterone causes sodium retention which in turn leads to water retention in the blood thereby increasing blood volume and pressure.

Haemorrhages stimulate the posterior pituitary to secrete vasopressin as a response to low blood volume. Vasopressin reabsorbs water from kidneys to prevent loss of fluids and increases water retention, elevating blood pressure by increasing blood volume.

Aldosterone is secreted causing sodium retention thereby leading to water retention.

Catecholamines(adrenaline) secreted by the adrenal medulla initiate “fight or flight” response and stimulate the sympathetic nervous system(vasoconstriction and elevated blood pressure). Erythropoietin (EPO) is secreted and the secretion of the Atrial Natriuretic Peptide is inhibited. Myogenic controls bring about vasoconstriction and secretion of nitric oxide(a vasodilator) is inhibited.

Hence, to summarise, the **mechanism works to increase the dropping blood pressure**.

Other Considerations

Pregnancy

Abdominal stab wounds in pregnant women might result in uterine perforation, foetal chest injury. It can cause elevated levels of cortisol leading to foetal distress and can adversely affect the development of the foetus. Uterine contractions and premature labour, need for immediate MTP's or foetal loss. Hence, an OB-GYN must be available to attend to the foetus.

Location(internal bleeding)

The location of the stab wound is a crucial factor. The five areas of a potentially life threatening haemorrhage are: the thorax, the abdomen, retroperitoneum, the pelvis, and the

thighs. Hence, greater care is required as they can possibly cause damage to the internal organs. Depending on the extent of the injury, it should be decided whether the woman needs surgery or not.

A stab wound may simply cause a small cut in the skin but may be grave, rupturing tendons, delicate blood vessels and organs.

Stab wounds to the chest may cause rib fractures, lacerations to vital arteries, reduction in cardiac output, impairment of ventilation or hemothorax. Penetrating abdominal injuries may cause hypovolemic shock or peritonitis.

Retroperitoneal hematomas may occur due to stab wounds in the retroperitoneum.

Pelvic or femoral fractures occur due to stab wounds in the pelvic area and may also cause damage to the intestines, rectum, part of the descending colon, uterus, fallopian tubes and ovaries (should be brought into consideration if the woman is pregnant).

Statistically, it has been found that the intestines were most commonly impacted by penetrating trauma (70.1% of cases), followed by the liver and spleen (19.4% and 17.9%, respectively).

Surgery is required to stop internal bleeding and repair lacerations in organs (if any).

Infection

. Increasing pain, swelling, pus, redness are signs of infection. On light skin, spreading redness and on dark skin, purplish-grey or darker colour indicate infection. Puncture wounds may also cause tetanus as the object that caused the wound may carry bacteria or spores that cause tetanus. Contaminated penetrating bodies is the predominant cause of infection. Stab wounds or puncture wounds are prone to get infected thus must be treated with utmost care.

Medical History

Medical history plays a pivotal role in deciding the course of treatment. Previous use of anticoagulants, antiplatelet medications, recent trauma procedures and bleeding diathesis should be known by the doctor.

Severity of Haemorrhage

The course of treatment and action depends on the severity of the haemorrhage.

Class I- 15 % loss of total blood volume

Class II- 15-30% loss of total blood volume

Class III- 30-40% loss of total blood volume

Class IV- Greater than 40% loss of total blood volume.

At the very beginning (just after being stabbed), the woman may be a Class II as this includes tachycardia, increased heart rate and deviation of vital signs from normal. This can be expected due to the negative feedback mechanism and the homeostatic mechanisms of the body to restore normal conditions.

Cause of Stab Wound

The cause of the stab wound is extremely important. Stab wounds can be caused by accidents

such as getting impaled by falling ice shards, falling pieces of glass due to the breaking of a window or a vase, breaking of glass apparatus in a laboratory, mishaps with sharp tools. If a criminal factor is involved then the hospital must immediately inform the police.

It is crucial to not only understand the physiological changes that occur due to a trauma or injury but also holistically understand the patient's history as well as the possible complications to determine the best course of treatment while adhering to the principles of ethical medicine such as non-maleficence and beneficence. Various considerations along with anatomy, physiology need to be taken into account in order to ensure quality treatment. In conclusion, the 30 year old woman's medical history, cause and location of stab wound, possibility of infection, pregnancy, severity of haemorrhage must all be taken into account during treatment.

-Tanisha Chadha

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