Risk of Developing Cardiovascular Diseases on Radiation Exposure to Thoracic Region: A Review

By

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Bachelor of Pharmacy (Hons.)

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Declaration

It is hereby declared that

1. The thesis submitted is my own original work while completing degree at BRAC University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I have acknowledged all main sources of help.

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Approval

The thesis titled "Risk of Developing Cardiovascular Diseases on Radiation Exposure to Thoracic Region: A Review" submitted by Dhrubanil Mazumder (ID 19146061) of Spring, 2019 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Pharmacy.

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Ethics Statement

This study does not include any animals or human trials.

Abstract

Radiotherapy is widely used in the treatment of carcinoma and tumors. Exposure to radiation in itself isn't necessarily detrimental to the patient undertaking it but here one important point of consideration is for how long and to what extent, the kind of radiation the patient is exposed to and in which part of the body. Considering all aspects and necessities of radiation therapy, extreme caution should be taken by the professionals administering it especially in the thoracic region because a subtle indifference can boost up chances of developing cardiovascular diseases which may or may not be lethal which again depends on the degree of exposure to radiation. In this review paper, the risk of developing cardiovascular diseases on radiation exposure to thoracic region has been discussed.

Keywords: Radiation, endothelial dysfunction, cardiovascular diseases, oxidative stress.

Dedication

I dedicate my work to my beloved parents whose tireless and selfless endeavors made me come this far.

Acknowledgement

First of all, I would like to thank Almighty for his guidance.

Secondly, I want to thank my supervisor, Tanisha Tabassum Sayka Khan, Lecturer, School of Pharmacy, BRAC University, for mentoring me through every stage of this project. She has been a key support throughout.

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Last but not least, I would like to express my sincere gratitude to my parents, who are truly deserving of praise for the person I have become.

Table of Contents

List of Figures

List of Acronyms

CDV	Cardiovascular Disease
CT	Computerized Tomography
RICVD	Radiation Induced Cardiovascular Diseases
WHO	World Health Organization
NHS	National Health Service
DNA	Deoxyribonucleic Acid
ROS	Reactive Oxygen Species
eNOS	Endothelial Nitric Oxide Synthase
NO	Nitric Oxide
DDR	DNA Damage Response
IMRT	Intensity-Modulated Radiation Treatment

Chapter 1

Introduction

1.1 Background

Cardiovascular diseases (CVDs) are the major reason for deaths around the globe giving it the highest mortality rate among other prevalent diseases. There is an estimation that around 17.9 million people have died from CVD alone which makes up around 32% of deaths worldwide. Of this percentage around 85% deaths were because of stroke and heart attacks and most of these deaths took place in third world countries (*Cardiovascular Diseases (CVDs)*, 2021). There are certain factors that contribute more or less to this extreme prevalence of CVDs throughout the globe some of which can be irregulated consumption of alcohol, smoking, sedentary lifestyle, following an unhealthy diet consisting of junk foods eventually causing obesity, lack of physical activity and so on and so forth (*Cardiovascular Diseases (CVDs)*, 2021). Now since our research mainly focuses on CVDs that are caused by radiation so let's shed some light on radiation, what it is and how a human body can be affected by it.

Radiation can be emitted from a variety of sources and people can be exposed to it in different ways. Here are some common ways people can get exposed to radiation. Some notable sources of radiation can be natural like radioactive materials on the earth's surface, radioactive gases like radon. People can get exposure to radioactivity via some medical procedures such as X-ray, computerized tomography (CT) scans, radiotherapy and ionizing radiation in the diagnosis of several diseases. Apart from that, radiation exposure can be found in people working in industries like nuclear plants, medicine facilities and also because of nuclear accidents. The degree of threat from radiation exposure depends on the type, amount and duration of exposure as well as some physiological factors such as age and health status.

It has been found after extensive studies and research that there is a link between radiation exposure and cardiovascular disease precisely due to the exposure to radioactivity in the thoracic region. Blood vessels can be damaged by radiation, which can result in atherosclerosis, endothelial dysfunction, and inflammation. This can raise the chance of developing a number of cardiovascular diseases, including peripheral artery disease, coronary artery disease, heart attack, and stroke. High radiation exposure, the presence of factors associated with cardiovascular disease, or a family history of susceptibility to CVD all contribute to the risk. Additionally, it has been seen that the risk of developing CVD from radiation exposure may persist for several years after exposure. In order to lower the risk factors, those who have been exposed to radiation should quit smoking, maintain a healthy weight, control their blood pressure, and monitor their cholesterol and blood sugar levels. They should also get frequent cardiovascular health checkups.

Now some underlying reasons for pathogenesis of radiation induced cardiovascular diseases (RICVD) has been backed by some studies. It has been found that radiation treatment administered directly to the thorax can cause myocarditis, acute pericarditis, and pericardial effusion, which are acute inflammations of the pericardium and myocardium (*Radiation and Health*, 2022). In addition to that, high-dose irradiation of heart tissues may cause deaths of all cell categories, such as those of the epithelium, the myocardium as well as the transport system (*Radiation and Health*, 2022). In this review paper, a comprehensive insight has been provided on the risk of developing cardiovascular diseases due to exposure to radiation in the thoracic region.

1.2 Objectives of the Study

Radiotherapy is an inseparable means of cancer treatment as no other viable and efficient alternatives has not been developed till date. In this regard there are multiple instances or cases of carcinogenicity as well as cardiovascular irradiation observed in patients that were under cardio-oncology study. Thus, it is crucial to recognize risks and to enrich our methodologies in combating the risks associated with cardiovascular complications caused by thoracic radiation without jeopardizing cancer control.

The objectives of this study are-

- To provide a comprehensive insight on the impact of radiation in developing cardiovascular diseases
- To highlight some preventive measures

1.3 Rationale of the Study

To better understand the possible health concerns connected to radiation exposure in the thoracic area, researchers have been examining the risks of cardiovascular disorders caused by this exposure. There are certain occupations which demand being exposed to radiation, for example working in a nuclear power plant or healthcare professionals like radiologic technologists and so on and so forth. Patients undergoing specific medical treatments, such as X-rays, computed tomography (CT) scans, and radiation therapy for cancer, also expose the thoracic area to radiation. Therefore, it is imperative to study the relationship between CVD and radiation in order to process a safety guideline and thereby help the healthcare professionals and radiation workers minimize unnecessary exposure to radiation while providing appropriate monitoring and care for those who are exposed. In the long run, this research may assist those who are at risk for CVD have better health outcomes.

Chapter 2

Methodology

This review paper has been written in accordance to the terms and policies regarding plagiarism and originality all the while collecting necessary information and data from the most authentic and reliable sources comprising of renowned websites such as World Health Organization WHO, mayo clinic, National Health Service (NHS) as well as article databases such as Pubmed, Scopus, Springer and Science direct. A comprehensive outline covering all the relevant topics and subtopics was made beforehand to make the paper look concise, informative and well organized. Furthermore, repetitive and irrelevant information were omitted out. The relevant articles and topics were found on the internet and databases by searching keywords like radiation, endothelial dysfunction, cardiovascular diseases, oxidative stress etc.

Chapter 3

Applications of Radiation

3.1 Radiotherapy for Cancer

Radiotherapy or radiation therapy is a common prophylaxis in oncology for treating various types of cancers which involves use of high energy rays like X rays or gamma rays to target and eliminate cancer cells while minimizing damage to healthy surrounding tissues.

Radiation mainly damages the DNA of cancer cells thus preventing their ability to divide and multiply (Torgovnick & Schumacher, 2015). Radiotherapy can be used as a standalone treatment or in combination with other modes of treatment like chemotherapy and surgery depending on the type, stage and location of the cancer cells.

It can be divided into two main types depending on their mode of action which are-

- External beam radiation therapy- Involves delivery of radiation from a machine outside the body.
- Internal beam radiation therapy- Involves placement of radioactive sources inside the body near tumor cells (*Radiation Therapy to Treat Cancer*, 2019).

The use of radiotherapy is applicable in different stages of cancer like curative intent by killing the cancer cells, palliative care in order to remove symptoms and enhance quality of life and adjuvant therapy in order to prevent possibility of recurrence after surgery (*Radiotherapy*, 2020).

Despite its efficacy and success rate, radiation therapy has some potential side effects just like any other conventional medical intervention depending on the area where the radiation is used and to what intensity. Common side effects include death of healthy non tumor cells, changes in skin color, discomfort in the area and many more (*Radiotherapy*, 2020). But due to technological advancement, newer and more precise techniques are being developed which cause minimal damage to the surrounding healthy tissues while efficiently reducing the cancer cells.

High professionalism and competence are required to administer radiotherapy on patients. A team of healthcare professionals which includes radiation oncologists, medical physicists and radiation therapists work as a unit to personalize a treatment for a patient (*Who Gives Radiotherapy*, 2020).

3.2 Radiosurgery for Cardiac Arrhythmia

A minimally invasive method called radiosurgery for cardiac arrhythmias employs high-energy radiation to correct irregular heart rhythms. For individuals with cardiac arrhythmias that are not effectively managed by conventional medications, it is a relatively new and growing therapy option (Zei & Soltys, 2017).

While doing a radiosurgery for cardiac arrhythmia, a specialized team of healthcare professionals, by using advanced imaging techniques, precisely locate the abnormal areas of the heart that are responsible for arrhythmia. High energy radiation is delivered to these targeted areas, using highly focused and precise beams to destroy the abnormal heart tissue while sparing healthy tissue around it (Zei & Soltys, 2017)

There are a number of possible advantages to radiosurgery for cardiac arrhythmia. Since there are no incisions or scars and it is a minimally invasive or non-invasive technique of therapy, patients frequently experience less pain and recover more rapidly than with traditional surgical treatments. Additionally, it permits extremely accurate targeting of the aberrant cardiac tissue, which may lead to better results and a lower risk of problems (Kondziolka et al., 2012).

In order to completely comprehend its long-term safety and effectiveness, further study is required because it is currently regarded as a relatively new and developing therapy strategy. The choice to undertake radiosurgery for cardiac arrhythmia should be made in conjunction with a skilled healthcare expert because it may not be appropriate for all individuals.

3.3 Radiation for Diagnostic Purpose

To aid medical professionals in the diagnosis and management of numerous medical disorders, radiation is frequently employed in diagnostic imaging. Using controlled radiation doses, diagnostic imaging methods like X-rays, CT scans, and nuclear medicine scans produce images of the inside of the body that are helpful for diagnosis and therapy planning (*Radiation in Healthcare:Imaging Procedures*, 2021).

One of the most widely used radiation-based diagnostic imaging methods is the use of X-rays. They can identify fractures, infections, cancers, and other abnormalities and are used to see bones and organs. Ionizing radiation, which is used in X-rays, is used to form an image on a detector or film after passing through the body. As X-ray radiation is rigorously regulated and kept as low as possible to prevent any potential injury, the dangers associated with it are often minor.

X-ray technology is used in CT scans to provide finely detailed cross-sectional images of the body. In addition to aiding in the diagnosis of diseases including cancer, cardiovascular illness, and trauma injuries, CT scans are particularly helpful for imaging interior organs, blood vessels, and soft tissues. However, compared to X-rays, CT scans do subject the body to a higher dosage of ionizing radiation, and the advantages of the treatment are balanced against any possible hazards (Schmidt, 2012).

Radiopharmaceuticals are a subset of medications that are administered to patients via injection, ingestion, or inhalation. These radiopharmaceuticals produce gamma rays that are detected by a specialized camera to produce images of the internal processes of the body, such as metabolism, blood flow, and organ function. Nuclear medicine scans are frequently used to identify ailments like cancer, thyroid issues, and bone abnormalities. Nuclear medicine scan radiation levels are constantly monitored and adjusted to reduce patient exposure (*General Nuclear Medicine*, 2022).

3.4 Individual Radiation Sensitivity: Genetic and Gender Effects

The response of organisms to ionizing radiation, or radiation sensitivity, can differ based on genetic and gender factors. A person's sensitivity to radiation damage is mostly determined by genetic characteristics, and gender can have an impact on how various organs and tissues response to radiation exposure (Narendran et al., 2019). These two factors are described briefly below:

Genetic effects: Radiation sensitivity might vary from person to person depending on genetics. An individual's risk of contracting radiation-related illnesses like cancer or other radiation-induced disorders can be increased by specific genetic abnormalities. For instance, those who have mutations in the DNA repair genes BRCA1 and BRCA2 may be more vulnerable to radiation harm since these genes are involved in the repair of DNA damage brought on by radiation exposure (Kan & Zhang, 2015). Further influencing an individual's radiation sensitivity is their capacity to digest and expel radiation-induced poisons from the body, which is influenced by hereditary variables.

Gender effects: Both men and women's radiation sensitivity can vary depending on their gender. According to studies, there may be variations in how people react to radiation due to physiologic and hormonal variables. Women, for instance, typically have stronger defenses against radiation-induced Deoxyribonucleic Acid (DNA) damage, including higher levels of antioxidants, estrogen, and progesterone, which can lessen the effects of radiation. On the other hand, because of variations in hormonal and physiological reactions, men may be more susceptible to radiation-induced health issues, such as cancer (Narendran et al., 2019).

It's important to note that radiation sensitivity is a complex and multifactorial trait, and genetic and gender effects are just some of the factors that can influence an individual's response to radiation exposure.

Chapter 4

Mechanism of Radiation Induced Injury

4.1 Endothelial Dysfunction Causes Cardiovascular Diseases

The inner lining of blood vessels is made up of endothelial cells, which are essential for controlling blood flow and preventing blood clotting. Impairment in the function of these cells is known as endothelial dysfunction, and it is a prevalent underlying factor in many cardiovascular illnesses.

A number of processes are involved in the complex process of radiation-induced endothelial dysfunction. Ionizing radiation can directly harm endothelial cells, the cells that line the inside of blood arteries, and impair their ability to function normally when it enters the body (Wijerathne et al., 2021).

Changes in the expression of genes involved in endothelial cell function, such as those involved in cell adhesion, migration, and proliferation, can also be brought on by radiation. Endothelial cells may be less able to heal themselves as a result of these modifications, which could result in additional dysfunction and damage (Smirnov et al., 2009).

Several factors can contribute to endothelial dysfunction, including high blood pressure, high cholesterol, smoking, diabetes, obesity, and inflammation (Sun et al., 2020). These elements can harm endothelial cells, reducing their capacity to create nitric oxide, a substance that widens blood arteries and supports normal blood flow. Blood arteries may stiffen and constrict as a result of decreased nitric oxide production, which raises the risk of heart attacks, strokes, and other cardiovascular events (Ahmad et al., 2018).

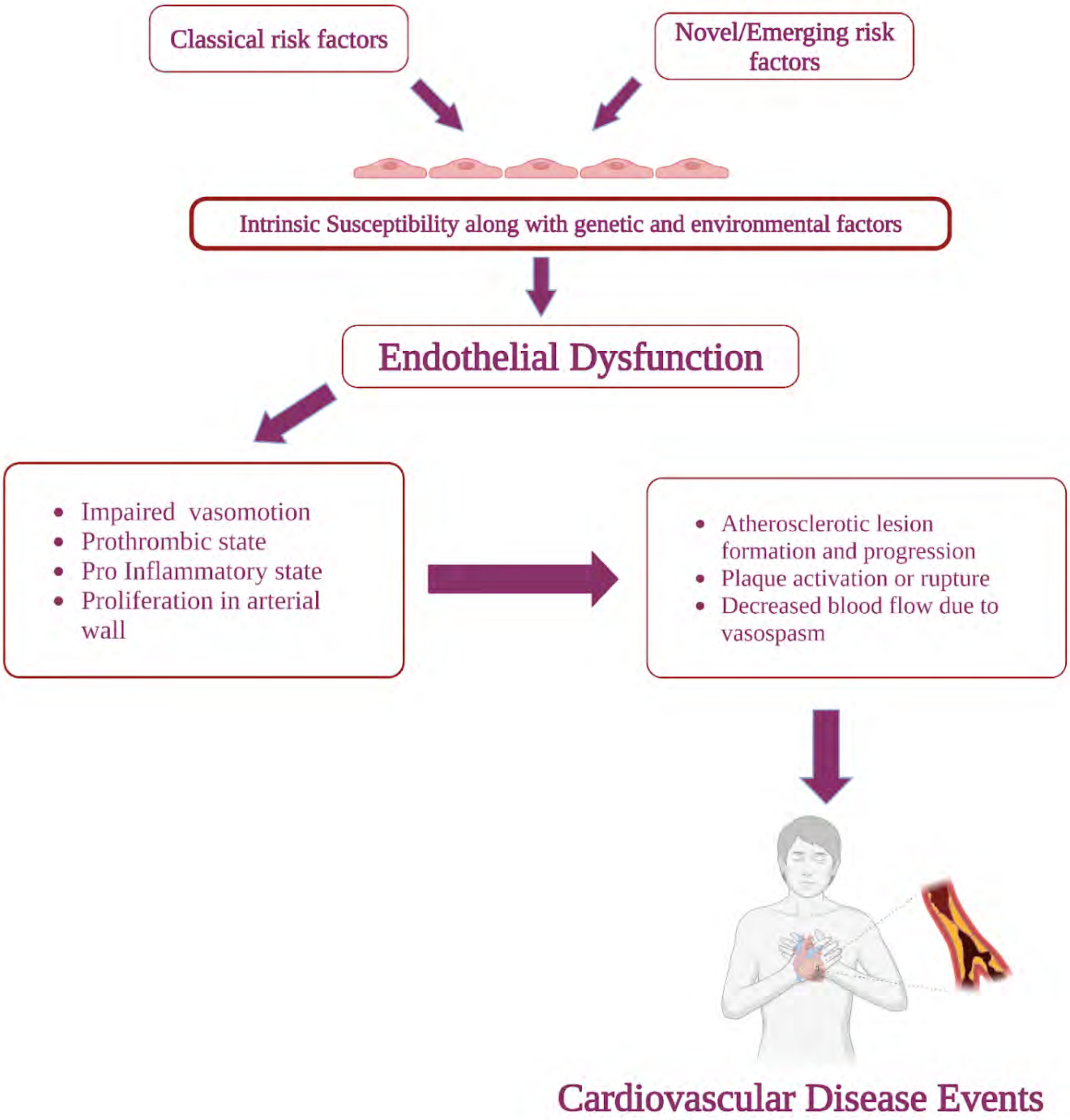

Figure 1: Radiation induced endothelial dysfunction causing CVD (Adapted from Widlansky et al., 2003)

As seen from Figure 1, there are several factors and events involved in causing endothelial dysfunction which in turn leads to cardiovascular diseases. The risk factors can be categorized into two which are classical (diabetes, smoking, hypertension, aging) and novel or emerging (infection, physical inactivity, obesity). These factors causing endothelial dysfunction are again based on one's individual susceptibility, genetics and environmental factors. If someone has endothelial dysfunction, it then triggers the following events such as impaired tone, prothrombotic and proinflammatory state as well as proliferation in arterial cell wall which eventually leads to atherosclerotic lesion formation and progression, plaque activation and rupture and decreased blood flow to the organs due to thrombosis and vasospasms thus causing cardiovascular diseases.

Furthermore, endothelial dysfunction can cause an uptick in inflammation and oxidative stress, which can worsen blood vessel damage and encourage the development of plaque buildup in arteries (Sun et al., 2020).

Overall, many cardiovascular illnesses are mostly a result of endothelial dysfunction. These disorders may be prevented or treated with endothelium function-improving methods including targeted therapy, medicine, and lifestyle modifications.

4.2 Aging and Oxidative Stress Induces Senescence in Endothelial cells

The complex process of aging is linked to a number of physiological changes in the body, such as a deterioration in organ function, a reduction in tissue repair, and an elevated risk of disease. Radiation can significantly affect aging and the oxidative stress that causes endothelial cells to senescence. The inner blood artery walls are lined by endothelial cells, which are essential for preserving vascular health. Endothelial cells are susceptible to radiation damage, which can result in cellular senescence, an irreversible growth halt. Reactive oxygen species (ROS), which can harm cellular components like DNA, proteins, and lipids, are one way that radiation might cause senescence. Cellular senescence and aging may be brought on by the accumulation of oxidative damage over time (Liguori et al., 2018) Furthermore, exposure to radiation can activate cellular signaling pathways like p53 that control cell development and senescence (Okazaki, 2022).

Endothelial cells are essential for keeping blood vessels healthy and functioning properly, and their malfunction is linked to a variety of age-related illnesses, including cardiovascular disease. Senescence can be brought on by oxidative stress in endothelial cells, which results in an irreversible cell cycle arrest and the release of pro-inflammatory chemicals that can further harm the tissue around them (Klein & Ackerman, 2003).

Senescence of endothelial cells can cause a number of aging-related diseases, including atherosclerosis, hypertension, and thrombosis. Senescent endothelium cells have a modified secretory profile, releasing growth factors, cytokines that can cause inflammation, and other substances that can hasten the onset of age-related illnesses (Hwang et al., 2022).

Let's now talk about how radiation-induced endothelial nitric oxide synthase (eNOS) activation results in the senescence of vascular endothelial cells. Vascular endothelial cells senescence when eNOS is activated by radiation, which impairs the endothelium's ability to function. Reactive oxygen species (ROS) are hypothesized to operate as a mediator in this process by activating eNOS and increasing the production of nitric oxide (NO). However, excessive NO production can cause DNA damage, oxidative stress, and eventually cellular senescence. Studies have suggested that endothelial dysfunction-related illnesses like atherosclerosis and diabetes, as well as radiation-induced vascular injury, may be exacerbated by eNOS activation-induced senescence (Nagane et al., 2021). In order to prevent or treat these disorders, it may be therapeutically advantageous to target the eNOS pathway.

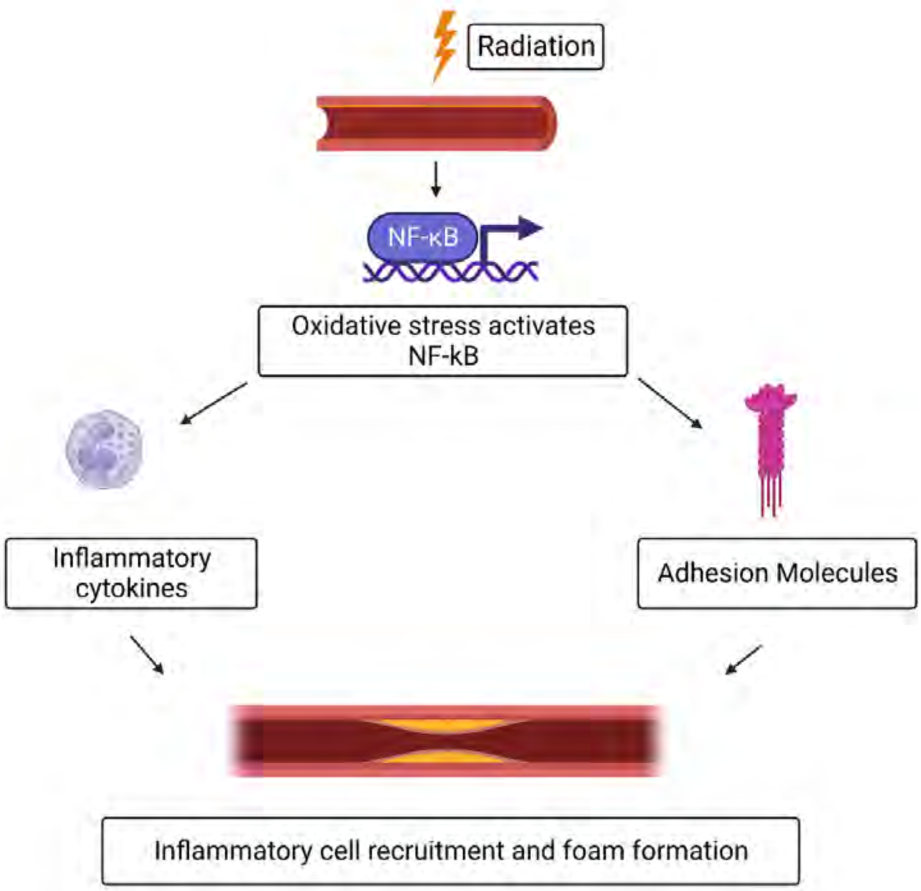

Figure 2: Radiation induced oxidative stress causing endothelial dysfunction (Adapted from DeZorzi, 2018)

The diagram above gives us a detailed insight on how radiation is eventually causing endothelial dysfunction. When the cells of the inner lining of blood vessels are exposed to radiation, it causes oxidative stress that activates the protein transcription factor Nuclear factor kappa B(NF-kB). This factor helps release of inflammatory cytokines as well as causes molecular adhesion which then causes an unnatural cell growth and foam formation in the vessel linings known as endothelial dysfunction.

In a nutshell, radiation exposure can cause endothelial cells to undergo oxidative stress and cellular senescence, which can aid in the emergence of age-related illnesses. The development of new medicines aiming at reducing the negative effects of radiation exposure and preventing or curing age-related disorders may be facilitated by understanding the mechanisms underlying these processes. To completely comprehend the mechanisms underlying radiation-induced eNOS activation and its contribution to vascular dysfunction, additional research is also required.

4.3 DNA Damage Response-induced Endothelial Dysfunction After Radiation Exposure

The DNA of endothelial cells, which line the interior of blood arteries, can be damaged by radiation exposure. The DNA damage response (DDR), which is triggered by this DNA damage, is a complicated network of signaling mechanisms.

The DDR is a safeguard that aids in the repair of damaged DNA and helps stop the spread of potentially dangerous mutations. However, the DDR can also start a chain of events that results in endothelial dysfunction when the extent of DNA damage is high or prolonged (Liguori et al., 2018). Endothelium dysfunction describes a condition in which the endothelium cells are unable to correctly carry out their typical tasks. Radiation-induced endothelial dysfunction can cause a number of cardiovascular issues, such as inflammation, oxidative stress, and poor blood flow.

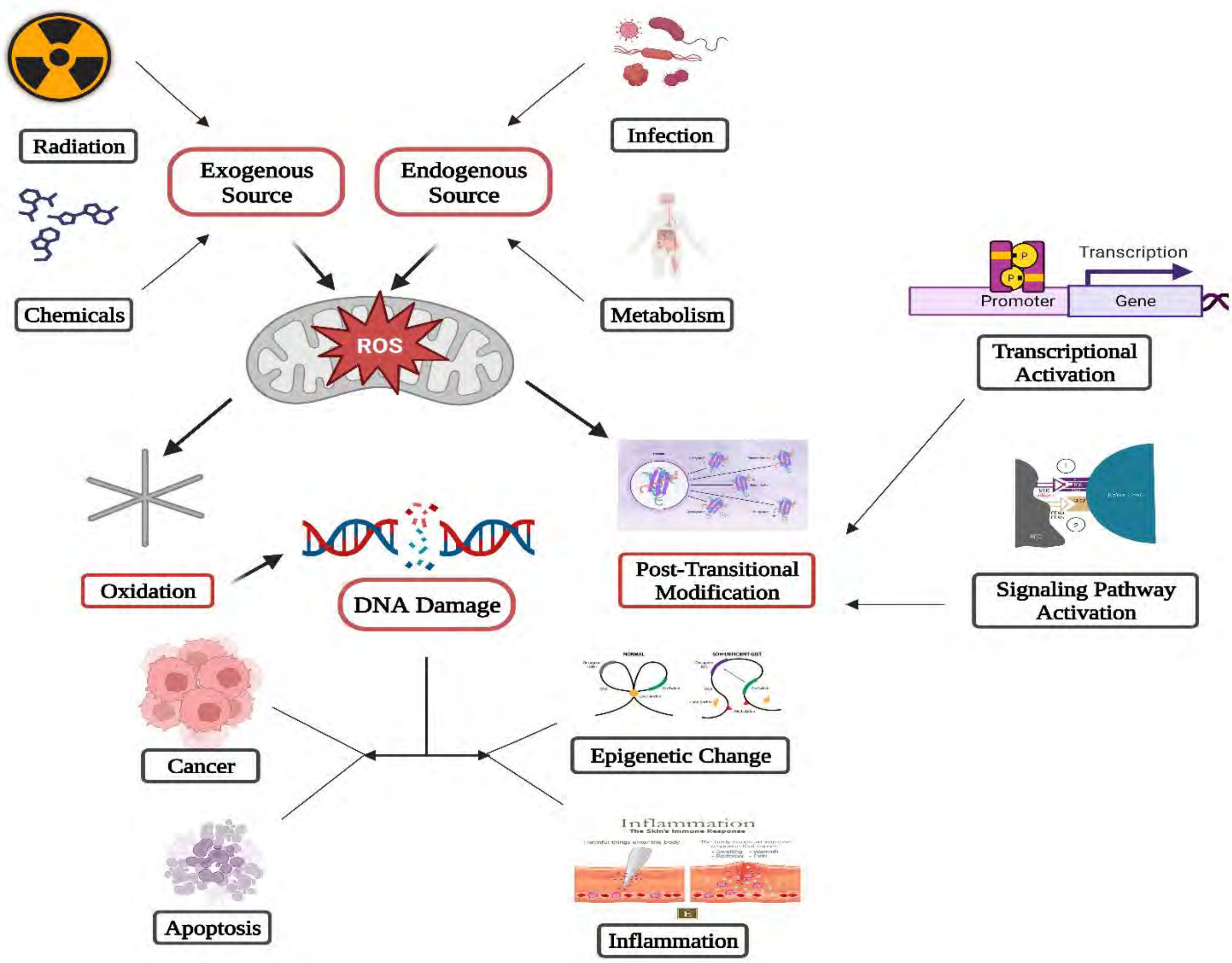

Figure 3: Radiation induced oxidative stress causing DNA damage (Adaped from Sahan et al., 2018)

The flow diagram shown in Figure 3 above tells us how radiation can trigger DNA damage response which sometimes causes endothelial dysfunction. Radiation exposure to the thoracic region from external sources can cause formation of reactive oxygen species. These species are responsible for oxidative stress which in turn damages the DNA crucial for cellular mechanisms such as division and proliferation. As the DNA of the endothelial cells are damaged, the normal cells become apoptotic or carcinogenic. They behave abnormally and they no longer carry out cellular activities which eventually impairs the flow of blood to the respective organs.

In outcome, it can be said that exposure to radiation can cause DNA damage in endothelial cells, which activates the DDR and ultimately results in endothelial dysfunction. This emphasizes how crucial it is to reduce radiation exposure and create practical methods to shield endothelium cells from radiation-induced harm (Nagane et al., 2021)

Chapter 5

Radiation Induced Cardiovascular Diseases

5.1 Radiation-induced Pericarditis

A condition known as radiation-induced pericarditis is characterized by inflammation of the pericardium, the heart's protecting membrane, as a result of radiation therapy exposure. It is a potential adverse reaction to radiation therapy for a number of chest malignancies, including breast cancer, lung cancer, and lymphomas (Marinko, 2018).

Although the precise process of radiation-induced pericarditis is not entirely understood, it is thought to be the result of radiation damage to the pericardial tissue. Chest pain, especially when breathing deeply or resting flat, a persistent cough, breathing difficulties, exhaustion, and occasionally fluid buildup around the heart are typical symptoms of pericarditis.

An extensive medical evaluation, including a review of the patient's radiation treatment history and imaging tests like echocardiography or cardiac magnetic resonance imaging, is required to make the diagnosis of radiation-induced pericarditis. Anti-inflammatory drugs to treat symptoms, pain management, and possibly pericardial fluid drainage if there is a large buildup are all possible treatments (*Pericarditis*, 2022).

To avoid problems and enhance outcomes, radiation-induced pericarditis must be identified and treated immediately. Patients who have undergone radiation therapy should be aware of the possibility of developing pericarditis and should notify their medical professionals right away if they experience any symptoms. For those who are at risk, frequent follow-up appointments and heart monitoring are frequently advised.

It's crucial to remember that radiation-induced pericarditis is a rather uncommon consequence and that, overall, the advantages of radiation therapy outweigh any possible hazards. Healthcare providers make every effort to reduce the likelihood of such side effects and offer effective management when they do.

5.2 Radiation-induced Valvular Disease

Radiation therapy for cancer treatment can cause a condition called radiation-induced valvular disease. The heart valves may get damaged as a result of the radiation exposure, creating valvular dysfunction. Despite being relatively uncommon, this illness can develop months to years following radiation treatment.

Heart valves damaged by radiation-induced valvular disease gradually get thicker and stiffer, impairing their ability to function. The aortic valve and mitral valve are the two valves that are most frequently harmed. Breathlessness, exhaustion, chest pain, and fluid retention are possible symptoms.

Echocardiography, which employs sound waves to evaluate valve anatomy and function, is frequently used in diagnosis. Options for treatment depend on the degree of valve involvement and symptom severity. To control symptoms at first, conservative management techniques and medicines may be used. Surgery to replace the valve may be required in more serious situations. Reduced radiation exposure to the heart during cancer therapy is the goal of prevention methods. Advanced radiation methods can help protect the heart from needless radiation, such as intensity-modulated radiation treatment (IMRT) and proton therapy. To identify and treat radiation-induced valvular disease in its earliest phases, radiation therapy patients must be closely monitored (Gujral et al., 2016).

Finally, radiation therapy may result in a long-term side effect called radiation-induced valvular disease. In order to reduce the negative effects of this condition on patients' cardiovascular health, awareness, early detection, and proper care measures are essential.

5.3 Radiation-induced Coronary Artery Disease

The term "radiation-induced coronary artery disease" (RICAD) describes heart disease that develops as a result of ionizing radiation exposure. This illness develops when radiation harms the heart's blood vessels and tissues, which causes coronary arteries to narrow or get blocked. High-dose radiation exposure, which may occur during specific medical procedures or at work, can raise the chance of developing RICAD. Additionally, those who have received radiation therapy for chest cancer treatment may also be at risk.

The development of atherosclerosis, a disorder in which fatty deposits build up in the arteries and obstruct blood flow to the heart, is thought to be the mechanism behind RICAD. Radiation exposure has the potential to inflame and harm the endothelial cells lining blood arteries, which can lead to the formation of atherosclerotic plaques (DeZorzi, 2018).

Similar to traditional coronary heart disease, RICAD can cause symptoms like chest pain (angina), exhaustion, shortness of breath, and, in severe situations, heart attacks. A diagnosis is often made after taking into account a patient's medical history, physical exam, imaging tests (such as an angiography), and radiation exposure assessment.

In order to prevent and treat RICAD, radiation exposure must be minimized whenever possible (DeZorzi, 2018). Techniques for radiation therapy have evolved throughout time to minimize harm to healthy tissues. Regular monitoring and lifestyle changes, including eating a heart-healthy diet, exercising frequently, and managing risk factors like high blood pressure and cholesterol, might help reduce the incidence of RICAD in those who have undergone radiation treatment.

Overall, radiation-induced coronary heart disease is a potential long-term side effect of radiation exposure, and its effects on those who are affected must be minimized through early detection, effective care, and lifestyle changes.

5.4 Radiation-induced Cardiomyopathy

Damage to the heart muscle brought on by radiation therapy is known as radiation-induced cardiomyopathy. This syndrome often develops as a result of radiation therapy for cancer of the chest. Radiation exposure can cause the heart's tissue to become inflamed, fibrotic, and scarred, impairing heart function (Belzile-Dugas & Eisenberg, 2021).

Fatigue, breathlessness, palpitations, chest pain, and fluid retention are just a few of the signs and symptoms of radiation-induced cardiomyopathy. After radiation therapy, the emergence of symptoms might happen months or years later, depending on a number of factors.

Radiation-induced cardiomyopathy requires a multimodal approach to treatment. Patients may be given beta-blockers and diuretics to treat the symptoms of heart failure. A heart-healthy diet, consistent exercise, and quitting smoking are other crucial lifestyle changes.

For individuals with significant heart dysfunction, more sophisticated procedures including the installation of a pacemaker or defibrillator, cardiac resynchronization therapy, or heart transplantation may occasionally be considered (Belzile-Dugas & Eisenberg, 2021).

Radiation therapy is highly concerned with preventing radiation-induced cardiomyopathy. In order to lower the risk of cardiac problems, modern methods and technology try to limit radiation exposure to the heart during treatment planning.

5.5 Autonomic Dysfunction

Radiation-associated cardiac autonomic dysfunction is a situation where radiation therapy has an adverse effect on the autonomic nervous system, which regulates the heart's automatic

actions. Breast, lung, and lymphoma malignancies are among the many cancers for which radiation therapy is frequently employed.
The local autonomic nerves and ganglia can sustain injury when radiation is administered to the chest or mediastinum. In order to control heart rate, blood pressure, and other cardiovascular processes, the autonomic nervous system is essential. The usual balance and regulation of these functions can be upset by damage to these nerves, which can result in cardiac autonomic dysfunction.

Symptoms of radiation-associated cardiac autonomic dysfunction can vary depending on the extent of nerve damage, but they commonly include:

1. Abnormal heart rate: This can manifest as tachycardia (elevated heart rate) or bradycardia (reduced heart rate).
2. Blood pressure fluctuations: Radiation can cause blood pressure to become unstable, resulting in episodes of high or low blood pressure.
3. Arrhythmias: Radiation damage to the heart's electrical system can lead to irregular heart rhythms, such as atrial fibrillation or ventricular arrhythmias.
4. Exercise intolerance: Patients may experience difficulty in performing physical activities due to reduced cardiovascular capacity.
5. Fatigue and dizziness: Autonomic dysfunction can cause fatigue and dizziness, especially during exertion or changes in body position.
6. Shortness of breath: Radiation-related lung damage can contribute to shortness of breath, which may be worsened by cardiac autonomic dysfunction (Teng et al., 2021).

A comprehensive approach is necessary for the treatment of cardiac autonomic dysfunction caused by radiation. An individualized treatment plan is created in collaboration with cardiologists, oncologists, and other medical specialists. Medications to control blood pressure and heart rate, cardiac rehabilitation programs to increase cardiovascular fitness, and lifestyle changes like dietary adjustments and stress reduction strategies are all possible treatment choices.
It's critical for people who have received radiation therapy to frequently check on their cardiovascular health and notify their medical team of any new or deteriorating symptoms. For patients with radiation-related cardiac autonomic dysfunction, early detection and treatment can help manage the symptoms and enhance overall quality of life.

5.6 Carotid Artery Disease

The main blood vessels in the neck that feed blood to the brain, the carotid arteries, are prone to narrowing or obstruction in carotid artery disease. Atherosclerosis, or the accumulation of plaque on the inner walls of arteries, is the primary cause of this illness.

Blood flow to the brain is restricted when the carotid arteries narrow or get blocked as a result of plaque buildup, raising the risk of stroke or transient ischemic attack, sometimes known as a "mini-stroke." The face or limbs may seem weak or numb, and other symptoms could include speech impediment, eyesight issues, and dizziness.

Imaging methods like ultrasonography, magnetic resonance angiography, or computed tomography angiography are frequently used to diagnose carotid artery disease (Sobieszczyk & Beckman, 2006). Treatment options depend on the severity of the disease and may include lifestyle changes, medications to manage risk factors like high blood pressure and cholesterol, and surgical interventions such as carotid endarterectomy or carotid artery stenting.

To reduce complications and avoid strokes, carotid artery disease must be identified and treated early. The course and effects of this disorder can be considerably slowed down by routine checkups, leading a healthy lifestyle, and managing risk factors. A correct diagnosis and a suitable treatment plan require the assistance of a healthcare expert.

Chapter 6

Conclusion

Radiotherapy can be termed as a necessary evil when it comes to treating cancer because of its risk and benefit tradeoff. It has been seen that prolonged exposure to high dose radiation therapy to the thoracic region can most likely develop cardiovascular ailments like atherosclerosis, coronary artery disease, valvular dysfunction etc. however, the effects of low dose radiation are still unclear.

Some studies indicate that low dose radiation exposure can cumulatively be a reason for CVDs given the time and type of radiation an individual is exposed to. It is to be noted that careful evaluation by healthcare professionals is a must to evaluate the risk and benefit ratio of radiation-based therapeutics and should only be administered by effective optimization and moderation while avoiding unnecessary irradiation to minimize potential adversities.

Safe to say that the momentous advancements in the fields of medical technology will further take this research to a whole new level. The threshold at which radiation can pose a significant threat can be better understood in days to come and risks associated with it can eventually be mitigated. The knowledge that we yield from this will bring refined radiation safety guidelines and help us implement proper state of the art strategies to further mitigate the potential risks associated with radiation exposure to the thoracic region.

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