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COMPLICATIONS OF TREATMENT

Radiotherapy to patients with artificial cardiac pacemakers

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Summary
Background: The in vitro studies show that the modern cardiac pacemakers utilising the complementary metal-oxide semi-conductor (CMOS) circuitry can be adversely affected by therapeutic radiation. However, the published clinical data are sparse regarding the safety of radiotherapy delivery to patients with artificial pacemakers. Despite the potential risk of life threatening complications, there are no national guidelines and most radiotherapy departments have no formal clinical risk management strategy in place. A literature review was performed to assess the risks involved in irradiating patients with pacemakers and to identify strategies, which minimise the risk of pacemaker malfunction. Recommendations for radiotherapy departments are made.
Conclusion: Modern multi-programmable pacemakers are very sensitive to therapeutic megavoltage irradiation. There is no safe radiation threshold for megavoltage radiation. The low energy kilovoltage X-rays used for radiotherapy simulation cause no pacemaker malfunction. Megavoltage radiation can be safely delivered to patients with cardiac pacemakers provided direct irradiation of pacemakers is avoided, adequate monitoring is done during and after irradiation, and the dose to the pacemaker generator is kept below 2 Gy. Close liaison with cardiologists and a pacemaker clinic is essential and radiotherapy departments should have protocols in place to identify and care for cancer patients with pacemakers.

Introduction

Even by conservative estimates, at least one million patients in USA have permanent artificial cardiac pacemakers and this figure could be in excess of five million worldwide.[1–3] This number

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is set to increase because of various reasons. Firstly, the life expectancy of the population, particularly in the West, has dramatically improved over the past century. For instance, the life expectancy has increased by more than 65% in England and Wales over the past century.[4] One consequence of the increase in longevity is the increase in prevalence of cardiovascular morbidity.[5,6] This in turn is leading to an increase in the number of patients with implanted permanent pacemakers. Secondly, the indications for artificial pacemaker insertion are expanding and the recent guidelines issued by the National Institute of Clinical excellence in UK and the American College of Cardiology reflect this trend.[7,8]

Cancer, like cardiovascular disease, is mostly a disease of the elderly. The age-standardised incidence of cancer has increased by more than 25% in the past 30 years.[9] It has been estimated that 50–60% of all patients with cancer will require radiotherapy at some point during the course of their illness.[10] Consequently, with an ageing population the number of patients with pacemakers presenting to the radiotherapy department is increasing.

The older generation of pacemakers were made up of bipolar semiconductor devices and were fairly resistant to radiation damage. Hence delivery of radiotherapy, in the past, posed no significant clinical risk.[11] By contrast, the modern programmable pacemakers are very sensitive to megavoltage radiation.[12,13] This increased sensitivity is due to the complementary metal-oxide semiconductors (CMOS) circuits used in the manufacture of cardiac pacemakers over the past three decades.

In fact, electromagnetic interference from any source can adversely affect pacemaker function. Such interference from linear accelerators can inhibit or inappropriately trigger the pacemaker. In the future, it is likely that sources of electrical interference will steadily increase because of new accelerators features, such as beam gating, and the appearance of in-room accessories such as breathing control systems. Special care may also be required when using automatic set up since reduced time in the treatment room may potentially increase the patient risks. However one of the main risks is from therapeutic megavoltage radiation which can damage or destroy both the hardware and software components of the pacemaker.[12]

Despite the potential risk of catastrophic complications, the published clinical data are sparse regarding the safety of radiotherapy delivery to patients with pacemakers. Most of the clinical data found on PubMed search are case reports of single patient. There are no reports of large case series and as far as the authors are aware, there are no ongoing prospective studies. There are no uniform recommendations from the manufacturers and the available recommendations are often unreliable.[14] Most radiotherapy departments do not have a formal protocol in place to deal with patients with pacemakers.[15] The American Association of Physicists in Medicine published guidelines in 1994 and in spite of the increasing sophistication of pacemaker technology over the part decade, there has been no other recent official publication of guidelines.[13] Hence, we did a literature review analyzing the hazards associated with irradiation of patients with artificial pacemakers.

Methods

The online PubMed database (1966–2004) at the National Library of Medicine was searched using the following key words. Artificial pacemaker, artificial cardiac pacing, implantable defibrillators, X-rays, photons, ionising radiation, radiotherapy, linear accelerators, electromagnetic fields, equipment failure, radiation damage and radiation effects. The reference lists of selected articles were searched for articles not retrieved by database search.

Overview of artificial cardiac pacemakers

The concept of cardiac pacemakers as potentially life saving devices emerged in 1950s. Since the first pacemaker implant in 1958, the technology and clinical practice of cardiac pacing has evolved rapidly over the past four decades.[16] It has been estimated that there are more than a million people with pacemakers in USA and these are being implanted at a rate of nearly half a million each year worldwide.[1]

Cardiac pacemakers are commonly inserted into a subcutaneous pocket over the anterior chest wall. The artificial pacemakers commonly pose a problem to the radiotherapists during the treatment of lymphomas, breast, lung, head and neck, thyroid and oesophageal cancers. In fact, management of these cancers often involves extensive use of radical as well as palliative radiotherapy. It has been estimated that up to 66% of patients with lung and breast cancers might require radiotherapy at some point during the course of the illness.[17–19]