Historically speaking, medical radiation therapy is a relatively old medical branch as it originated two centuries ago with the discovery of x-radiation by W. C. Röntgen in 1895. Shortly after this historical event the first treatment attempts were carried out by some courageous physicians. Since then radiation therapy evolution has undergone several major leaps due to essential developments in mechanical engineering, electronics, and computer science.

An introductory part gives an overview of these developmental steps through history. This is followed by some basic information on the physical and technological principles of radiation physics. Here radiation types, radiation sources, and the interaction of radiation with biological tissue are covered and finally rounded out with a more detailed look at dosimetry.

Furthermore, the three therapy fields for radiation treatments are discussed: percutaneous therapy, brachytherapy, and radionuclide therapy.

The main part covers equipment technology for the generation of radiation. In radiation therapy, ionizing radiation is used, which either results from radioactive decay processes or is generated by the acceleration of charged particles. The technologies described are x-ray equipment, cobalt unit, linear accelerator, brachytherapy sources/treatment units, and radioactive implants. A main focus is on the technology of linear accelerators, which serve as the daily workhorses nowadays.

Finally, special techniques and newer developments in teletherapy are discussed. Besides stereotactic and tomotherapy approaches, technological developments and refinements in the field of linear accelerator technology are described in more detail.
35.1 X-Radiation

On 8 November 1895 at Würzburg University’s Institute of Physics, W. C. Röntgen discovered a new type of radiation. In his first disclosure, Röntgen spoke of so-called x-rays because he didn’t know what type of radiation he was dealing with. With this he laid the foundations for medical radiation therapy (RT). Therapy with ionizing radiation began in 1896 in Vienna, only a few months after Röntgen’s discovery. Initial reports regarding the successful therapeutic application of X-radiation can be traced back to Freund, Sjögren, and Stenbeck. Based on newspaper reports of erythema and alopecia following exposure to x-rays, Professor Freund from Vienna had in 1896 treated a young girl suffering from nevus pigmentosus et papillomatosus with radiation. In 1966, the patient was presented at the German Radiology Congress. The result, which is illustrated in Fig. 35.1, clearly showed that the radiation had undeniably had the desired effect, which is to say that the hair on that patch had definitively disappeared. However, presumably also as a result of a lack of knowledge about adequate dosage, there was a significant side effect – considerable curvature of the spine in the radiation area. This illustrated in a striking manner where the main problem lies with this form of treatment: achieving a desired effect while avoiding undesirable side effects.

In 1899 in Stockholm, T. Sjögren and B. Stenbeck reported the first successful treatment of carcinomas of the lip and cheek using X-radiation. Figure 35.2 shows examples of the treatments of carcinomas of the lip and cheek using X-radiation.

35.2 Historical Development of Radiation Therapy

Initially, gas ion tubes consisting of a partially evacuated glass bulb with a cold cathode and anode were used as therapy systems. The first x-ray tube was a Hittorf tube as shown in Fig. 35.3.

The high voltage necessary for generating x-rays was produced using induction coils, which were, in principle, a transformer with a primary and secondary coil on a ferrite core. The cathode is in the form of a concave mirror, so that the cathode rays that emerge from the cathode perpendicular to the cathode surface meet at a point. At this focal point is the anticathode, a piece of sheet metal composed of platinum or tungsten that is inclined by about 45° and conductively connected to the anode. X-radiation is generated as a result of the metal ions and electrons impinging on the electrodes (cathode and anode), and there is simultaneous sputtering of the electrode material. The gas molecules present in the Hittorf tube are absorbed by the sputtered metal particles, and the vacuum in the tube increases. Ever higher voltages must be applied in order to ensure the flow of current. Because of the higher voltage, the x-rays become increasingly hard and finally the tube ceases to work. To make them usable again, gas had to be let into the tube. Soft x-rays are rays with a relatively