# Radiofrequency Physics for Minimally Invasive Aesthetic Surgery

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**KEYWORDS**

• Radiofrequency • Aesthetic • Collagen remodeling • Skin tightening • Nonsurgical • Facial rejuvenation

**KEY POINTS**

- Radiofrequency energy has multiple medical applications, including many noninvasive aesthetic uses.
- Nonablative technology, through capacitive coupling, can deliver therapeutic energy to dermal structures without damaging the overlying epidermis.
- Radiofrequency technology includes multiple indications for skin tightening, body contouring, or promotion of healing, with low morbidity and a limited side effect profile.

## INTRODUCTION

Radiofrequency (RF) energy is used frequently in a variety of consumer technologies, such as radio and television broadcasting, telecommunication, microwave ovens, and radar systems. RF energy has long been used for medical applications, dating back to the 1920s as a means of electrocautery.[1] At present, RF technologies extend to a multitude of clinical uses, ranging from tumor ablation to MRI to an assortment of noninvasive aesthetic practices.

The first monopolar RF device (Thermage, Hayward, CA) was approved by the US Food and Drug Administration (FDA) for use on periorbital tissues in 2002. Given its safety profile, FDA approval was quickly expanded to full facial use in 2004 and then body contouring in 2006.[2] Since this initial RF device, delivery devices have continued to advance with a growing range of indications. As consumer demand for noninvasive aesthetic procedures increases, there will continue to be an expanding market for this evolving technology. This article reviews the background physics of RF as applied clinically for minimally invasive aesthetic treatment purposes.

## BIOPHYSICS

A basic grasp of physics is necessary to understand RF technologies and their potential applications. By definition, RF includes any electromagnetic wave frequencies within the range of 3 kHz to 300 GHz. An RF field is composed of both electrical and magnetic components. These components are typically measured in volts per meter (V/m) for an electric field and amperes per meter (A/m) for a magnetic field. RF waves are further characterized by frequency and wavelength (**Table 1**).

When RF is applied by an alternating current, an electric field is generated throughout the skin. Rapid shifts in polarity within this electric field then cause alterations in particle orientation. All tissues have some intrinsic resistance (impedance) to these oscillating electrons and this causes heat to be generated as the electric current is converted to thermal energy. This relationship can be described using Ohm's law (**Fig. 1**).

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**Table 1**
**RF definitions and units or measurement**

| Term | Definition | Units |
|---|---|---|
| Electric field | Electromagnetic force per unit charge | V/m |
| Magnetic field | Magnetic effect of electric currents and magnetic materials | A/m |
| Wavelength | Distance covered by 1 complete cycle of an electromagnetic wave | Distance (m) |
| Frequency | Number of occurrences of a repeating event per unit of time | Hz |
| Impedance | Resistance to current within a circuit when voltage is applied | Ohms |
| Radiation | Energy emitted as waves or particles | V |
| Specific absorption rate | Amount of radiation absorbed | W/kg |

Ultimately, this heat generated by variable resistance within biological tissue results in the observed clinical effects. These thermal effects from RF energy are similar to the way a microwave heats food. Because different biological tissues have variable levels of impedance, a specific frequency of applied RF has divergent effects in different tissue types. In particular, the eyes and testes are more sensitive to RF energy. Successful transfer of RF energy depends on both the size and depth of the tissue being treated (**Table 2**).

During whole-body exposure, adults can absorb RF energy maximally in the frequency range of 80 to 100 MHz. Accordingly, safety standards are most restrictive at these frequencies. The specific absorption rate attempts to quantify the amount of radiation exposure measured by the amount absorbed per unit weight. However, standards, including maximal exposure limits to RF, are as yet poorly defined. It is therefore of great importance to approach the many emerging RF technologies with caution and limit RF exposure whenever possible, particularly for health care operators with chronic exposure.[3]

## PHYSIOLOGIC EFFECTS

When applied to different tissue types, RF energy generates a variable amount of energy based on the tissue impedance. Each layer of the soft tissue must be considered individually, including the dermis, adipose, muscle, and connective tissues. Of importance for body contouring applications, subcutaneous fat has high impedance, generating more energy and subsequent deeper thermal effects.[4] The mechanism of RF involves both

$$\text{Energy (Joules)} = I^2 \times Z \times t$$

Where I = current (amps), Z = impedance (ohms), t = time (sec)

**Fig. 1.** Ohm's law.

immediate effects (collagen contraction) and long-term effects (wound-healing response with neocollagen production).

### *Immediate*

Collagen is composed of a triple helix of proteins with interchain hydrogen bonds.[5] RF heating disrupts these bonds and causes tissue contracture as proteins partially denature from a triple helix to a random coil structure[5] (**Fig. 2**). Excess tissue heating causes complete protein denaturation and cell death with resultant scarring. Ideal shrinkage temperatures range from 57°C to 61°C but also depend on exposure time.

Deeper tissue penetration disrupts fibrous septae, leading to three-dimensional tissue contracture.[6] RF has also been shown to increase local capillary blood flow, leading to an upregulation of local adipocyte metabolism. Additional proposed nonionizing (nonthermal) effects of RF include adipocyte stimulation leading to lipase-mediated degradation of triglycerides or even adipocyte apoptosis.[7]

### *Delayed*

Aging skin is characterized by epidermal atrophy, flattening of the dermal-epidermal junction, and decreased fibroblast and collagen levels.[8] Photodamaged skin (solar elastosis) likewise shows decreased collagen synthesis and alteration of fiber networks.[9] After initial RF-induced thermal injury, tissue undergoes a microinflammatory response, leading to increased collagen (neocollagenesis), elastin, and ground substance production. Collagen remodeling eventually causes long-term dermal tightening and contour changes within treatment areas.[10]

## CLINICAL APPLICATIONS

RF technology is commonly used for noninvasive treatment of fine lines, wrinkles, sagging jowls,