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Rare earth elements: Therapeutic and diagnostic applications in modern medicine

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The rare earth elements (REE) are a group of metals comprised of fourteen lanthanide elements [lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu)] , yttrium (Y) and scandium (Sc) [1]. Their unique physical and chemical properties have rendered them indispensable for a growing number of high-tech technologies as high-performance permanent magnets, magnetic resonance image scanning systems, superconductors and laser technology [2,3].

Lanthanides are also used in many health and medical applications, such as in anti-tumor agent, kidney dialysis medicine and surgical equipment. Due to their optical properties, REE has been used in many imaging techniques such as computed tomography scans, magnetic resonance image (MRI), positron emission tomography (PET) imaging and X-rays [4,5]. The medical applications of REE are summarized in (Table 1).

Gadolinium is the most used REE in medical diagnosis in the MRI. Gd (III) ions enhance MRI images and have also been used in intravenous radio-contrast agents to improve the sensitivity and specificity of diagnostic images. In this technique, it is possible to visualize the morphology of the body with a very high resolution once Gd (III) ions are the best paramagnetic compounds of the periodic table. The contrast of the images is dependent on magnetic relaxation of the nuclei, and this relaxation can be enhanced by Gd (III) ions, which improves the contrast in magnetic resonance imaging scans with very low toxicity [6,7].

Table 1. Medicine applications of rare earth elements

REE	Medical applications
La	Lanthanum oxide nanoparticles can be used for MRI [10]
Ce	Cerium-doped lutetium orthosilicate is a scintillator that has been mainly used for PET imaging, a type of test that reveals tissue and organ function [11]
Pr	Praseodymium oxide nanoparticles have been used in radiotherapy techniques [12]
Nd	Neodymium has been used in lasers as crystals and is employed in the treatment of skin cancers, as well as laser hair removal [13]
Sm	A radioisotope Sm-153 has been used to treat severe pain in patients whose tumors have advanced into bone tissues [14]
Eu	Europium presents bioapplications due to its optical properties as nanoprobes with an emphasis on their heterogeneous/homogeneous biodetection as well as *in vitro* and *in vivo* bioimaging [15]
Gd	Gadolinium enhances MRI images of tumors, and its magnetic properties are also of use in intravenous radio-contrast agents in MRI scans [6]
Tb	A radioisotope Tb-149 has been used in targeted cancer therapy [16]
Dy	A radioisotope Dy-165 has been employed in the treatment of rheumatoid knee effusions [17]
Ho	Holmium based solid-state lasers have been used for non-invasive medical procedures for treating cancers and kidney stones [18]
Er	Erbium-based lasers have been used in medical and dental practice [19]
Tm	A radioisotope Tm-167 has been used as power sources in portable X-ray devices [20]
Yb	A radioisotope Yb-176 can be used to produce Lu-177 which is known to be a promising radioisotope for a medical application [21]
Lu	Lutetium is being researched for its potential uses in targeted radiotherapy, for the advancement of new cancer therapies as prostate cancer [22]

Besides, a considerable variety of luminescent bioassays and sensors also have been developed based on lanthanides that preserve a relatively long-lived emission. Living tissue researchers rely on the Europium for the sensitive luminescence in molecular genetics to mark specific strands of DNA when attached as a tag to complex biochemicals [8]. Nowadays, rare earth elements have also been considered on the anti-cancer treatment because of their therapeutic radioisotopes, especially as agents in radioimmunotherapy and photodynamic therapy [9]

The use of REE into health and medical applications is now well established. However, much of the future of diagnostic imaging analysis could depend on these paramagnetic elements. Demand for REE is expected to exceed its supply soon. It also considers the possibility of reclaiming the used or worn out REE and reutilizing them; highlighting some companies that have started to recycle the elements, those derived from medical use as well, reducing the demand for newly mined elements. The recycle of REE will be imperative to continue the advancement of RMI and radioisotopes technologies. The future holds many new innovative ideas.

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