RaDistance Safety Meter

2/25/15

Team
David Mott – Leader
Justin Faanes – Communicator
Jesse Wang – BWIG & BPAG
Elliott Janssen Saldivar – BSAC

Client
Dr. Sarah Hagi
Prof. John G. Webster

Advisor
Dr. Kris Saha

Contents

Abstract

Nearly 200 million people are affected by thyroid disorders worldwide (1). The thyroid gland is crucial for metabolic processes and hormone regulation, and serious symptoms can arise when the thyroid gland is malfunctioning. Treatments of thyroid disorders include medications and lifestyle changes. However, in more severe disorders such as cancer and hyperthyroidism, radioactive iodine (I-131) is utilized to destroy malignant tissue surrounding the thyroid, sometimes also including the thyroid. In these instances, radioiodine is taken into the body via liquid or capsule and concentrated in the thyroid cells, where it will spend four to six weeks decaying and destroying surrounding tissues (1). Because of its radioactive properties, radioiodine can also damage healthy tissues of those near the patient in treatment, warranting the need for a device that alerts the patient when he or she is within close proximity of another person. This device must alert the patient when a human is detected within a one-meter radius, as well as function a continuous 16 hours on a single charge. Through discussion with the client and brainstorming with the team, four design concepts were chosen for deliberation and comparison. The most successful design based on weighted criteria was composed of distance and thermal sensors embedded in a belt-like framework, powered by a lithium ion battery and controlled with a microcontroller. This design is based on simplicity and adaptation for the user. Future work must be done to fabricate the device and test for accuracy and reliability.

Background

The thyroid is one of the largest glands in the human endocrine system responsible for regulating metabolic processes. Located in Figure 1, the thyroid gland sits at the base of the human neck.

In coordination with the anterior pituitary gland and hypothalamus, the thyroid regulates metabolic processes, growth, behavior, and puberty. Figure 2 demonstrates the negative feedback loop this report is concerned with. Note that this is not the only function of the thyroid (1).

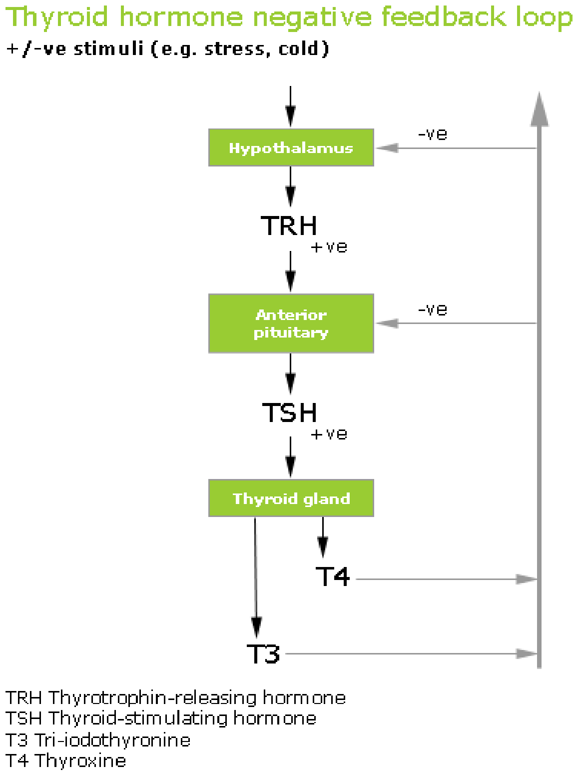

Figure 2: Thyroid stimulation begins with the hypothalamus secreting TRH in response to a lack of T3 or T4 in the bloodstream. The anterior pituitary receives this hormone via the median eminence and then releases TSH to the thyroid gland, increasing metabolism (2).

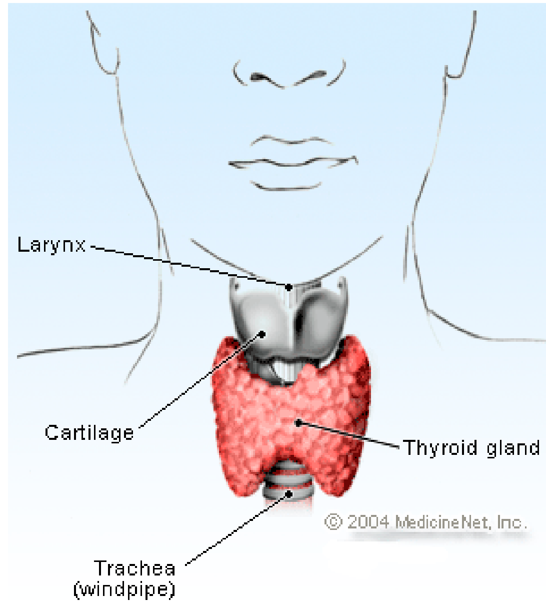

Figure 1: A normal thyroid gland (1).

The hormones secreted by the thyroid, triiodothyronine (T3) and thyroxine (tetraiodothyronine or T4), contain three and four iodine atoms respectively. This property will be of significance further into the report. T3 and T4 are synthesized within the thyroid from the molecule tyrosine, and are secreted into the bloodstream with small amounts of T3 relative to those of T4 (2).

The thyroid is prone to dysfunction and disease however. As stated above, disorders of this gland present in over 200 million individuals worldwide (3). These diseases can inhibit thyroid function. This report will only relate to those disorders in which the thyroid becomes overactive, including Goiters (enlargement), hyperthyroidism and nodules (cancerous and noncancerous). An overactive thyroid poses many risks to an individual. Metabolic dysfunction is a common symptom of these phenomena: weight loss, tremors, sweating, and cardiac arrhythmias (4). Luckily, thyroid disorders are usually quite treatable.

Such treatments include an antithyroid drug regimen. These drugs act to suppress the functions of the thyroid by blocking hormone production (5). Another treatment plan includes surgically removing a portion or the entire thyroid gland from the individual. Lastly, either before or in tandem with surgery, radioiodine is administered to the individual to destroy thyroid cells through radiation exposure (4)(5).

The Iodine isotope I-131, dubbed radioiodine, can be administered by to the patient via liquid or capsule form (6). The thyroid gland is the predominant consumer of iodine present in the body and utilizes it to synthesize the hormones mentioned above, T3 and T4. Unable to distinguish any difference between the two isotopes, thyroid cells will naturally absorb the radioiodine for hormone production.

In doing so, the gamma and beta radiation emitted from the radioiodine molecules is concentrated in the thyroid gland destroying only these desired cells with little effect to the rest of the body (6). Despite the crucial role in metabolism that the thyroid plays, if removed, the gland's responsibilities can be substituted through hormone treatment and drug therapy (7).

This treatment does also pose adverse side effects including an increased risk of leukemia and other cancers, lowered sperm count, lowered blood cell count (temporary or permanent), irregular menstrual cycles, and reduced tear formation (6)(7). The focus of this report will revolve around the weeks following administration of radioiodine treatment.

Problem Motivation

During the proceeding one to two months after radioiodine treatment, patients will constantly be emitting radiation at levels of concern for surrounding individuals. Patients are asked to remain isolated from extended close contact (more than 2-3 hours) during this time period; a difficult task for a timespan of up to six weeks. Dr. Hagi and Dr. Webster have recognized a need for a device that will respond to a human proximity breach of 1 to 2 meters from the patient during this time.

This poses many obstacles to overcome. The main concern of the device is being able to accurately and effectively detect a distance breach by a *human*, not just any object. Another is communicating these phenomena to not only the patient, but to the bystander whom perhaps has no awareness of the danger posed in the situation. This will typically not be the case however as the individuals of most concern will be family members, physicians, and possibly coworkers; all groups who will likely have previous awareness of the patient's treatment.

The overall goal is to effectively introduce a device that will help alert surrounding individuals of a proximity breach in order to reduce the chance of secondhand radiation exposure.

Competition

Both fortunately and unfortunately for the outlook of this project, many cheap and effective distance sensors are present on the market. This could pose an issue for third party individuals to create their own devices, reducing a need for ours. However, as stated by Dr. Webster, the administration of this device will likely be through the process of prescription by the patient's physician. No other device has been FDA approved to present findings, designating this project as a pioneering endeavor.

Another distantly related technology that has already been developed and commercialized is a human detection device intended to activate video capturing when an individual enters the device's "seeing field." Overall this type of detection is not an undiscovered field, but the application in which this project is addressing has yet to be successfully developed.

Design Requirements

The design requirements include constructing a device capable of detecting and distinguishing humans within a one-meter radius. The accuracy of the device should allow detection in a ±10 cm range. The device should also possess a 360° field of view such that reorienting of sensors is not necessary for detection. After detecting another human, the device will need to alert the user of a distance breach through audio, visual, or physical means. Finally, the device should be light (<0.5kg) and capable of lasting approximately 16 hours on one single battery charge. Additional detailed requirements can be found in the product design specifications (Appendix).

Design Alternatives

The first consideration of the design is the placement on the user. All alternative placement choices will employ the same number/model of sensors and electrical components since they are largely independent of each other. These pieces include a 9-volt battery to power an Arduino pro mini microcontroller, vibrational motor, wires and LED. The placement will be divided into four categories: the head, neck, torso, and hip region. All designs except the torso will consist of a band-like model that will either be secured using a Velcro or buckles. The use of Velcro in many of the designs is ideal for adjustments based on the user's body size. As a result, elastic materials will not be necessary; stiffer fabrics can be used for increased durability and strength.

Common Features of Design Alternatives

Design 1: Headband

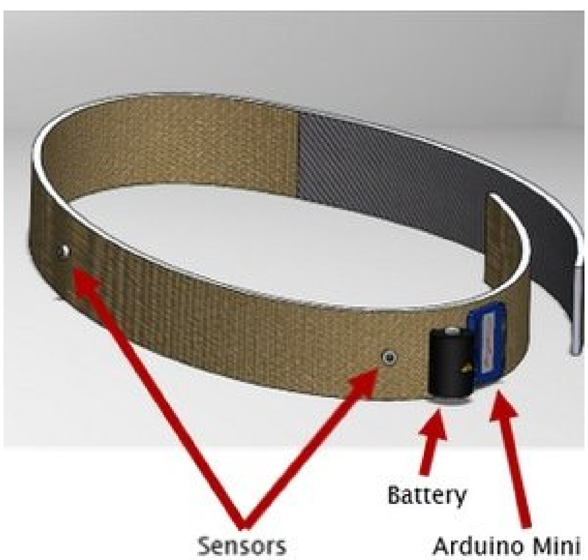

Figure 3: Headband design with microcontroller, battery, sensors, stretchable material, and Velcro.

The headband design was one initial solution for detection humans and alerting them of a one-meter distance breach. The device will have sensors located around the band with a microcontroller and a 9-volt battery attached. About four to six distance sensors coupled with thermal sensors will be used to provide a 360-detection angle. The electrical components will be sewn onto a durable polyester fabric and secured using Velcro. The length of the device will be approximately 50 cm long and should accommodate people with head sizes ranging from 40 cm - 50 cm in circumference. The total estimated weight of this device would be under 0.5 kg. After the sensors detected humans within the one-meter range, it will likely trigger a vibrating motor also located on the head band. The motor should not cause discomfort to the patient, so it will be calibrated to vibrate in a small, but noticeable manner.

The advantage of this design is that there are no limb obstructions that can disrupt or trigger the sensors. On the other hand, placing a 9-volt battery and microcontroller on someone's head may cause discomfort after extended use. In addition, the accuracy and sensitivity of the sensors may be influenced by the user's height. Multiple calibrations may be necessary as a result. The estimated cost per unit is approximately $235.

Design 2: Collar

Figure 4: Collar design with microcontroller, battery, sensors, and soft material.

The second design is titled the neck warmer. This alludes to a scarf-like design in which wool will be used as the primary fabrication material. Elastic bands will be sewn into the wool to allow stretching. The diameter of the device should be capable of extending from 8 cm to 13 cm. Similarly, the 9-volt battery, microcontroller and vibrational motor will also be located on the band itself. The advantages and disadvantages of this design is similar to the head band in that there are no limb obstruction to block the view of the sensor, but it is rather bulky for placement around the neck. The accuracy of the sensor will also be affected by the height and posture of the user. Furthermore, the heavier portion of the neck warmer will cause sagging, thus altering the device's lateral viewing angle and cause discomfort to the user. The estimated cost per unit is $235.

Design 3: Shoulder Pads

The third design is titled the shoulder pads. It has a harness that is secured around the user with a Velcro in the back. There will be two shoulder pads with sensors located on the edges. There will be sensors, a battery, and a microcontroller located in the center of the harness. Circuits embedded within the harness will connect them. The placement of the sensors (On the shoulders, chest, and back) allows a 360 view from the user. As a result, there are no potential obstructions caused by the limbs. In addition, the shoulder pads can be secured snug on the user, allowing more comfort for extended use. The drawback of this design is that the harness will have limited size, thus it cannot accommodate all size users. Furthermore,

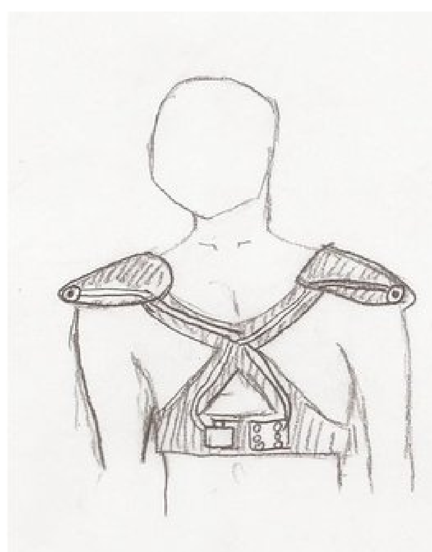
Figure 5: Shoulder pads design with microprocessor, battery, sensors, and rigid material.

movement of the arms may trigger the sensor to provide a false positive signal. The total cost per unit is estimated to be $295. It is the least cost effective design compared to the other three.

Design 4: Belt

The final design is titled the belt because it is a webbed nylon fabric secured around the user's hip with a buckle in a manner very similar to a traditional belt. The belt will be double layered so that wires and electrical components can be embedded within. The heaviest component would likely be the steel buckle that holds the belt in place; however, the estimated weight of the device is still under 0.5 kg. The length of the belt is adjustable from 72 cm to 86 cm. This is so that anyone from waist sizes of 28'' to 34'' can fit into the device. Similar to the headband and neck warmer designs, there will be a 9-volt battery, microcontroller, vibrational motor, and 4-6 sensors located around the belt to provide a large view angle. The disadvantage of this design is that since it is fastened around the hip, movement of the arms may have potential to block or trigger the sensor. Setting a minimum distance for the distance sensors such that detection of objects under the minimum distance will not trigger a signal can solve this issue. The advantage is that it is the most aesthetically pleasing design, easy to fabricate, and is capable of fitting various size users. The total estimated cost per unit is $270.

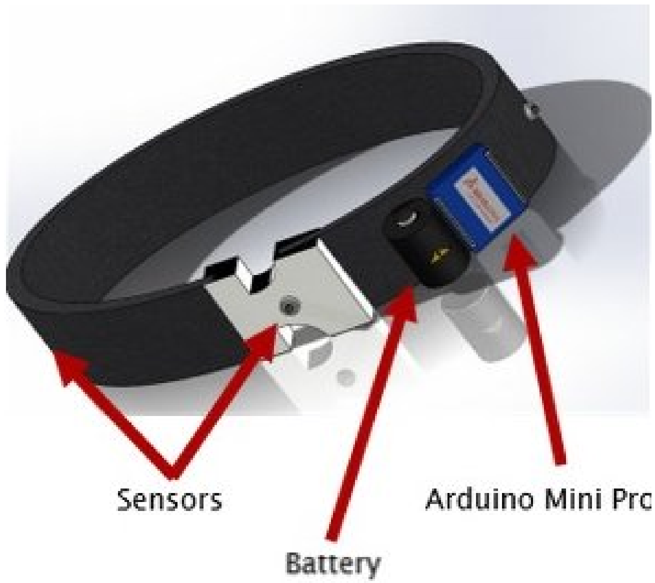

Figure 6: Belt design with microcontroller, battery, sensors, nylon, and buckle.

Design Matrix

Comfort/Ergonomics

Since the patient is expected to wear the device for 16 hours a day, the device must be comfortable and easy to use. Therefore, comfort and ergonomics was the highest weighted criteria with a score of 25. The belt design had the best score in this category, as the waist is relatively non-intrusive to the patient's daily operations and close to the hands.

Fabrication

Ease of fabrication is crucial, as one semester is devoted to designing, fabrication, and testing of the device. Programming the microcontroller and wiring the various element connections, warranting a weighted score of 20, also stress the fabrication time. The headband and collar designs tied for highest scoring in fabrication, as they both required the least amount of material in a simple form factor.

Accessibility

With a score of 20, accessibility is a very relevant criterion to consider. The device will be worn for four to six weeks and needs to be easy to put on, take off, and adjust. Because of its close proximity to the hands and familiarity with belts, the belt design won the accessibility category.

Aesthetics

The device must not be intrusive on the patient's life, which includes appealing aesthetics that do not make the patient feel uncomfortable to use in public. A score of 15 was assigned to aesthetics when applied to the design aspects. Since the belt design is the most covert design and can pass as a belt, it scored highest in aesthetics.

Cost

Cost is weighted lower at 10 because there are no competing prices to meet and the patient will not own the device, but rather rent it from the physician or clinic. The designs with the least amount of fabric and sensors, the headband and collar designs, won the cost category.

Safety

Although the device was designed as a safety measure, it is not of great concern of safety to the patient due to its low-powered components, durable materials, and enclosed design, justifying a weight of 10. The designs with the best-rated safety were the shoulder pads and belt because the components could be placed relatively far from the face and head compared to the headband and collar designs.

Sensor Alternatives

Common Features of Sensors

Each sensor shares several features that need not be considered in the matrices. Firstly, all sensors are capable of detecting objects at and within one meter. It is not necessary if a sensor can detect anything past this range, and increased range will not be beneficial to the goal of the design. In addition, the power consumption for all sensors is very low and comparable. Lastly, the distance sensors specifically are capable of relaying the distance measurements to the microcontroller, and therefore do not need to be ranked in this category.

Sensor Matrices

Field of View

Field of view was the highest scoring category due to its importance in detecting humans while keeping costs low. The better the field of view, the less money spent on sensors. It also keeps our design more efficient and lighter. Field of view, therefore, has a weight of 30. The winning distance sensor in this category was the MB EZ0 due to its wide field of view, while each thermal sensor scored the same due to similar narrow fields of view.

Accuracy

Accuracy received a weight of 25 because it is essential for the device to be able to distinguish humans from the surroundings. The most accurate distance sensor was the MB EZ0 due to its high quality transducer and specialized beam pattern. The most accurate thermal sensor was the Omron D6T8L06 due to its grid detection system.

Cost

Cost is very important, as each sensor can be relatively expensive. Therefore, cost has a weight of 20. The lowest priced distance and thermal sensors were the Infrared Proximity Sensor Long Range and the TI-TMP007, respectively.

Fabrication

Although fabrication is necessary, it is not a huge factor when determining sensors, scoring a weight of 15. This is because most sensors have relatively similar circuit integration methods that do not require extensive wiring to function properly. The Ping))) Ultrasonic Distance Sensor scored the highest in fabrication, as the sensor is has simple connections to a circuit and is made specifically for use with Arduino and other similar microcontrollers. For the same reasons, the Omron D6T8L06 is the winner for the thermal sensors.

Safety

Since the sensors emit relatively small amounts of heat and are generally durable and light, safety is not a major concern. Consequently, safety received a weight of 10. Each device for both distance and thermal sensors scored identically for safety, as each poses very minimal threat to the patient.

Future Work

Fabrication

As the prototype will contain numerous sensors situated at different locations on the belt around the subject, multiple protective housing modules will need to be obtained or constructed. These modules will allow the sensors to be connected to the belt via small loops that can be loosened to move the module around the belt and tightened in place. Similar protective housing we be obtained or constructed for the microcontroller, battery, vibrating unit, and notification LED. Connecting each module will be insulated lead wire, allowing for the proper circuit to be completed.

Powering the entire prototype will be a single 2000 mAh rechargeable battery. The battery will be housed with and connected to an Arduino Mini Pro microcontroller, which will in turn power the rest of the components via its Vcc and ground pins. These components include all of the sensors, as well as the vibrating unit and notification LED that will be housed with the microcontroller and battery. In addition to the power and ground leads, each sensor will have its output connected to a different pin on the microcontroller to be read continuously.

The last connection needed to complete the prototype circuit will be used to time the activation of the ultrasonic distance sensors. To avoid interference, each sensor must emit its ultrasonic signal either at the exact same time or completely separate from all of the other sensors. For our prototype, we will connect the activation pin of each ultrasonic distance sensor to a single digital pin on the microcontroller to allow simultaneous activation and deactivation. The sensors will then be controlled through logic loops that will deactivate and reactivate the sensors all together every 100 ms.

Software

The software for the prototype will be fairly simple overall, consisting of just a few loops that can activate certain other parts of the code. For the majority of the time, when a person has not yet been detected, a loop controlling and reading data from the ultrasonic distance sensors will be run. This loop will deactivate and reactivate the sensors to keep them running in sync and then accept and analyze the signals they send back. If any signal received indicates that an object is within 1 m, the process will jump to a second loop.

The second loop will control the infrared temperature sensors. Depending on which ultrasonic distance sensor reported an object to be within 1 m of the user, the output of one or two temperature sensors with a similar field of view will be read. If the temperature reported by these sensors falls between 35° C and 40° C, the pins controlling the vibrating unit and notification LED will be written high, activating the two components. After several seconds, the components will be deactivated and the code will return to the loop that reads the ultrasonic distance sensors.

Testing: Field of View

To test the competency of our constructed prototype, we will subject the device to a series of field of view tests. First, we will measure out a 1 m radius circle around a subject wearing the prototype. Around the diameter of this circle, we will place markers separated by 5 degrees, starting from one directly in front of the subject’s frontal field of view. As such, we will have 72 total markers evenly spaced around the subject at a 1 m distance. The test will then consist of a different subject walking from outside of the circle directly towards a specific marker, with the goal being to see whether or not the prototype recognizes them and alerts the subjects. Each marker will be approached 10 times, and will be considered covered by the prototype's field of view if the moving subject is recognized at least 7 of these times.

Testing: Battery Life

After we have established the field of view of our final prototype, we will conduct exhaustive battery life tests to ensure the ability to be used continuously for at least 16 hours. To do so, we will either have one team member or multiple different team members wear the prototype for a minimum of five 16-hour periods. In order to consider this test passed, the prototype will have to maintain powered on and functional for the entirety of these periods. After these tests, we will attempt to obtain an actually number for the device's battery life by draining it all the way from fully charged. This complete drainage will be done at least twice, and the values will be averaged to obtain the prototype's expected battery life.

References

[1] Ec.europa.eu, 'Chemicals - Environment - European Commission', 2015. [Online]. Available: http://ec.europa.eu/environment/chemicals/endocrine/definitions/definitions_en.htm. [Accessed: 19- Feb- 2015].

[2] 'The Thyroid Gland', *Nature*, vol. 171, no. 4352, p. 551, 1953.

[3] Thyroid.ca, 'Thyroid Foundation of Canada', 2015. [Online]. Available: http://www.thyroid.ca/know_the_facts.php. [Accessed: 15- Feb- 2015].

[4] J. Torpy, C. Lynm and R. Golub, 'Hyperthyroidism', *JAMA*, vol. 306, no. 3, 2011.

[5] G. PERERA, 'The Effect of an Antithyroid Drug on the Clinical Course of Malignant Hypertension', *Annals of Internal Medicine*, vol. 55, no. 1, p. 29, 1961.

[6] H. Padmanabhan, 'Radioiodine Therapy After Pretreatment With Recombinant Thyroid-Stimulating Hormone (TSH) in Toxic Multinodular Goiter With Low Radioactive Iodine Uptake', *The Endocrinologist*, vol. 20, no. 5, pp. 208-210, 2010.

[7] S. Baunfire.com, *Thyca.org*, 2015. [Online]. Available: http://www.thyca.org/pap-fol/rai/. [Accessed: 09- Feb- 2015].

Appendix

Product Design Specifications

~Radiation Distance Safety Meter~

David Mott, Justin Faanes, Elliott Janssen Saldivar, and Jesse Wang

Current as of January 30, 2015

Client: Dr. John Webster

Problem Statement: Patients treated with therapeutic doses of radioactive iodine (I-131) can be potentially harmful to those in close proximity when discharged. The radiation from the doses can be a threat to those less than one meter away from the patient, especially family members and healthcare providers who are in frequent contact. Our client, Dr. Sarah Hagi, from the radiology department at King Abdulaziz University Hospital, requested a device that alerts the patient if individuals are within one meter. A device will be created that provides acoustic and optical feedback to alert the patient of his or her proximity to others.

Client Requirements:

- Must sense a human within a one-meter range
- Must provide a feedback to alert the patient
- Must be comfortable enough to where on a daily basis

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements*: The device must detect human presence within one meter for at least 6 weeks. Must provide feedback to alert user of human presence. Must function under mild radioactive conditions.

b. *Safety*: The device must have a sufficient feedback mechanism to warn user of unsafe distances with minimal discomfort. The materials must not become radioactive in the period of use. Electrical components must be concealed.

c. *Accuracy and Reliability*: The device must be battery powered and function accurately for at least 6 weeks. The device must detect distances within a 0.1 meter tolerance.

d. *Life in Service*: When the patient is discharged from the hospital after therapeutic radioactive iodine treatment, it is recommended he or she avoids coming within one meter of another person for 4-6 weeks. The device would have to be constantly active for this period of time. It is possible that the device could be recharged at night while the patient is sleeping. The device should hold a charge for at least 17 hours/day, 7 days a week, for 6 weeks.

e. *Shelf Life*: The device should be able to be stored for 10 years without using any of its functionality.

f. *Operating Environment*: The device will be operated in various interior and exterior environments throughout the world. For this reason, it should ideally be operational at extreme temperatures (-25 – 50 degrees Celsius) and humidity (5 – 95 percent) ranges. It should also be water resistant in the event of rain or spilling.

g. *Ergonomics*: The device must be comfortable to wear throughout the day for up to 6 weeks.

h. *Size*: The device must be small enough to not disrupt the patient's daily activities.

i. *Weight*: The device must weigh no more than one kilogram.

j. *Materials*: The materials must not be affected by radiation from I-131. The device should not be made out of a common allergen, such as latex. Electrical components should maintain their electrical properties in the presence of radiation.

k. *Aesthetics*, *Appearance, and Finish*: The device should be aesthetically appealing to ensure the patient feels comfortable wearing the device.

2. Production Characteristics

a. *Quantity*: One prototype.

b*. Target Product Cost*: Around $100.00.

3. Miscellaneous

a. *Standards and Specifications*: The device must meet the requirements of the National Institute of Standards and Technology.

b. *Customer*: Therapeutic iodine radiation clinics and hospitals and the patients they treat.

c. *Patient-related concerns*: The device needs to be durable and comfortable.

d. *Competition*: There are no devices currently on the market targeted towards therapeutic radioactive iodine patients.