Canine Noninvasive Stereotactic Frame

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Abstract

One of the most viable options for treating canine head tumors is to undergo radiation therapy. A stereotactic frame is needed to accurately position the anesthetized canine's head into the same position for each treatment. The purpose of this device is to provide a noninvasive frame which will position the canine's head while incorporating a bite block, which will keep the canine's mouth open during treatment. The device will be mounted onto a Computed Tomography (CT) and tomotherapy table and should not interfere with the radiation. In addition, the frame should be reusable and adjustable so that the canine's head can be repositioned to within 0.5° of its position during the first treatment. The device will have many adjustable parts that will allow it to change the pitch, yaw, and height to fit all sizes of canines.

Problem Statement

While there are other stereotactic frames available, this device will be different because it will be noninvasive and interchangeable for many subjects. This device should be able to adjust the canine's head with a 10° range to be within 0.5° of its position during the first treatment. Since the majority of treatments will be for nasal or jaw tumors, the mouth must be kept open during the treatment to ensure that the minimal amount of healthy tissue will receive radiation. Additionally, there will be an endotracheal tube that continually provides anesthesia to the canine. A bite block that is able to clasp onto different sized dental molds of a canine's upper jaw will be attached to the central part of the design. While the dental mold will be disposable, the rest of the frame should be reusable. In addition, a strap will be placed around the mouth to keep the lower jaw from hanging freely. The material used for the frame should be lightweight and have a low atomic number to ensure that it does not interfere with the radiation. Most importantly, the device should not harm the canine.

Background

The most common treatment for cancer to date is by using radiation to kill cancerous tumors; over half of all people with cancerous tumors in the United States are treated with radiation therapy (National Cancer Institute 2008). Likewise, tumors in canines are frequently treated with radiation therapy, which involves the use of ionizing radiation to reduce tumors by killing cancerous cells (National Cancer Institute 2008). The cancerous cells die because of the damage done to their DNA upon receiving radiation. Radiation also limits the ability of cells to grow and divide, which reduces tumor growth (National Cancer Institute 2008). Radiation therapy has proven to be a very successful treatment for tumors, as is evident by its frequency of use. One of the major drawbacks of radiation therapy, despite its success and utility, is the damage done to healthy tissue surrounding the tumor in the process. Just as radiation kills cancerous cells, it is also harmful to healthy cells. The quantity and intensity of radiation that can be given to the tumor is limited severely by the amount of radiation that the surrounding healthy tissue can receive without detrimental effects. Therefore, not as much radiation can be given to the tumor as might be needed to be effective (Lester *et al.* 2001).

A different form of radiation therapy – Intensity-Modulated Radiation Therapy (IMRT) – addresses this issue. IMRT is a form of radiation therapy for cancerous tumors that allows the most intense dose of radiation to be delivered to the tumor while the sensitive healthy organs surrounding the tumor receive significantly less intense radiation (Mayo Clinic 2008). Beams of radiation are shot at the tumor in IMRT by a medical linear accelerator (Radiological Society of North America 2008) from several different angles and are controlled to give the maximal amount of radiation to the tumor, while minimizing the detrimental effects to the healthy surrounding organs (Mayo Clinic 2008). In order to avoid healthy organs, the shape of the radiation beam is changed hundreds of times throughout the treatment to bend around the healthy organs to hit the tumor with the most intense radiation (Mayo Clinic 2008).

The specific radiation treatment given to each patient is determined before the IMRT by first using a CT scan to determine the anatomical position of the tumor. Because canines cannot be expected to stay still during the CT scan, they are anesthetized throughout the procedure to ensure that they remain in the necessary position. Then, the best radiation treatment to maximize dosage to the tumor and minimize dosage to the healthy tissue is designed by a computer program based on the CT scan. Finally, the canine is placed on a tomotherapy table in order to receive the radiation treatment. Due to the complex motions required for the radiation beams, it is imperative that the canine is positioned in precisely the same way on the tomotherapy table as the canine was on the CT table.

This reproducible positioning requires some sort of patient-positioning device to use to plan treatments and ensure a reproducible position of the patient (Mayo Clinic 2008). If the patient is positioned even the slightest bit off when given the radiation, the most intense radiation may be targeted at healthy tissue, which will destroy the healthy tissue and not destroy the tumor.

Figure 1: The frame system shown to the right is one device that has been made to accurately and reproducibly position a dog's head during canine brain biopsy. As the picture shows, this frame works by sticking two ear bars (at position "a") into the dog's ear canal in order to ensure reproducible position. The parts at "b" and "c" are eye bars that are positioned on the lower part of the eye socket (Troxel and Vite 2008).

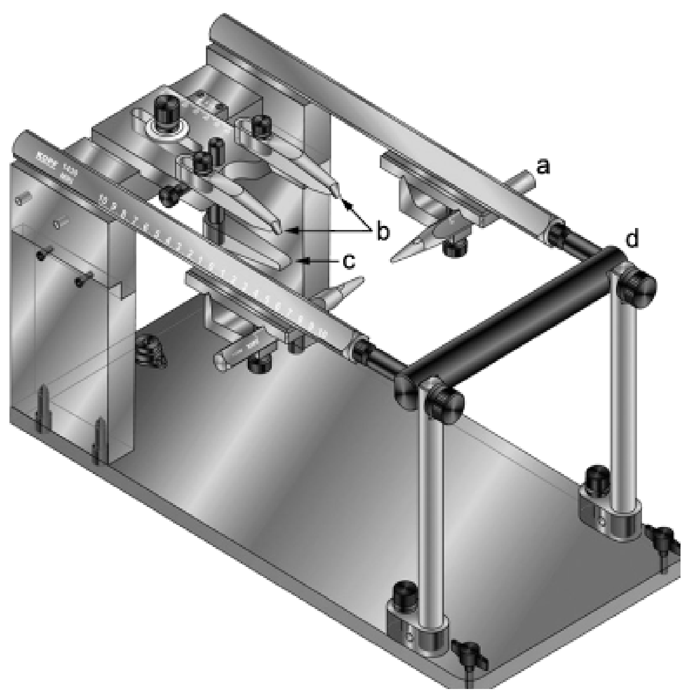

Figure 2: This device, shown with a feline, is compatible with smaller animals because padding can be placed underneath the animals (Troxel and Vite 2008).

Destroying healthy surrounding tissue is especially problematic in IMRT done on and around the brain as the brain is the most important organ. Several different methods for reproducibly positioning the human head with a stereotactic frame for IMRT have been used successfully. However, this is not the case with canines, and the same devices for positioning the human head cannot be used to accurately and reproducibly position a dog's head due to large anatomical differences. In addition, there is more variability in the head sizes and nasal shapes in dogs than in people, which makes a universal positioning system less feasible.

A few designs have been made and tested for accurately and reproducibly positioning a canine's head, though none have been made specifically for IMRT. One design, called the Kopf Stereotactic Frame, positions the canine by having an ear bar on either side of the ears that sticks directly into both ear canals (Troxel and Vite 2008). This design is intended for CT-guided stereotactic brain biopsy, using a needle to inject contrast medium into the brain for determine accurate placement (Troxel and Vite 2008). A clear advantage that this frame has is its versatility: it can be used for a wide range of dogs and cats due to its adjustability (Troxel and Vite 2008). This device has been shown to be competent at reproducibly positioning the patient within about one millimeter. However, the Kopf Frame is invasive due to the needle that must be put into the animal's head to position it correctly, which is not ideal for IMRT because it is given every day for about two weeks.

Another stereotactic frame was made by Nola Lester *et al.* (Lester *et al.* 2001). Like the Kopf Frame, Lester's frame was not designed for IMRT, but was intended to position the canine's head for radiosurgery. The frame in this design keeps the dog in a reproducible position by screwing into the dog's zygomatic arch with a plastic pin (Lester *et al.* 2001). This frame keeps the dog in a rigid position between the CT scan and the radiation treatment, but, like the Kopf Frame, Lester's frame is invasive and therefore not ideal for IMRT. In addition, another problem with this frame is its lack of versatility because it is only usable for larger canines.

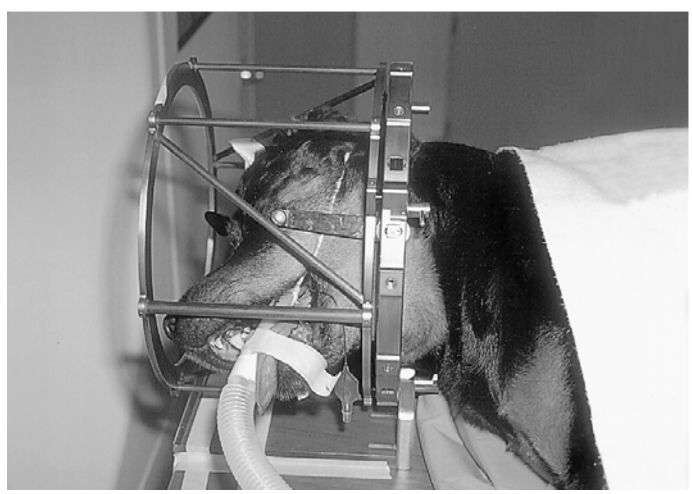

Figure 3: The dog shown above is set up in Lester's stereotactic frame. The tube going into its mouth is providing anesthesia during the surgery, and the frame is screwed into the dog's zygomatic arch with a plastic pin (Lester *et al.* 2001). This frame is compatible with large dogs, such as the one pictured, but it is incompatible with smaller dogs because it cannot screw into their zygomatic arches to keep them still.

Design Considerations

Since most of the current stereotatctic frames for canine radiation procedures are invasive, the client would like a noninvasive stereotactic frame specialized for canines during IMRT.
The device must fit into both the CT and tomotherapy table, which have a diameter of 0.51 m and 0.84 m, respectively. The device must incorporate a dental mold, which will be created by the Dentistry and Oral Surgery Department at the School of Veterinary Medicine at the University of Wisconsin.

Valley Design

The first design option is very basic and easy to use. It consists of a carbon fiber sheet that has an indentation on one side for the dog's upper jaw, which is placed on four poles. The jaw is placed in the dental mold, which is firmly strapped to the board in order to minimize movement of the upper jaw. The lower jaw is left hanging freely underneath the board. Since the lower jaw is rarely targeted during IMRT, it is very useful to have it out of the way. The endotracheal tube can be inserted in dog's throat underneath the board. Some advantages to this design are that it can fit any size canine, it is simple to build, and it does not require many materials. When the valley is constructed, it can be built to fit the largest dog because the dental mold and strap keeps the dog's upper jaw in place. The board can also be moved up and down the poles to adjust to different sized dogs. Because of the simplistic nature of this design, it has some very big disadvantages. The biggest disadvantage is that you will not be able to move the dog's head in pitch or yaw. The dog's head is in a fixed position and it cannot be moved.

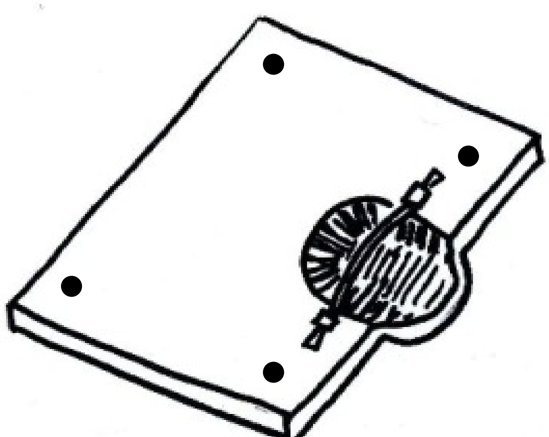

Figure 4: Valley Design

Track Design

The second design option is more complex and meets more of the design specifications. A carbon fiber sheet is clamped on top of the CT and tomotherapy table to ensure stability of the sheet. There is movable platform that the dental mold will be placed on, and the endotracheal tube will be below the platform so it will not interfere with the procedure. The canine's mouth will then be strapped around the platform, dental mold, and endotracheal tube. The poles holding the platform will be able to move up and down to adjust the pitch and positioning for different sized dogs. The poles will be able to tighten at fixed positions. To move in yaw the whole platform will be able to slide in the "c" shaped track. Some of the biggest problems with this design are its lack of rigidity, difficulty of construction, and lack of reproducibility in positioning when moving from the CT table to the tomotherapy table.

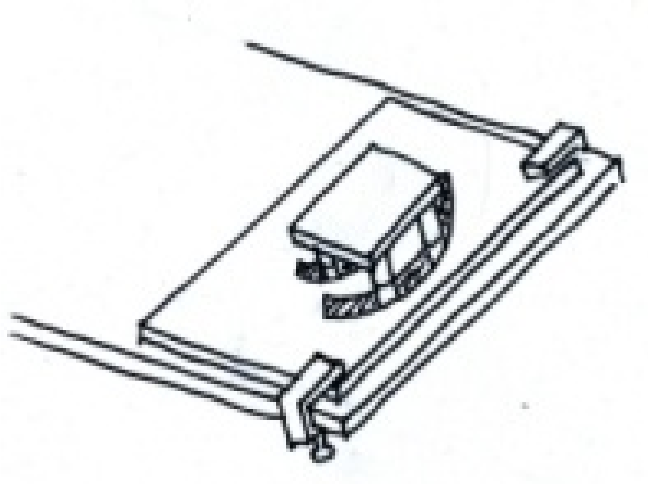

Figure 5: Track Design

Adjustable Pole Design

This design includes multiple adjustable and locking parts to fit the changes that need to be made to replicate positioning for different sized dogs. The main frame (shown in grey in Figure 6) fits snugly to the end of the table while the head frame consists of a rotating plate for pitch adjustments (blue) connected to a collar (green) on each side which can move up and down on two poles (orange). These collars can then be aligned with measurement lines on the poles and locked in place using a circular clamp or rubber stopper to change the height for each dog. On top of the frame's plate is an adjustable clamping system (red) to hold the canine's dental mold. This clamping system is able to fit various sized dental molds and also can rotate in the plane of the rotating plate for yaw adjustments. Underneath the rotating plate is an adjustable strap that can be tightened so the dog's

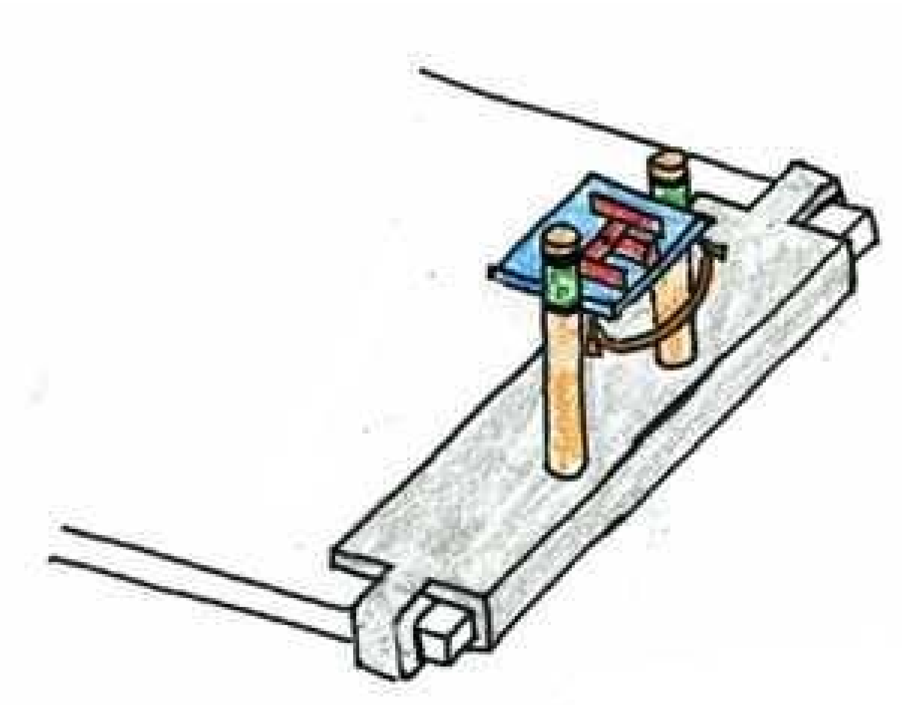

Figure 6: Adjustable Pole Design

jaw is not freely hanging. The rotating plate and dental clamping system is locked into place using a pin and socket lock or tightened with a screw. The angles of adjustments in yaw and pitch can be measured with a built-in protractor. The major drawback of this design is its complexity and difficulty of construction

Design Evaluation

The valley design, track design, and adjustable pole design were all evaluated on a scale of one to ten on a variety of design criteria shown in Table 1. Based on the results, the adjustable pole design is the most favorable design.

Design Criteria	**Option 1**	**Option 2**	**Option 3**
Prototype Cost	9	7	4
Mass Production Cost	9	7	6
Ability to move in yaw	1	9	9
Ability to move in pitch	1	3	9
Feasibility of development	7	2	3
User Friendliness	3	5	8
Rigidity	2	3	9
Total	32	36	48

Table 1: Design matrix of possible prototype designs. Each criterion is out of 10 with 1 being poor and 10 being excellent.

Future Works

Once the correct adjustable parts have been identified and ordered, the material for the frame will be ordered. After all the necessary parts have arrived, the prototype will be constructed. Once finished, the device will be tested to determine if it provides the accuracy needed for radiation treatment. If time and permission is obtained, the device will be tested on anesthetized canines during IMRT treatments. After the testing is complete, the prototype will be updated and finalized to be used in future radiation treatment.

References

Giroux, A., Jones, J., Bohn, J. H., Duncan, R., Waldron, D., & Inzana, K. (2002). A new device for stereotactic CT-guided biopsy of the canine brain: Design, construction, and needle placement accuracy. *Veterinary Radiology & Ultrasound, 43*(Radiological Society of North America 2008), 229-236.

Radiological Society of North America. *Intensity-modulated radiation therapy (IMRT).* (2008). Retrieved October 11, 2008, from http://www.radiologyinfo.org/en/info.cfm?pg=imrt&bhcp=1

Lester, N. V., Hopkins, A. L., Bova, F. J., Friedman, W. A., Buatti, J. M., Meeks, S. L., *et al.* (2001). Radiosurgery using a stereotactic headframe system for irradiation of brain tumors in dogs. *Journal of the American Veterinary Medical Association, 219*(11), 1562-1567.

Mayo Foundation for Medical Education and Research. (2008). *Intensity modulated radiation therapy*. Retrieved 10/12, 2008, from http://www.mayoclinic.org/imrt/howitworks.html

National Cancer Institute. (2008). *Radiation therapy for cancer: Questions and answers.* (2008). Retrieved 10/12, 2008, from http://www.cancer.gov/CANCERTOPICS/FACTSHEET/THERAPY/RADIATION

Troxel, M. T., & Vite, C. H. (2008). CT-guided stereotactic brain biopsy using the kopf stereotactic system. *Veterinary Radiology & Ultrasound, 49*(5), 438-443.

Appendix A: Product Design Specification

Project Design Specification—Stereotactic Frame

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Function:

The purpose of the non-invasive stereotactic frame is to hold the canine's head in a fixed position for repeated dosage of intensity modulated radiation therapy (IMRT). The positioning for each dog should be reproducible for each treatment. The device should be reusable and adjustable for different species of dogs with varying body size. The materials used should be able to withstand and not interfere with the radiation therapy procedures.

Client Requirements:

- The frame should be reusable for all dogs
- The device should be non-invasive
- Adjustable parts that allow the canines to be moved over a 10° range
- Reproducible positioning for each dog for every treatment
- The device should not interfere with the radiation treatment
- The device should be cost efficient

Design Requirements:

1) Physical and Operational Characteristics
    a) *Performance requirements* – The device should hold the subjects in a fixed position during IMRT treatment for up to ten uses a day.
    b) *Safety* – The device should not hurt the canine during IMRT. Also, there should be no interactions between the radiation and the prototype's material.
    c) *Accuracy and Reliability* – The device should be able to repeatedly position each canine to within 0.5° in pitch and yaw for every treatment.
    d) *Life in Service* – The device will be used for several years, with multiple uses each day.
    e) *Shelf Life* – The device should be able to withstand everyday laboratory and radiation therapy environment.
    f) *Operating Environment* – The device will be sterilized after each use and it should be able to withstand the IMRT without degrading or interfering with the radiation treatment.
    g) *Ergonomics* – The device should not interfere with regular IMRT procedures.
    h) *Size* – The device should be able to fit inside the tomotherapy machine, which has a diameter of .838 m
    i) *Weight* – The device should be as lightweight as possible.
    j) *Materials* – The device should be constructed using cost-efficient material. The material should have a low atomic number, preferably carbon fiber. The materials should be able to withstand IMRT and follow animal care policies.
    k) *Aesthetics* – The device should not affect the radiation procedure.
2) Production Characteristics

   a) *Quantity* – The goal is to produce two devices, one for the CT machine and one for the tomotherapy machine. However, it should be designed with the intent of mass production in the future.
   b) *Target Product Cost* – The device should cost under $1,500
3) Miscellaneous
   a) *Standards and Specifications* – The device should not harm the canine during the IMRT. It should also be animal friendly.
   b) *Customer* – This device will be used by the veterinary community when treating canines, and possibly felines as well, who have tumors in their head
   c) *Patient-related concerns* – The device should be non-invasive and should not harm the canine's well-being.
   d) *Competition* – Other stereotactic frames currently exist. However, they are used with smaller animals and are invasive and non-reusable.