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Application of a Mechatronic Device for Local Tumor Radiotherapy in Animal Treatment

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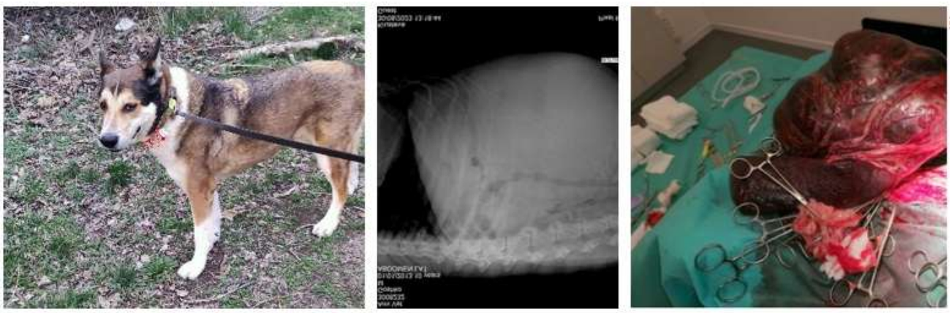
Abstract: Local radiotherapy is a good non-invasive treatment solution for this disease in both humans and domestic animals. A major challenge in telemedicine related to radiotherapy is the planning of the radiation dose in small animals where tubes are to be avoided. large dose accumulation effects. The article discusses the mechatronic device for local tumor radiotherapy in pets which is an upgrade to a mechatronic system for laparoscopic surgery. The aim of the work is the development of a modern device for local therapy of tumors in pets, which meets the modern needs for the treatment of these animals and their owners. The system is built on a modular principle, as well as the software. Some of the details of the software application are also presented. The diagnosis of tumor formations is carried out with a special sensor construction, which is not described in this work, to be able to plan its subsequent treatment The Results are illustrated in the Table. In addition, a graph with a comparison between minimum, maximum, and average force for various tissues is shown. The potential possibilities of the software for a mechatronic device for local radiotherapy in animals are also described. To implement the Local Operator Station, an application for working and processing databases – MetaKit for Tcl (Mk4Tcl) was used. The results demonstrate the potential of the therapeutic device in the field of local radiation. Further studies with Local Tumor Radiation Devices in Animal Treatment are needed to explore their full potential.

Keywords: *Mechatronics Radiotherapy, Animal Treatment, Telemedicine, Robotics, Software Applications*.

1. Introduction

Tumors are neoplasms that are the result of unlimited, unregulated and uncontrolled reproduction of cells that do not reach the maturation and differentiation phase. They can occur in all tissues of the human and animal body. The main standard methods of treating tumors in animals include surgery (surgical removal of the tumor), chemotherapy and radiotherapy.

1. Surgery is usually recommended for tumors that can be physically removed without significant risk to the life of the animal (dog or cat). It is particularly effective in isolated tumors and can often result in a complete cure if the cancer has not spread. As an example, a successful operation was performed in 2023 to remove a tumor mass from the abdominal cavity (of the spleen, which was removed together with the tumor) of a 10-year-old dog weighing 39 kg. The operation was performed at Vet Patrol Veterinary Clinic, Sofia, Bulgaria, by Dr. Fikinchev and Dr. Petrov. The removed tumor mass measured 27.60 cm x 24.27 cm and weighed 6.4 kg. Figure 1 shows information about the tumor entity.



a)¤ b)¤ c)¤

Fig.1. Tumor formation: a) Dog (Gosho), b) radiograph of the tumor, c) the removed tumor formation (*Photos are published with the consent of the medical team that performed the surgery and the owner of the dog*)

2. Chemotherapy is used to treat various types of cancer that have spread or cannot be completely removed with surgery. This method uses special drugs to destroy cancer cells while trying to minimize the impact on healthy cells.

3. Radiotherapy is one important method that uses high-energy rays to destroy cancer cells in places where surgery is not possible or where the cancer has spread. An example is the radiotherapy of a dog receiving adjuvant definitive radiotherapy for an incompletely excised mast cell tumor using electron beam therapy. An electron applicator is used to protect surrounding tissue from electron scattering. Wet swabs are used to avoid air gaps and improve dose distribution.

The other devices are used to immobilize the patient in the required treatment position as shown in Figure 2. More detailed information can be found in [1].

Fig. 2. Radiotherapy in a dog [1].

In addition to traditional methods, there are also alternative approaches such as immunotherapy. These methods can help stimulate the animal's immune system to attack cancer cells. Other alternatives include the use of nutritional supplements that support the general health of the animal.

In the present material, we have mainly focused on the treatment of tumor formations in animals using radiotherapy.

Radiotherapy is a treatment method based on the use of high-energy rays to destroy neoplastic cells, which has become an integral therapeutic tool in veterinary medicine. Radiotherapy can be an effective treatment for tumors that are not easily managed with surgery or chemotherapy, even for patients with advanced-stage neoplasia. New applications of radiotherapy include salvage therapy for specific benign conditions that are refractory to conventional therapy. Acute and late toxicity depends on the protocol prescribed as well as the sensitivity and volume of normal tissue in or near the radiation field. The potential risks associated with the treatment should be thoroughly discussed with the owners before starting radiotherapy. New hardware and software technology has dramatically advanced the ability to precisely target tumors, improving the efficacy and safety of treatment [1, 2].

Telemedicine finds its place in radiotherapy under various applications. Telemedicine in the form of virtual training improves the skills of radiotherapy doctors in low- and middle-income countries, enabling the application of new radiotherapy techniques and improving the quality of treatment and service. Teleradiotherapy consultations and patient follow-up improve treatment efficiency, while teleradiotherapy planning allows patients wide access to radiotherapy experts. Telemedicine also facilitates access to radiotherapy trials. Although telemedicine in radiotherapy has significant progress and promise, there are several drawbacks to its wider application. These include lack of infrastructure, data security concerns, regulatory challenges, resistance from providers and patients, financial constraints, misunderstanding during remote consultations, and lack of training [3].

Telemedicine is a rapidly developing field for veterinary medicine as well. The world and the expectations of animal owners are changing to the extent that veterinary practice will need to adapt due to the advancement of software applications. Veterinary telemedicine is a service along with other veterinary services that meets customer needs, delivers quality medicine and improves animal welfare. A major challenge in radiotherapy-related telemedicine is radiation dose planning in small animals where it is important to avoid large dose build-up effects. Various models of radiation calculation for small animals have been introduced such as Monte Carlo simulation and Superposition-convolution is the most famous More research is needed on how telemedicine improves veterinary care, especially for underserved regions.

In addition, at the moment, small animals are irradiated only with special devices. For local therapy of small animal tumors, the devices are in the clinical or experimental stage [4-7]. Therapy of tumors in domestic cervids to meet the modern treatment needs of these animals and their owners. To achieve this goal, the publication includes: an introduction, followed by a description of the types of radiotherapy, and the Methods section examines the determination of radiation dose. The Results and Discussion section includes a Table with the Results of conducted experiments. In addition, a comparison between minimum, maximum, and average force for various tissues is shown. The software for a mechatronic device for local radiotherapy in animals is also described, and at the end of the article there are Conclusions

2. Types of Radiotherapy

Radiotherapy (RT) is the use of high-energy X-rays to kill cancer cells. These are usually produced by a device called a linear accelerator, which produces a beam of X-rays that can be directed at a tumor.

RT is usually used:

- After the operation, we can see that the cancer is removed, but microscopic cancer remains on the flesh during the operation and there is a risk of repeated growth on the tumor (example, including mast cell tumors and sarcomas on the soft tissue);

- For treatment of melanomas in dog's mouths, in combination with surgery or an alternative to surgery;
- For palliation/ slowing the growth of tumors that cannot and will not be removed surgically – or in any case, the operation would carry a significant risk for the patient;
- To relieve pain in dogs with primary bone tumors (eg osteosarcoma) or tumors that have metastasized (spread to) bone areas.

The types of radiotherapy are shown in Figure 3.

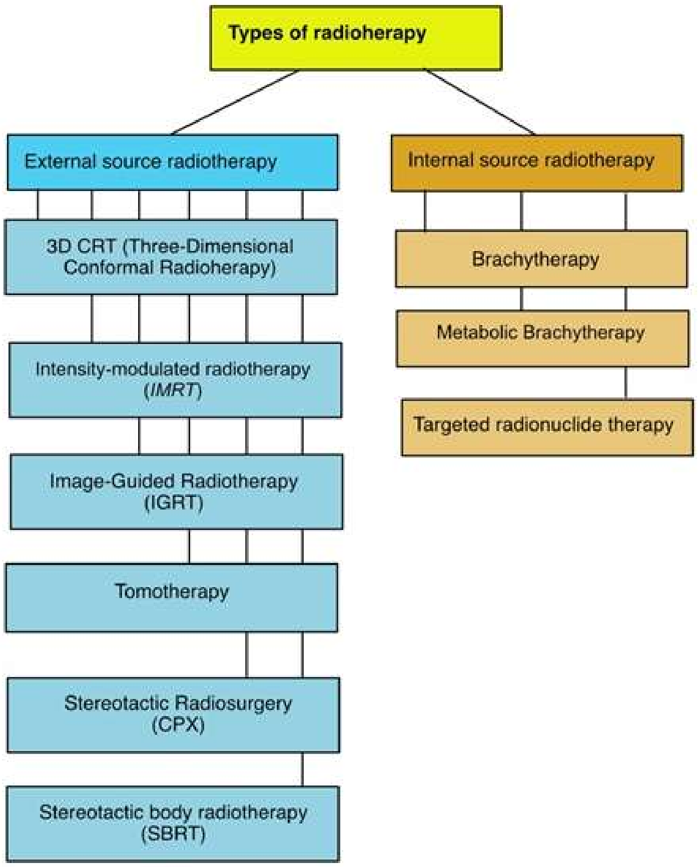


Fig. 3. Types of Radiotherapy

Depending on the source used, Radiotherapy is divided into two types: Radiotherapy with an external source and Radiotherapy with an internal source [6]

2.1. External source radiation therapy

1. *Three-Dimensional Conformal Radiotherapy (3D CRT)* – this method uses images from CT, MRI and PET scans to precisely plan the treatment area, a process called simulation. A computer program is used to analyze the images and to design radiation beams that match the shape of the tumor;
2. *Intensity-Modulated Radiotherapy (IMRT)* – like 3-D conformal radiation, the beams are directed at the tumor from several directions. IMRT uses much smaller beams than 3-D conformal, and the strength of the beams in some areas can be changed to give higher doses to certain parts of the tumor;
3. *Image-Guided Radiotherapy (IGRT)* – this therapy is a type of IMRT. However, he uses imaging scans not only for treatment planning before radiotherapy sessions but also during radiotherapy sessions. During treatment, you will have repeat scans, such as a CT, MRI or PET scan. These scans are processed by computers to detect changes in the size and location of the tumor. Re-imaging allows the position or radiation dose to be adjusted during treatment if necessary. These adjustments can improve treatment accuracy and help spare normal tissue;
4. *Tomotherapy* – this method is a type of IMRT that uses a device that is a combination of a CT scanner and an external beam radiation machine. Devices for this type of therapy take pictures of the tumor immediately before treatment sessions to allow very precise targeting of the tumor and sparing of normal tissues. It rotates around the patient during treatment, delivering radiation in a spiral, piece by piece;
5. *Stereotactic Radiosurgery (CPX)* – focused, high-energy beams are used to treat small tumors with well-defined edges in the brain and central nervous system. GammaKnife is a type of stereotaxic radiosurgery.
6. *Stereotactic Body Radiotherapy (SBRT)* – this is a therapy similar to stereotaxic radiosurgery, but is used for small, isolated tumors outside the brain and spinal cord, often in the liver or lung. Both stereotaxic radiosurgery and stereotaxic body radiotherapy use special equipment to keep the patient still during the treatment. It delivers a highly precise beam to a limited area.

2.2. Internal Source Radiotherapy

1) *Brachytherapy* – it is a method of treating malignant diseases in which tumors are irradiated from the inside out. This is done by introducing a radiation source into the tumor itself, extremely escalating the dose into the tumor itself while protecting critical adjacent structures from damage. In this way, it is possible to realize higher doses of radiation that are unthinkable with external irradiation.

2) *Metabolic Brachytherapy* – this therapy, called radioactive iodine, or I-131, is most often used to treat certain types of thyroid cancer.

3) *Targeted Radionuclide Therapy* – this is another type of Metabolic Brachytherapy. It is used to treat some patients with advanced prostate cancer or gastroenteropancreatic neuroendocrine tumor (GEP-NET). This type of treatment can also be called molecular radiotherapy.

2.3. Application in Veterinary Medicine

Radiotherapy is a treatment method based on the use of high-energy rays to destroy neoplastic cells, which has become an integral therapeutic tool in veterinary medicine. Radiotherapy can be an effective treatment for tumors that are not easily managed with surgery or chemotherapy, even for patients with advanced-stage neoplasia. New applications of radiotherapy include salvage therapy for specific benign conditions that are refractory to conventional therapy.

Acute and late toxicity depends on the protocol prescribed as well as the sensitivity and volume of normal tissue in or near the radiation field. The potential risks associated with the treatment should be thoroughly discussed with the animal's owners before starting radiotherapy. New hardware and software technology has dramatically advanced the ability to precisely target tumors, improving treatment efficacy and safety.

External beam radiotherapy is the most common form of radiotherapy used in veterinary medicine [1, 8, 9]. There are many different radiotherapy protocols described for the treatment of canine and feline cancer. - number of fractions, dose per fraction and total dose, risk of developing acute or late toxicity and others. Radiotherapy is effectively managed and used successfully for tumors in dogs and cats. Most animals enjoy significant clinical improvement after radiotherapy and do not develop clinically significant radiotherapy toxicity as long as appropriate dose planning and dose prescription are performed [1, 10, 11]. As such, the authors believe that radiotherapy is the preferred way of dealing with most intracranial tumors in pets.

3. Methods

Using some system upgrading ideas [12], a device described in detail in [6, 9] as a tool has been upgraded for animal radiotherapy purposes. With appropriate updates, the controllers described in [13] are also suitable for local tumor therapy devices due to some of their characteristics.

To determine the dose of radiation, we start from the known fact that a unit of measurement is a unit of measurement of the absorbed dose of ionizing radiation received in the system SI e Grey (Gy) (*1 Gy ≈ 100,185 R (x-ray); 1 Gy*

= *100 rad (rd)*). The received dose is equal to one grey if, as a result of the absorption (acceptance) of ionizing radiation, the substance received (absorbed) one joule of energy per kilogram:

$$1Gy = 1\frac{J}{kg} = 1m^2.\ s^{-2}, \quad (1)$$

where: Gy – Grey; J – Joule; kg – Kilogram

Gray, like the sievert unit (international designation *Sv*) is an SI unit of measurement for the dose of ionizing radiation), and is used to measure the amount of radiation received. A dose of the order of 10 – 20 *Gy* taken at once is lethal to humans. This equates to around 750 – 1,500 joules for an adult weighing 75 *kg*. In medical practice, the multiple unit milligray (mGy) is used because the basic unit is too large. An X-ray, for example, irradiates the person with 1.4 mGy.

One sievert (*Sv*) is the amount of energy absorbed by a kilogram of biological tissue equal in impact to the absorbed dose of gamma radiation of 1 *Gy*. While greys measure the radiation absorbed by any material, sieverts measure the radiation absorbed by a person. The relationship between the two is expressed by the formula

$$1Sv = 1Gy * w\ , \quad (2)$$

where: *Sv* is the notation for sievert; *Gy* for grey, and *w* is a weighting factor specific to a certain type of radiation (*wR*) and a certain type of tissue (*wT*).

Because radiation cell destruction follows Poisson statistics, the radiation dose-response curves for tumors and normal tissue response are sigmoidal in shape. This form suggests that small errors in the delivery of radiation doses can lead to large changes in the probability of normal tissue necrosis or tumor control. Thus, radiation oncology veterinarians must be familiar with the basic aspects of radiation physics and dose calculation as they relate to radiation therapy.

The utility of radiation treatment planning computers to improve the radiation oncologist's knowledge of dose distribution and selection of an optimal treatment plan is emphasized. More information can be found in [14, 15].

4. Results and Discussion

Table with results of conducted experiments by an Experimental Model of a mechatronic device is shown in Table 1.

Table 1. Results of conducted experiments

	Minimum force (N)	**Maximum force (N)**	**Average value (N)**
Styrofoam sample	0.1	1.670	0.83
Styrofoam rubber sample	0.785	2.26	1.13
Muscle tissue sample	0.45	2.4	1.21
Sample liver, pork	0.05	1.96	0.93

A comparison between the minimum, maximum and average force for different weavings is shown in Figure 4.

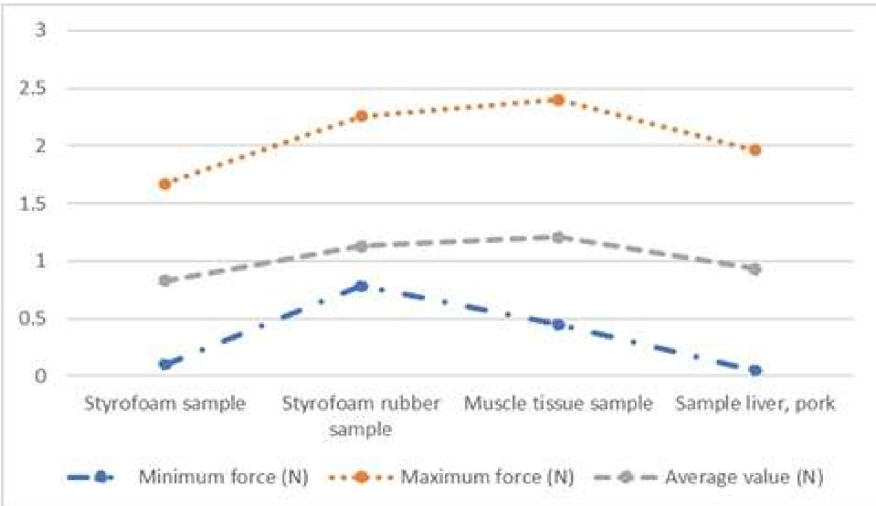


Fig. 4. Comparison between minimum, maximum, and average force for various tissues

In the case of muscle tissue, pressure is applied which is the greatest. On the other hand, the least amount of pressure is needed with the pig liver specimen.

4.1. Software for a mechatronic device for local radiotherapy in animal treatments

The mechatronic device for local tumor radiotherapy in pets is an upgrade to a mechatronic system for laparoscopic surgery [19]. The system is built on a modular principle, as is the program insurance [20].

Figure 5 shows control panel of the Local Operation Station to the local tumor radiation device in pets.

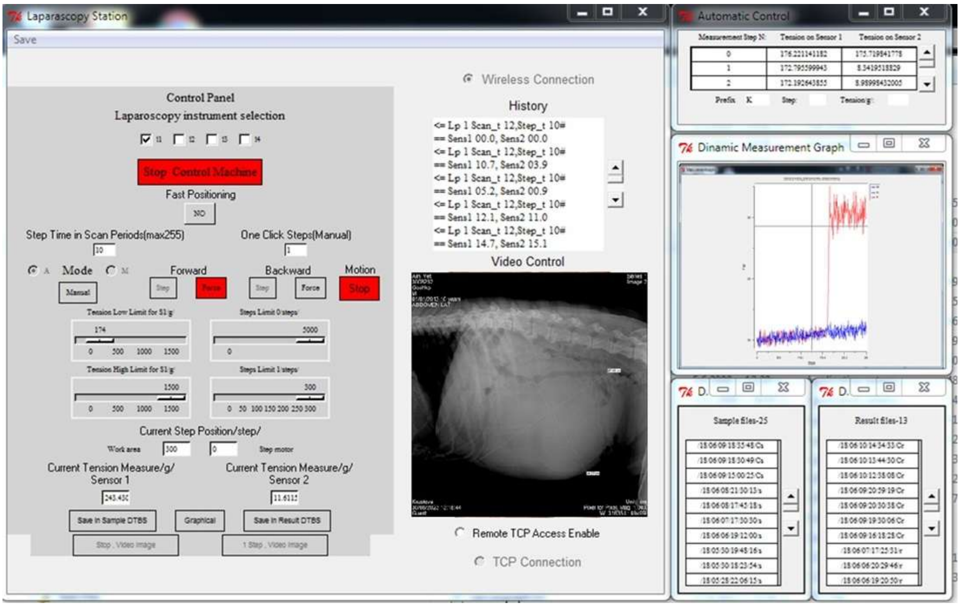


Fig. 5. The control panel of the graphical user interface (GUI) that is realized by Tcl/Tk

The software is developed in the scripting language Tcl using the graphics library Tk (Tcl/Tk – Tools Common Language/Tools Kit) [16]. A Local Operating Station is a software package installed on a PC, laptop or medical tablet This software application provides a graphical user interface of the operator/veterinarian. Tcl/Tk is a Windows programming environment that uses operating system resources to create user projects.

The software application contains the following software modules.

System software [9]:

- User software (GUI);
- Implemented database;
- Software application for realizing a connection over the Internet with a central veterinary network and a cloud one;
- Program tools for encrypted exchange and protection of the program package and the information in the database.

An application for working and processing databases – MetaKit for Tcl (Mk4Tcl) [17] was used to implement the Local Operator Station. The database is implemented as separate directories for each treated animal and subdirectories that contain different types of information – about the pet, the owners, the disease, etc. Each directory is accessed by a unique identification code.

It is planned that the information from the database of the local operator station will be transferred over the Internet to a central server of the Veterinary Center or a Cloud server located on the Internet. This software application makes it possible, if necessary during the treatment, to search and receive information about the treated animal and from other specialists having access to the cloud server in the shortest possible time.

The possibility of working together with other databases such as SQL.

Another software application possibility being explored is transferring the information from the treated animal database onto a processor card to be stored as an electronic medical record of the treated pet.

In connection with the privacy requirements of the personal information of treated pets, special measures have been taken to protect and encrypt the information [21], as well as to protect access to the program module.

A program package for coded information exchange - Coder 1.0 [22] has also been developed to work under different operating environments. The software package can be used both as a stand-alone product and as part of the Veterinary Clinic's software network security system. Hardware requirements are minimal.

In connection with the increase in requirements for the reliability of information on medical networks, work will continue with the study and use of other encryption algorithms and the development of software products for the encryption of information in multimedia objects (images and sounds) using the capabilities of the Tcl language/Tk.

The use of means to control access to the program module is also in the process of commissioning. The access control tools used can be combined and serve both for access to a relevant office and to protected software products. Identification chips or smart cards can be used.

One possible option is the use of an identification chip from the company Dallas Semiconductor/Maxim - DS9490B. (Figure 6) shows the identification chip (iButon) and the reading device [23].

Fig. 6. ID chip and reader kit [23].

The connection of the DS9490B to the computer is made as the reader of the identification chip is plugged into the computer's USB port.

5. Conclusion

Local radiotherapy is an extremely good non-invasive treatment for tumors, both in humans and domestic animals. A major challenge in radiotherapy-related telemedicine is radiation dose planning in small animals where large dose accumulation effects must be avoided. The article discusses the use of local tumor radiation devices in animal treatment. The system is built on a modular principle, as well as the software. It describes how the radiation dose can be determined. In difference to other development, the presented device detects the presence, size and hardness of the tumor formation and then local therapy with the same can be applied.

The Results are illustrated in the Table with the Results of conducted experiments. In addition, a graph with a comparison between minimum, maximum, and average force for various tissues is shown.

The potential possibilities of the software for a mechatronic device for local radiotherapy in animals are also described.

An application for working and processing databases was used to implement the Local Operator Station. - MetaKit for Tcl (Mk4Tcl). The results demonstrate the potential of the therapeutic device in the field of local radiation. Further studies with Local Tumor Radiation Devices in Animal Treatment are needed to explore their full potential. The use of these devices has significant potential in Animal Treatment.

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