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Unité d'évaluation des technologies
et des modes d'intervention en santé

Use of the linac-integrated cone beam CT in Radiation Oncology at the CHUQ

Summary

CHUQ

CENTRE HOSPITALIER
UNIVERSITAIRE DE QUÉBEC

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L'UNITÉ D'ÉVALUATION DES TECHNOLOGIES ET DES MODES D'INTERVENTION EN SANTÉ

Centre hospitalier universitaire de Québec

Use of the linac-integrated cone beam CT in Radiation Oncology at the CHUQ

Summary

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NOTE TO READER

The Unité d'évaluation des technologies et des modes d'intervention en santé (UETMIS) of the CHUQ as for mission to support and advise policy makers (managers, clinicians and professionals) in decision-making related to the efficient allocation of resources for the implementation of a technology, a new practice or revision of an existing practice in addition to new problems.

A preliminary advice is a synthesis and analysis of knowledge based on a brief review of various sources of available documentation. It is approved by the Scientific Council of UETMIS.

This paper presents the information available to November 25, 2007 according to the research methodology documentary restraint. The informations do not replace the judgement of the clinician that can be applied in a more particular context. This document does not in any way engage the responsibility of CHUQ, its employees, professionals in respect of the recommendations. The information contained in this document do not represent neither an approval nor a disavowal for the utilization of the technology investigated.

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DISCLOSURE OF CONFLICT OF INTEREST
No conflict of interest to report

SUMMARY

Introduction

The Radiation Oncology Department at the CHUQ recently acquired a new linac-integrated cone beam CT. In addition to irradiating tumours, this device can generate 3D x-ray images in real time and in treatment position. Users found the quality of the images generated by the new device to be superior to that of the 2D imaging currently used to verify patient positioning.

The Head of Radiation Oncology at the CHUQ has requested an advice from the CHUQ Health Technology Assessment Unit to identify how to best optimize the use of the linac-integrated cone beam CT and to document the strategies for implementing the device, slated for October 2007.

Methods

This draft opinion is a brief review of the literature on the technical performance, clinical efficacy, clinical applications and implementation strategies regarding the linac-integrated cone beam CT. This survey includes several online health databases, including the Cochrane Library and PubMed (Medline). Other data sources (grey literature) were also consulted. Two UETMIS members selected the relevant articles and extracted the data. Contextualization enabled the characterization of the respective situations at the CHUQ, the Centre hospitalier universitaire de Montréal (CHUM) and Princess Margaret Hospital (PMH) in Toronto. A multidisciplinary work team was created, comprising representatives from Radiation Oncology at the CHUQ (radiation oncologists, physicists, technologists and supervisors). Moreover, a questionnaire was sent to the two other hospitals using the linac-integrated cone beam CT.

Results

Technical performance of the linac-integrated cone beam CT

With respect to positioning accuracy, studies have shown positioning error differences of 2 mm or less between cone beam CT kilovoltage (kV CBCT) and traditional portal imaging. Moreover, one study reported that CBCT could detect rotation errors as small as 2 degrees, which is not possible with 2D portal imaging. The device used at the CHUQ is manufactured by Varian, whereas Elekta is the brand of technology analyzed by the above-mentioned studies. Because the technology is similar, therefore, the study results are relevant.

In terms of image quality, the findings of several authors indicate that the images obtained using a kV CBCT device are superior to those obtained using traditional radiation therapy (portal imaging) devices. However, images obtained using kV CBCT devices contain more artifacts than do CT scan images. Nonetheless, the quality of kV CBCT images is generally adequate to verify patient positioning.

Clinical efficacy of the linac-integrated cone beam CT

In order to identify the best indications for using the linac-integrated cone beam CT, it would be preferable to review studies assessing the clinical efficacy of this technology in comparison with traditional therapy. However, to date, no clinical trial has been completed. Therefore, it is impossible to evaluate the clinical benefits (survival rate, better tumour control, lower treatment toxicity, etc.) of CBCT for specific patient types or tumour sites.

The studies reviewed used clinical data to support and measure the potential of image-guided radiation therapy (IGRT) to minimize irradiation of healthy tissues and maximize the dose to the target. However, these studies have major limitations: they are retrospective studies simulating the expected results; the number of participants is usually low; an exact correction of positioning errors is assumed, as compared with a situation where no correction is made; neither the intrafractional movement nor the organ deformation is considered; and, in certain cases, imaging devices more powerful than CBCT are used, such as CT scan. Moreover, none of these studies uses Varian technology. Consequently, these studies only indicate potential clinical benefits, and the actual impact on the patient has yet to be shown through clinical trials.

Applications of the linac-integrated cone beam CT

The main indications cited in the literature and by the experts interviewed are cancers of the prostate, head and neck, lungs, bladder, liver and central nervous system. In terms of clinical applications, this type of device appears to be used most often to check positioning. Given the variability of indications and procedures cited by the authors, this information is provided for information purposes only, to enable a comparison between current practices at the CHUQ and those recommended by the authors.

Implementation of the linac-integrated cone beam CT

Indications and initial procedures for the implementation

With respect to priority indications and procedures for implementing the device, both hospitals consulted started with cases of prostate cancer in which gold markers were used. The PMH has followed using soft tissue as a landmark in patient for whom the insertion of gold markers was difficult and in patients for whom matching images by portal imaging was difficult, particularly pediatric patients, lung cancer patients and patients undergoing retreatment.

Skills development strategies

In both hospitals, certain physicists and technologists received on- and off-site training from the manufacturer of the device. The CHUM limited the rotation of staff members using the new device for the first few months to enable them to master the technique, whereas the PMH created a team comprising a radiation oncologist, a physicist and a technologist, all of whom were released from their regular duties to focus exclusively on implementing the technology. According to the authors, full-time, dedicated teams help to reduce procedure time.

Impacts of implementation

At both hospitals, the time required for a single treatment during the startup phase was twice that for traditional therapy (30 vs. 15 minutes), exceeding the initial time observed in the literature. During implementation, the authors noted each treatment required an additional 7-8 minutes, which was later reduced to 4-5 minutes. Other authors stated that the initial time to obtain an image first increased by 5-10 minutes, and then decreased to 2 minutes. The reasons for these differences are not known. The learning curve varies from one institution to another; at the CHUM, the curve stabilized after about three weeks of using the device, whereas this took 2-3 months at the PMH.

Another impact of using CBCT is the large amount of disk space required for data storage. In regards to quality assurance, it appears that this aspect can be integrated into the existing activities.

Main findings

Several major findings emerged from the scientific literature and the experiences described by medical professionals at the CHUM and PMH.

First finding: The studies reviewed have certain limitations.

The documents consulted mainly presented expert opinions based on clinical experience involving, for the most part, a small number of patients, which greatly limits the level of scientific validity. Moreover, several authors have ties with the industry, which raises the issue of conflicts of interest.

Second finding: The technical performance of the device is adequate.

In general, comments from users of the linac-integrated cone beam CT are positive regarding its technical performance. Several authors found that kV CBCT images were of higher quality than portal images and would enable an adequate verification of patient positioning. However, it was noted that kV CBCT images contain more artifacts than do CT images and that their quality could be improved.

Based on studies comparing positioning errors measured with CBCT and portal imaging, it is difficult to say which technology is more accurate. There is currently no reference value (benchmark) enabling the exact position of the tumour to be established.

Third finding: The clinical efficacy of the device is unproven.

Another important finding is the absence of clinical trials, which prevents an in-depth evaluation of the efficacy and safety of IGRT. Therefore, it is difficult to say whether the technical advantages of IGRT or CBCT translate into actual clinical benefits and, consequently, to identify the types of patients who stand to gain the most from this technology. Moreover, it has yet to be shown that the additional doses of radiation associated with more frequent imaging are without side effects.

Despite the lack of clinical trials demonstrating the efficacy of this technology, some researchers maintain that there are theoretical benefits. Nonetheless, it is not currently possible to evaluate the clinical benefits associated with better positioning. In fact, studies simulating the impact of corrections made using IGRT on the dose administered to the target site and to healthy tissues cannot be generalized due to the small number of patients and to the use of ideal treatment conditions that do not accurately reflect the clinical context.

Fourth finding: The most common indications are those with the highest incidence.

There are more than a dozen indications for the use of the linac-integrated cone beam CT in the scientific literature and institutions consulted. The most common indications are prostate, lung, and head and neck cancers. However, it is possible that these indications reflect a publication bias associated with their high incidence in the population rather than the actual advantage of the technology for these indications. In fact, with respect to head and neck cancers, the authors mention that 3D imaging is not always required and that 2D imaging is often sufficient. Other authors found that prostate cancer treatment is effective without IGRT and that other types of imaging can be used with satisfactory results.

Fifth finding: The main application of CBCT is currently for verifying patient positioning.

Another finding that emerged from the reviewed documents and interviews is that CBCT is being used mainly to check patient positioning prior to treatment. kV CBCT imaging is not used to plan treatment, since the image quality is inferior to that of the CT scan, the planning standard. For the time being, it would appear that adaptive radiation therapy is still not very common, possibly due to time constraints and limited resources.

Sixth finding: Procedures vary and practices are changing.

Interestingly, the procedures used with respect to a given tumour site vary somewhat between institutions. Nonetheless, in most hospitals, the imaging frequency has increased and, in several cases, this technique is used daily. The impact on the length of treatment sessions is difficult to measure, since the times reported vary from one author to another (between 5 and 30 minutes), and the authors do not always clearly state which steps (positioning, imaging, correction, treatment) are included in the time specified.

Seventh finding: Implementation strategies are important.

With regard to implementation strategies, the people consulted suggest initiating the use of CBCT on prostate cancer patients with gold implants. At the PMH, the recommendation is to create a startup team whose members are released from their normal duties in order to concentrate on the implementation. At both hospitals, it is recommended to restrict the rotation of staff members using the new device during the first few months to enable them to perfect their technique.

Discussion and conclusion

The aim of this draft opinion was to identify the best indications to optimize use of the linac-integrated cone beam CT, based on recent articles on the efficacy of CBCT and its applications. Other articles addressing more technical issues, such as quality assurance, dosimetry, respiratory gating, dose reconstruction and organ deformation, were excluded. This information could possibly be of interest in the future, depending on the chosen applications for the linac-integrated cone beam CT. Its relevance and applicability will be addressed by the appropriate experts.

Whereas it is not possible to make firm recommendations regarding the best indications and applications, certain elements could nonetheless help clinical teams decide how to best use this new device. Accordingly, current practices involving the use of other radiation therapy devices and the various types of imaging by the CHUQ Radiation Oncology department should be analyzed in light of the benefits and limitations reported by the various authors having used the new device. The comparative analysis for each tumour site could be guided by the following analytical framework:

With respect to the accuracy of the image:

- Is the increase in accuracy reported by the authors large enough to cause major clinical impacts (better coverage of the target volume, reduced toxicity, generic margins, side effects)?
  - Does this increase justify the necessary resources (technologists' time, data storage) and potential impacts (patient wait times)?

With respect to the type of imaging and related frequency:

- Which type of imaging is best for checking patient positioning?
  - Portal imaging (adequate bony landmarks, absence of prosthesis causing artifacts, etc.)
  - kV/kV imaging (bony and soft-tissue landmarks)
  - kV CBCT imaging (significant rotation errors (elongated targets), organs providing good contrast (lungs, head and neck), etc.) given the dose of radiation required to perform the examination
- Are anatomical changes (shrinking of the tumour, weight loss, movement) significant enough to justify using imaging regularly? How often?
- Are anatomical changes (shrinking of the tumour, weight loss, movement) significant enough to justify a new treatment plan?

With respect to work organization:

- Which tools do medical professionals need to make decisions regarding corrections to patient positioning (procedures, rules, protocols, access to a physician, training)?

In regards to the strategies used by the various Radiation Oncology departments to implement the technology, the importance of limiting staff rotation as much as possible during the first few months in order to enable users of the technology to master the technique should be taken into account.

In conclusion, a balance is needed between the presumed clinical benefits of using CBCT and the additional resources required for imaging and IGRT procedures. It is also important to consider the potential risks associated with the accumulation of additional doses of radiation from imaging. Accordingly, it would be interesting to plan the use of this technology from a global assessment perspective, including its efficacy and safety, as well as the accuracy and technical performance of the Varian linac-integrated cone beam CT. Clinical trials are also necessary in order to evaluate these aspects.

GLOSSARY

CT SCAN	Computer-assisted tomography is a medical imaging technique in which the patient is scanned with a beam of x-rays.
DIGITALLY RECONSTRUCTED RADIOGRAPHS (DRR)	Reference images obtained by CT scan and used in treatment planning. The images obtained during treatment are superimposed on these images to pinpoint patient positioning errors.
GRAY (Gy)	The absorbed dose represents the amount of energy absorbed per unit of matter. It is measured in Gray units.
KILOVOLTAGE (kV)	Amount of low-energy radiation used for imaging and radiation therapy.
MEGAVOLTAGE (MV)	Amount of high-energy radiation used for imaging and radiation therapy.
ORGANS AT RISK (OARs)	Normal tissues with high risk to be exposed to radiation.
RADIOSURGERY	Radiation therapy techniques used in outpatient high-precision radiation therapy involving photon or proton beams that converge at the centre of the lesion.
ADAPTATIVE RADIATION THERAPY	Review of the conditions of irradiation based on the changes observed in the patient. This indicates the need for a regular evaluation of the dose administration procedure, requiring a new clinical approach.
CONFORMAL RADIATION THERAPY	Radiation therapy using various medical imaging techniques to identify the edges of a tumour in 3D with a high degree of accuracy.
IMAGE-GUIDED RADIATION THERAPY (IGRT)	Radiation therapy using an imaging system to locate the target volume in real time and in treatment position, with the aim of increasing treatment accuracy.
HYPOFRACTIONATED RADIATION THERAPY (OR IRRADIATION)	Radiation therapy involving the administration of a low number of concentrated doses.
INTENSITY-MODULATED RADIATION THERAPY (IMRT)	IMRT is a conformal 3D radiation therapy in which the fluence (amount of photons per unit of area) of the beams is modulated during treatment.
STEREOTAXIS	High-precision 3D localization of structures, mainly used in neurology and for brain tumours. Stereotaxis enables the localization and sampling of small lesions visible only on x-ray and their treatment by radiation therapy.

ON-BOARD IMAGING (OBI) SYSTEM	Linear accelerator-integrated imaging system with robotic arms that move along three axes to position a tube of x-rays and a flat-screen detector on either side of the patient in order to generate images of the patient in real time and in treatment position.
PORTAL IMAGING SYSTEM	Imaging system using beam radiation therapy to generate images of the patient in real time and in treatment position.
INTERFRACTIONAL VARIATIONS	Movement or deformation of an organ during the course of radiation therapy.
INTRAFRACTIONAL VARIATIONS	Movement or deformation of an organ during a single radiation therapy session.
GROSS TUMOUR VOLUME (GTV)	The apparent volume of the tumour as observed using various investigational methods.
CLINICAL TARGET VOLUME (CTV)	Equal to the GTV plus a margin of safety to account for the possibility of an invasion of adjacent tissues by a cancerous tumour.
PLANNED TARGET VOLUME (PTV)	Equal to the CTV plus an additional margin of safety to account for physiological variations (normal tissue/organ movements, possible variations in patient's weight, transformation of tumours, etc.) and patient movement during treatment.
VOXEL	Unit of volume.