The purpose of this teaching lecture is to examine typical approaches for representation of patient anatomical data in treatment planning systems and the impact of that representation on the accuracy of dose calculation.

Dose calculation in modern treatment planning systems, which can often report dose to water or dose to medium, require mass density and tissue composition information for accurate kernel scaling and radiation transfer. The planning systems use patient specific anatomical information in the form of high-resolution CT images for volume definition and dose calculation. CT information is obtained at kV energies so in order to obtain the relevant properties required for use in high-energy photon or proton beams, the CT numbers are converted to electron density or proton stopping powers using calibration curves obtained using phantoms with known properties. Following this, the patient data is resampled into a more coarse matrix and then segmented into a limited number of tissue types based on, for example, data from ICRU44 or ICRP23, which are themselves obtained from population based data sets. Dose calculations are performed on these converted, re-sampled data sets and output as distributions on the original high resolution CT image set. Errors at the conversion stage can propagate through to dose calculation and the number of tissue sets used in the conversion process has been shown to have an effect on the dose calculation. In particular, for low energy ranges including brachytherapy energies, it has been shown the assignment of tissue properties that can significantly affect dose calculations in various processes, including stoichiometric approaches, for converting CT data to tissue types will be described and recent data from a number of researchers showing the influence of the choice of conversion on dose calculation accuracy will be presented.

SP-0005
Improving treatment accuracy: new challenges in positioning, immobilisation and verification
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In-room patient imaging started in the 1950s. Different initiatives were taken to monitor and improve patient’s treatment positioning. Not earlier then the 1990s Electronic Portal Imaging (EPI) was developed and became commercially available. The development of EPI much improved both the process and the quality of the verification of the treatment position. The role of EPI grew and became an important part in the quality assurance (QA) chain of radiotherapy.

In the last decade, 3D volumetric imaging was introduced. Nowadays many vendors have some kind of 3D imaging device commercially available. One advantage of 3D imaging is the improved quality of patient registration. Different studies showed improved registration accuracy as compared to 2D EPI. Another advantage is the ability to register patients directly to the tumour, e.g. in case of lung cancer. The not only limited to the widespread application of Stereotactic Body RadioTherapy (SBRT), but it also resulted in more insight in fundamental processes like the baseline shift of lung tumours. Knowledge about these processes further underlined the importance of 3D image guidance.

More recent, the application of Adaptive Radiotherapy (ART) has increased and in-room volumetric imaging is a basic requirement for many types of the sophisticated treatment. For instance, in the Plan-of-the-day concept a treatment plan is selected daily from a library of plans based on the actual size/shape of the tumour as visualised with Conebeam-CT (CBCT) images. This type of treatment has been introduced for treatment sites like cervix and bladder cancer. Developments like ART force us to look at the changing physiology and pathological processes like the baseline shift of lung tumours. This not only contributed to the widespread application of Stereotactic Body RadioTherapy (SBRT), but it also resulted in more insight in fundamental processes like the baseline shift of lung tumours. Knowledge about these processes further underlined the importance of 3D image guidance.

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With all these new possibilities the need for a systematic analysis of 3D images is born. We no longer can perform image registration in terms of translation and rotations only. Ideally, the acquired images should be analysed on changing anatomy and immobilization device quality systematically, or at least at different moments during the treatment of the patient. Furthermore, we need to have a strategy on how to act when the anatomy no longer resembles the situation on the initial reference CT-scan. A protocolised method for evaluating the effect of anatomical changes e.g. by recalculating the actually given dose using the CBCT image, would be a necessity. But maybe the most challenging part is finding the time and resources to be able to truly utilize all benefits that volumetric imaging is offering us.

SP-0006
Patient reported outcomes versus clinical assessment of radiotherapy adverse effects
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Patient reported outcomes (PRO) are of increasing interest as measures of disease- and treatment-related outcomes after radiotherapy. They have long been accepted in the palliative setting, but it is only recently that a primary role in the curative setting has been investigated. This interest is stimulated, not only by the validity and reliability of PRO, but also by their relative ease of administration and collection.

PRO can be restricted to recording specific disease- and treatment-related symptoms or extended to include broader qualities such as emotional well-being, social and sexual functioning and overall satisfaction with life. Fully-validated multi-item questionnaires are available, including some that are cancer specific (MOS SF36, EQSD) and others that are cancer non-site specific (EORTC QLQ-C30), cancer site specific (EORTC QLQ-CR23) and treatment specific (FACT N, for neutropenic sepsis). The identification of questionnaire(s) appropriate for a specific clinical context is extremely important, and requires expert guidance. Assessing research questions are precisely defined and the appropriate PRO measures are fully incorporated in the analysis plan, questionnaires need to be administered to patients by trained staff with the time to explain how to respond to the questions. As with clinician assessments, >10% missing data present serious problems to analysis and interpretation, since reasons for missing data may be linked to the outcomes under study.

UK breast hypofractionated radiotherapy trials are among several studies that illustrate the potential power of PRO in research. PRO of breast shrinkage and hardness perform as well as change in photographic breast appearance scored by independent observers in discriminating small differences in randomised dose, and generate comparable estimates of α/β for endpoints such as change in breast size and hardness. This is despite limited concordance between clinician and self-assessments at the level of individual patient, however, full testing curative radiotherapy has yet abandoned clinical assessments of treatment outcome, this may be only a matter of time. Finally, although PRO and standard external assessments can function well as therapeutic endpoints, they do not necessarily distinguish between the different relevant pathological processes (atrophy, fibrosis, telangiectasia etc), a requirement that may prove essential in correlative research into genetic susceptibilities.

SP-0007
Consensus on brachytherapy dose - volume parameters in 2013
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Traditionally, treatment planning in brachytherapy has been based upon 2D imaging and specific points have been used for prescription and reporting. With the introduction of image guided brachytherapy (IGBT) it has been possible to move from point prescription to prescription of dose to 3D target volume in terms of dose volume histogram parameters. In radiotherapy in general, it is essential to use a common language in order to compare clinical results from different centres worldwide. Applying IGBT it is important to use a terminology adjusted to the complex nature of such treatment technique. Preferably the same terminology should be used for different brachytherapy sites. It should also be harmonized, as far as possible, to the terminology used in external beam radiotherapy (EBRT), e.g. ICRU83.

Several recommendations on 3D image based treatment planning have been published for various brachytherapy sites the last ten years. In an encompassing ICRU/GE/GEC ESTRO recommendation for cervical cancer brachytherapy, concepts and terms for target and OAR definitions, biological dose modelling and DVH parameters are described for IGBT.
Additional, specific issues related to combination of IGBT and EBRT are considered. These new recommendations may serve as a template for future recommendations in other brachytherapy sites.

To harmonise with the ICRU83 terminology, a new concept is suggested for brachytherapy treatment planning. This concept is introduced in order to clarify the process from defining planning aims for a treatment to final individual prescription. The “planning aims” are dose and volume values defined prior to treatment planning. The “prescription” is the finally accepted set of values after treatment plan optimisation which may be different from the planning aim.

The main parameter for reporting dose to target volumes is $D_{90}$, the dose delivered to at least 90% of the target volume. This is a parameter already widely used in brachytherapy. Due to the significant dose gradient the $D_{90}$ may look favourable even though a small part of the target volume receives much lower dose. Therefore, it may not be sufficient to only report and evaluate the $D_{90}$. The absolute minimum target dose, $D_{100}$, is very sensitive to delineation uncertainties and therefore it is suggested to report the near-minimum target dose, $D_{98}$, additional to $D_{90}$. This is in accordance with ICRU83.

Often recommendations are given for volumes related to a percentage of the prescribed dose, e.g. $V_{100}$, $V_{200}$. Such parameters are based on the prescribed physical dose and are consequently only relevant within a specific dose rate and fractionation schedule. Hence, it should solely be used for intra-patient plan comparison or in a series of patients treated with the same dose and fractionation. Additional, applying individual dose prescription (see above) such parameter should be carefully used. The upcoming ICRU/GEC ESTRO report suggest to use the concept of isodose surface volume, and link such volume to a dose that is judged as representative for a certain clinical effect. This report also suggests using $D_{50}$ to quantify the high dose volumes within the CTVs.

Reporting dose to OAR is challenging since the optimal parameter to use is depending on the type of organ and the specific endpoint in question. Reporting of absolute doses to absolute volumes is suggested to be the most valid, reliable and reproducible OAR dose assessment method. Examples from different OAR will be given in the lecture.