A great opportunity is offered by Tomo also in **medulloblastoma patients**. Until now these patients were treated in prone positions: cranial fields were matched with spinal fields, a position that allows better control of the junction. Instead with Tomo, there is no junction, so the child can be treated in a supine position, more comfortable for the patient and safer for the anesthesiologist (Figure 2). We have compared conventional and Tomo cranio- spinal irradiation (CSI). The differences between doses delivered to the anterior areas of the thorax and abdomen are relevant: 50% with conventional and 10% with Tomo CSI. Sometimes to obtain a good sparing of the bulbar space with Tomo means a sub-optimal coverage of the cribiform area. We could partially resolve this by using a Tomo field of 1 cm instead of 2.5 cm, but this option prolongs the treatment time from 20 to 40 minutes (unacceptable for children). The beam thickness, pitch, and modulation factor are important parameters in the planning of Tomo. Generally, a smaller beam thickness results in a better homogeneity of the planned target volume and a better sparing of critical organs like eyes.

In patients with **metallic implants**, we can make mistakes due to artificial images seen in the simulation CT. MVCT allows a means of resolving this difficulty because the prostheses disappear. In one of our cases the spinal space was corrected with the auxiliary use of MVCT, avoiding overdosage to the spinal cord.

Summarising our findings, even though the dosimetric results are better with Tomo the potential problems of this new technology in children are:

1) a longer treatment set-up;
2) a longer treatment planning and delivery time;
3) a prolonged anesthesia time but with the advantage of being always in a supine position and finally;
4) increased whole body dose would increase the risk of secondary malignancies.

Some authors concluded that IMRT increased the risk of secondary malignancies, as compared to conventional radiation therapy. In fact, multiple (nearly unlimited) fields in Tomo use may lead to an increase of low doses like V2Gy to non-tumor structures. We analysed the total body integral dose in CSI patients using the formula of D'Souza & Rosen (Med Phys 2003; 30: 2065-2071). It is nearly the same for conventional and Tomo CSI.

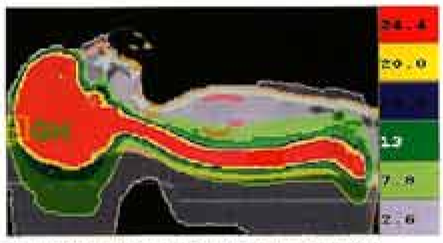

Figure 2: craniospinal irradiation with Tomo, in children with medulloblastoma.

**Conclusion**

Tomo appears as one of the most promising radiotherapy challenges in the treatment of children. A combined modality approach in pediatric oncology has served as a model for much of the cancer treatment today. Tomo treatment is a multi-step process that involves several specialists (radiotherapist, physicist, radiotherapy technologist, radiologist, nuclear medical doctor, radiobiologist, anesthesiologist, nurses). Using Tomo, we have generally observed an increase in the complexity of each phase of treatment due not only to the radiation time but to the specific length of the entire sophisticated procedure. Decisions made at the time of simulation, target and tissue delineation, planning, delivery and evaluation impact on the entire radiotherapy process. Successful implementation of this new radiotherapy technology will depend on the results of prospective assessment of functional outcomes and local control of diseases. Hence, possible problems like: increased low dose to non- target tissue and integral dose need to be evaluated with other studies. Our aim will be to continue to develop IMRT with linear accelerator or Tomotherapy for children with solid tumors that yields similar or slightly better target coverage than 3D-CRT and significant improvements in normal tissue doses. Concerns regarding the risk of radiation induced cancer, as a consequence of an increase in low dose radiation exposure, needs to be carefully addressed. ▮

**Joanne Cunningham,**
**RTT Committee Member**

# > Is there a role for Tomotherapy in children?

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In children, radiation is one of the most effective treatments for solid tumors, yet the threat of its effects on cognition, growth and development has for decades led physicians to seek alternatives to this form of therapy. In recent years, the advancements in conformation have renewed interest in the use of radiation therapy, even in very young children. Although radiotherapy remains an important modality of treatment, the main criticisms are the risk of long term side effects especially on cognition and growth development. The question is if applying conformal techniques can help to decrease the risk of acute and late effects, increasing the rate of local control. Proton therapy is considered the most advanced form of radiation therapy available, but until now size and cost have limited the technology's use. Guidelines are developing that ensure appropriate volume for each specific type of tumor, and assessment of outcome is essential to ensure that benefits of the new techniques outweigh the risks.

Actually Tomotherapy (Tomo) seems one of the most promising methods of treatment, as using IMRT can achieve a highly conformal distribution of radiation to the target volume while sparing critical, surrounding normal tissue. In the last two years we applied this kind of therapy in young patients affected by tumors that were complex, large, or close to critical areas. We began our experience with Tomo in children at the National Cancer Institute in Aviano (Italy), in May 2006, after 1 year of work with Linac-IMRT in children. Since February 2008, from about 50 pediatric patients undergoing IMRT treatment, we have used Tomo in a total of 36 pediatric-adolescent patients; sedation was used on 13 children between 2-6 years. The median age of patients was 12 years (range 2 -18 years). The most common diseases have been brain tumors, followed by soft tissue sarcomas, neuroblastoma and nasopharynx cancer.

**The process of Tomotherapy**

Applying these new technologies we implemented our step-by-step process: starting with a multi-modality diagnostic imaging set (CT, NMR or PET), we delineate the target and structures at risk. The Tomo plan is generated by a Tomotherapy planning workstation. Prior to optimization, dose volume constraints, precedence, importance and penalty factors are used to improve target dose homogeneities and reduce doses to normal structures. The next step is delivery of quality analysis (DQA) and verification. Tomo allows Megavolt CT (MVCT) imaging on board, and fused images with planning CT. The position of patients is adjusted and finally the treatment is delivered. With Tomo (and with IMRT in general) it is necessary to delineate more structure than with traditional conformal radiation therapy since the Tomo planning system sees only what we draw. This is of particular importance in children where there could be a structure at risk in the body.

The Tomo mechanism works in a similar manner to CT with a 6 MV linear accelerator mounted on a circular gantry. The radiation is delivered in a helicoidal mode resulting in a helical form of energy without junctional problems. The same radiation source but with less energy is used to acquire the MVCT. The MVCT images are fused with simulation CT to check the patient set-up. The set-up is indexed to fixed internal landmarks rather than external skin marks for daily patient positioning. The scan dose with MVCT is about 1-2 cGy per image set, in normal acquisition modalities. The time necessary for the patient's positioning, setup, scanning, and evaluation with MVCT, is about 5 -7 minutes. The Tomo average delivery time was about 20 minutes for craniospinal irradiation (CSI) and 8-12 minutes for smaller volume irradiation.

**Findings**

Tomo allowed a great versatility in treatment both with small and large tumor volume; it demonstrated excellent target coverage, homogeneity and organ-sparing compared with 3DCRT, especially for tumors close to critical areas. TOMO could also be a good alternative for stereotactic boost of the gross residual tumor, such as a brain tumor. Otherwise it offers the possibility to deliver simultaneous integrated boosts in a single treatment scheme, obtaining a dose escalation, such as in nasopharynx cancer.

Nonetheless, one of the most interesting applications of Tomo are large tumor volumes like **CSI** and **whole abdominal irradiation** in patients with advanced Wilm's tumors. Usually we treat the whole abdomen with 15 Gy, 2 opposing fields of radiation, and a block to the healthy kidney after 12 Gy. This technique results in an underdosed (abdominal) area in front of the healthy kidney. Instead with Tomo, the abdominal cavity is treated uniformly well with a dose to the healthy kidney less than 40% of the prescribed dose (Figure 1).

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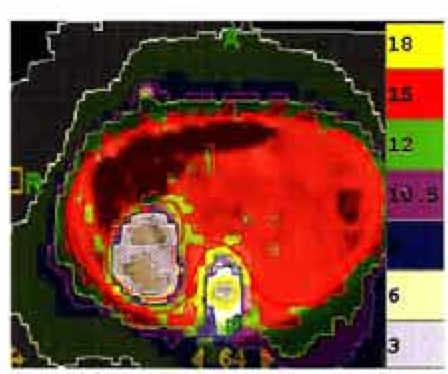


Figure 1: whole abdomen irradiation with Tomo, in children with Wilm's tumor.