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Intraoperative beta probe for brain tumor surgery

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Surgery is still considered the primary therapeutic procedure for high grade gliomas and several recent clinical studies have shown that gross total tumor resection is directly associated with longer and better survival when compared to subtotal resection. Considering this context and based on a first experience in radio-guided surgery [1,2], we are currently developing an intraoperative positron imaging probe specifically designed to help neurosurgeons to locate residual radiolabeled brain tumor (with 18F-FDG or FET) after the bulk has been excised. Our detector was conceived to be compact and electrically safe in order to be easily used inside the operative wound jointly to other surgical tools.

We chose to build our ⊠ imaging probe around plastic scintillating multiclad fibers which optimize the detection of positrons emitted by tumor while significantly reducing annihilation gamma rays background noise. Scintillating fibers are disposed on two concentric rings and are thermally fused to a 2 m length optical fiber bundle to export the signal outside of the operative wound until a multi-channel PMT. To eliminate the ⊠ background noise, each detection pixel is composed of 2 scintillating fibers: 1 on the internal ring and 1 on the external ring which is beta shielded wich a thin inox layer. The ⊠+ distribution is obtained in real time by subtracting the signal from these 2 fibers for each detection pixel.

Monte Carlo simulations using MCNP were realized on a voxelised anthropomorphic brain phantom with different radiotracer activities to optimize the detector geometry in a realistic clinical environment. A first prototype of the probe composed of 8 detection pixels is currently under development. Its experimental beta and gamma sensitivities were measured using 204Tl and 22Na point sources. Simulations show that optimal performances are obtained with 2 mm diameter and 0.5 mm length scintillating fibers giving a gamma ray rejection efficiency of 99.9%. These results were confirmed by experimental measurements. With a homogeneous tracer distribution in the tumor margins and a detector placed in contact with the tissues, the probe sensitivity is 11 cps/nCi/mm3 for each detection pixel. The theoretical minimum radiotracer detectable concentration is 1.8 nCi/mm3 for 18F-FET and an acquisition time of 5 s. This minimum value has to be compared to the 2.9 nCi/mm3 average concentration of 18F-FET in the bulk of the tumor and is expected to be sufficient to help surgeons to detect residual lesions in the resection margins of the tumor.

In addition to these promising performances, we are performing experimental measures on radioactive phantom to validate the operating parameters of the probe in a clinical context.

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