Investigations on fluorescence guided stereotactic biopsy

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I. BACKGROUND

In neurosurgery harvesting stereotactic needle biopsy to enable histopathological diagnosis of a suspected brain tumor is a surgical challenge. Doing this it is essential to perform it safely without damaging major blood vessels and to be sure to really obtain relevant vital material from the tumor. This study investigated the suitability of Indocyanine Green (ICG) fluorescence for blood vessel recognition thus guidance during introduction could be performed which may minimize the risk of blood vessel perforation. Additionally, 5-Aminolevulinic acid (5-ALA) induced Protoporphyrin IX (PpIX) fluorescence for identification of proliferative brain tumor tissue may help to recognize vital tumor cells as biopsy target. Limitations of the used light intensity were calculated for safety reasons.

II. METHODS

A fiber-optic endoscopic approach was studied to generate and detect both fluorescence signals. For this the PpIX-concentration within tumorous tissue was determined by extraction methods. Preliminary equipment was studied in a mouse model. Using simulation software, the temperature distribution in human brain tissue was calculated as a function of time for a realistic single-fiber probe (focus diameter 0.29 mm, numerical aperture 0.35). Simulations were performed at the two optimum excitation wavelengths (PpIX: 405 nm, ICG: 785 nm). Worst case szenarios were calculated. In addition to homogeneous normal brain and brain tumor tissue with homogeneous blood perfusion, models with localized extra blood vessels incorporated ahead of the distal fiber end were investigated.

III. RESULTS

PpIX-concentrations in glioblastoma tissue showed a high variability. A PpIX-concentration exceeding 2.4 \textmu mol/l is detectable by state-of-the-art fiberoptic fluorescence spectroscopy and imaging. Such an imaging fluoroscope with 30,000 pixels resolution could be introduced through a position controlled stereotactic needle. Furthermore ICG-fluorescence from vessels with diameters \geq 0.1 mm can be detected. If one demands that destruction of normal brain tissue must be excluded by limiting the tissue heating to 42 °C, then the radiant flux at the distal fiber end must be limited to 5.3 mW (33 mW) for excitation at 405 nm (785 nm). For 785 nm excitation, incorporating extra blood vessels of 0.1 mm diameter into homogeneously perfused brain tissue reduces the tolerable radiant flux to 22 mW. According to legal laser safety regulations for human skin tissue, threshold values of 19.2 mW (28.5 mW) would be obtained.

IV. CONCLUSIONS

Fluorescence detection during stereotactic biopsy might increase safety and precision of the procedure significantly. For the envisaged modalities of tumor and blood vessel detection, light power limits for an application-relevant fiber configuration have been determined. The power limit for 405 nm excitation lies significantly below the one according to present legal regulations for skin tissue.