Three dimensional modeling of bruise evolution for improved age determination

Stam, B.

Publication date
2012

Age determination of bruises can aid in the diagnosis of child abuse, but current methods are insufficient for medico-legal use, as they are solely based on the changing colors of the bruise. These colors do not only depend on the age of the bruise, but also on the size and shape of the bruise, the type of skin, etc. This complex non linear pathophysiology makes intuitive estimation of the influence of these factors on the temporal behavior of bruises impossible, and a mathematical model that can take these factors into account is required.

We built a numerical 3D model to simulate convection and diffusion of two chromophores, hemoglobin and bilirubin. The model includes Michaelis-Menten enzyme kinetics for the conversion of hemoglobin to bilirubin, 3D diffusion of both chromophores and clearance of bilirubin through the lymphatic system. The key output parameters of our 3D model are the concentrations and areas of hemoglobin and bilirubin during healing. With our model we could assess the influence of several factors such as bruise size and hemoglobin diffusivity on the temporal bruise behavior, and found that diffusivity and bruise size have a major influence. The initial concentration of hemoglobin did not influence the temporal behavior.

Next, we observed differences in the hemoglobin and bilirubin areas in clinical and simulated bruises. These areas could be measured from photos or using a hyperspectral imaging system, and we showed how these temporal differences in areas could be utilized in the age determination of bruises. This method also allowed the determination of 3 important tissue specific input parameters; the diffusivity of hemoglobin, the concentration of the enzyme that converts hemoglobin and the relaxation time of bilirubin. Knowledge of input parameters is of great importance, as they influence the spatial and temporal behavior of the hemoglobin and bilirubin distributions in the skin, in other words, influence the temporal behavior. We assessed the influence of the bruise parameters shape, size and concentration distribution of the initial blood pool on the spatial and temporal behavior of the bruise, and argued that inclusion of these factors is necessary for accurate age determination of bruises.

Clinical applicability of our method to determine the age of bruises is dependent on measurement frequency. If bruises on the same anatomical position would have comparable model parameters, the measurement frequency can be reduced. We grouped bruises that were measured once by their anatomical position and determined the group averages of the three tissue specific parameters diffusivity of hemoglobin, the concentration of the enzyme that converts hemoglobin and the relaxation time of bilirubin. We found that the parameter values were comparable between the three groups of bruises. Next we found that the spectral properties in these groups are also comparable.

Age determination of bruises will only be useful if physicians recognize the signs of child abuse, after which the technique may aid the diagnosis. In the Academic Medical Centre, a Child Protection Team was formed to provide a platform where all employees

of the hospital can find expertise and peer review on the subject, and which provides education and support within and outside the hospital. Using 3 cases of suspected abuse, we discussed the value of having such a team in the hospital.