Perfusion imaging of free flaps with contrast harmonic ultrasound imaging, laser-induced indocyanine green fluorescence angiography and magnetic resonance imaging

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INTRODUCTION:

Currently there is no image-guided modality which is sufficient and exact enough to evaluate the perfusion of tissue in its different layers after transplantation of microvascular flaps. Examination of capillary filling after compression (refill) allows merely a vague estimation. The cutaneous blood flow can be shown with different methods of fluoroscopy, but the perfusion of deeper tissue layers is not detectable with these methods. To a certain degree indocyanin green fluoroscene angiography can help to measure the cutaneous perfusion semi-quantitatively. To assess the perfusion in deeper tissue layers with high spatial (and temporal) resolution there are basically two methods available: dynamic MRI techniques and contrast enhanced ultrasound with high-resolution linear probes using the contrast harmonic imaging (CHI) technique. Therefore, the aim of this study was to evaluate post surgery tissue perfusion of free flaps with contrast enhanced harmonic ultrasound (CHI), laser-induced indocyanine green (ICG) fluorescence angiography and dynamic susceptibility contrast perfusion weighted (PW) MRI.

METHODS:

10 patients (33-77 years, mean: 54 years) with free flaps of the lower limb were evaluated (1-42 months postoperative, mean: 15 month) with CHI, ICG-fluorescence angiography and PW MRI. PW MRI was performed on a 1.5 T system (Magnetom Symphony, Siemens) after intravenous bolus injection of 25 ml Gd-DTPA using a gradient echo echo planar imaging technique (TR = 2230 ms, TE = 49 ms, flip angle 60°). A pixel size of 1.8 mm x 1.8 mm and a slice thickness of 5mm was selected to reach a time resolution of 2 s while covering the whole free flap. ICG (Pulsion Medical Systems) was dissolved in an aqueous solvent (pH 7.4) at a concentration of 0.75 mg/ml and immediately applied intravenously as bolus (0.5 mg / kg b.w.). The fluorescence of the activated chromophore through a near-infrared-laser device (λ_{em}=780 nm, fluence dose: 0.16 W) was detected in real time with a camcorder. Ultrasound was performed by an experienced examiner with a linear probe (6-9 MHz, Logiq 9, GE) after intravenous bolus injection of 2.4 ml SonoVue® (Bracco). For MRI time intensity curves (global bolus plot) as well as color-coded relative blood volume (rBV) maps of the whole free flap were qualitatively evaluated. For CHI and ICG time intensity curves (TIC) in selected regions of interest were analyzed. A score from 1-5 (1=low, 5=excellent perfusion) was used for analysis of perfusion images by three independent readers.

RESULTS:

Follow-up examinations for at least 9 months confirmed an adequate perfusion of the free flaps without wound healing disorder in all patients, PW MRI showed a strong perfusion of the parts near the anastomosis of the engrafted tissue. In the middle tissue layers and the central parts of the microvascular flaps the tissue perfusion was dependent upon the number of vessels and the fat part of the engrafted tissue. High perfusion values were therefore the result for very small flaps with low subcutaneous fat part and thick anastomosis vessel, e.g. a radialis flap, especially in the rBV maps of the MRI. This could also be confirmed with fluoroscopy and contrast-enhanced ultrasound. Central flap parts of soft tissue with a medium number of vessels showed only moderate perfusion in MRI. In 3 cases (radialis, parascapular and lateral thigh flap) CHI, MRI and ICG perfusion imaging showed an excellent (score 4-5) contrast enhancement of the cutaneous and subcutaneous part of the free flaps. In 2 cases of osteocutaneous flaps only the region of anastomosis showed a good (score 3) perfusion, but perfusion in central and distal parts of the free flaps was reduced (score 2).
Correlation between the results of the visual evaluation of CHI, MRI and ICG was 0.69 – 0.83 for the distal parts of the free flaps and 0.74 – 0.87 for the center of the flaps (Spearman test). The center of the free flaps showed significantly different perfusion for MRI and ICG and also for MRI and CHI ($p<0.05$, Wilcoxon test). According to rBV maps a good perfusion was detectable in the dermal plexus of the central flap parts, but apparently perfusion was missing in the deeper layers of the central flap parts. This led to a considerably worse evaluation of the MRI in comparison to fluoroscopy, which could only detect the superficial perfusion, and contrast-enhanced ultrasound, with which even the capillary perfusion in the deeper layers were detectable and could be quantified by means of the TIC analysis. A strong perfusion in the MRI with PWI could also be detected by a signal reduction >25% in curve presentation of the global bolus plot.

CONCLUSION:

These first results introduce CHI and PW MRI as a promising post surgery monitoring in patients with free flaps which allow the evaluation of perfusion in different areas of the engrafted tissue. Nevertheless, further refinement seems to be desirable – especially for the acquisition and assessment of MRI data.