Ultrasonographic evaluation of disturbances in the perfusion of renal graft - a new application for contrast-enhanced ultrasonography

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Purpose

In case of the evaluation of organs with a rich vascularization, contrast enhanced ultrasound (CE-US) allows for the separation of areas with reduced or absent microcirculation. A major advantage of this method is the ability to quantify tissue perfusion in defined areas of the parenchyma [1,2]. The method seems to be particularly useful in the evaluation of zones of parenchymal infarction, induced by closure of arterial vessels, since this type of contrast agent is purely intravascular [3,4]. The introduction of ultrasonographic contrast agents has opened new possibilities for diagnostic ultrasound in the evaluation of graft perfusion [5-8].

In the case of a renal transplant, a reduction in tissue perfusion translates directly into an impairment of function, causing a decrease in glomerular filtration and daily urine output. Early detection of decreased parenchymal perfusion in a kidney transplant (KTX) and implementation of appropriate therapy are essential for the survival of the graft in the immediate post-operative period as well as for its later function. Arterial occlusion can have a rich clinical manifestation when it involves a solitary renal artery or may be subclinical in cases where one of several renal arteries is occluded leading to ischemia in only a part of the parenchyma. Fig.1 and Fig.2

The current method of diagnosing KTx is real-time ultrasound (B-mode) and color Doppler ultrasound with spectral flow analysis (US-CD, US-PW) [9-11]. These techniques evaluate graft morphology and enable an indirect assessment of ischemic areas, based on the distribution and density of the vasculature as well as indirect indicators such as the resistance index (RI) and pulsatility index (PI) [12-16].

The aim of this study was to assess the disturbances in perfusion of transplanted kidneys (KTx) following an acute occlusion of one or more of the sectional arteries (SA). We compared the differences in quantity and the size of ischemic areas between routine B presentation ultrasonography with Doppler (US-CD) and Power Doppler (US-PD) evaluation, and contrast-enhanced ultrasound examination (CE-US).
Fig. 1: Small area of ischemia in the CE-US study. The important difference in signal intensity (about 25-27dB) between the renal parenchyma and the area of ischemic area.
Fig. 2: Large area of ischemia in the CE-US study. The large difference in signal intensity (about 28-30dB) between the renal parenchyma and the area of ischemic area.

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Methods and Materials

Sixty-three kidney graft recipients (31 women and 32 men, mean age 49±16 years) who received transplants from deceased donors, were examined in the early period after transplantation (24-120 hours). The patients ranged from 21 to 62 years of age (mean 38.7±13). For all the patients this was the first transplant, and all the grafts were from deceased donors. The anastomosis was performed with end to side technique on the aortic patch.

All patients underwent a routine B mode with US-CD and US-PD examinations. After routine examinations, the CE-US examination, following intravenous contrast administration was performed, SonoVue Diagnostics (Bracco Int., Milan, Italy), at a dose of 2.4 ml per examination [17]. All examinations were performed by the same, experienced ultrasonographer, who was unaware of the clinical information on kidney function. The examiner was however aware of the technique used for anastomosis of the renal vessels and the number of supernumerary arteries, from the surgical protocol. The ultrasonographic examinations were performed using GE Vivid 7, equipped with a convex type 3.5C head. All the US examinations (B presentation, US-CD, CE-US) had the same initial protocol of dynamic acquisition in the long and short axis of the kidney [18]. The examinations included the whole kidney. Recorded dynamic loops enabled the acquisition of identical cross sections, analysis of the image and measurements at the same level. For all acquisitions factory settings for evaluation of the kidneys were used (low mechanical index protocol for CE-US, MI 0.1).

The data was analyzed retrospectively on a workstation (EchoPack, GE) using the software for quantitative analysis of signal intensity (Q-analyze,GE) [19-22]. The data were analyzed in terms of disturbed tissue perfusion and regions of interest (ROI), the level of signal intensity and the size of the infarct. Using the time intensity curves (TIC), two foci with the same area of KTx parenchyma were analyzed: one identified as an infarct and another in the cortex of the unaltered parenchyma. The CE-US data were compared to those from the corresponding areas in B mode US and US-CD examinations. The differences in signal intensity between parenchyma with normal perfusion and areas with ischemia were statistically analyzed.

All results are expressed as mean±SD. Statistical significance was defined at p<0.05. The normality of data distribution was checked by Shapiro-Wilk test. Within-group comparisons were performed using t-test for normally distributed data. The Pearson correlation coefficient was used to assess relations between the variables. Statistical analysis was performed using the Statistica for Windows (version 6.0, StatSoft, Tulsa, OK, USA).

All subjects gave their written informed consent for the participation in the study and the study protocol was approved by the university bioethics committee.
Results

Occlusion of supernumerary arteries (4 cases) or segmental arteries (13 cases) was observed in 17 patients. Fig.3 and Fig.4

The renal parenchyma in B mode US is characterized by low echogenicity, which was in a range of -48dB to -59dB. The contrast medium administration increased the echogenicity of the parenchyma, which were significantly greater, between -24dB and -33dB. The mean difference of signal intensity between the two techniques was statistically significant (-53.7±5.3 dB vs -28.7±3.8 dB, p<0.001).

In the areas of ischemia, B mode US showed a signal decrease of -50dB to -62dB. The ischemic areas in the CE-US were also characterized by low echogenicity (lack of enhancement), which was in a range of -50.5dB to -62dB. The difference in mean signal intensity values, between the two techniques, was not statistically significant.

In B mode examinations, the difference in the echogenicity between the focus of the infarct and normal parenchyma was small, from -1dB to -4dB. The difference was larger for analogous areas in the CE-US examinations, from -21dB to -29dB. The mean difference in signal intensity (ischemic area vs. normal parenchyma), between the two techniques was highly significant (-2.75±1.5 dB vs -24.25±3.9 dB, p<0.001) Fig.3 and Fig.4

This greater echogenicity, significantly increased the detection of renal infarction, with 4 foci being observed in routine B mode/US-CD/US-PD and 17 foci in the CE-US examination.

The size of the ischemic areas after the standard B mode and Doppler examinations was approximate, due to poor separation of the ischemic foci, and was between 19 and 34 mm. These areas were much better visualized in the CE-US examination and were found to be between 32 and 50 mm. Fig.5 and Fig.6 There was a statistically significant difference in the size of the ischemic areas between the these examination techniques (25.5±7.3mm vs 38.5±9.7mm, p<0.001).
Fig. 3: Small area of ischemia in the CE-US study (area of ischemia - the white arrows). The important difference in signal intensity (about 25-27dB) in the charts perfusion curves (TIC) between the renal parenchyma and the area of ischemic area (red, vertical line - the moment of maximum saturation of the blood cavity). White ROI located in the infarct zone, green ROI in normal parenchyma.

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**Fig. 4:** Large area of ischemia in the CE-US study (area of ischemia - the white arrows). The large difference in signal intensity (about 28-30dB) in the charts perfusion curves (TIC) between the renal parenchyma and the area of ischemic area (red, vertical line - the moment of maximum saturation of the blood cavity). White ROI located in the infarct zone, green ROI in normal parenchyma.

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Fig. 5: Small area of ischemia in the CE-US study - the measurement technique of the focus.

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**Fig. 6:** Large area of ischemia in the CE-US study - the measurement technique of the focus.

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Conclusion

CE-US enables a precise evaluation of a graft's ischemic foci due to occlusion of SA in the early post-transplant period. CE-US significantly improves detection of renal infarction foci compared to routine testing.
References

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