Magnet resonance angiography versus conventional angiography for the planning of reconstructive surgeries

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Magnet Resonance Angiography versus Conventional Angiography for the Planning of Reconstructive Surgeries

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Abstract

Summary: Assessing the vascular status and anatomy of the lower extremity is of crucial importance when planning the coverage of a tissue defect with a free flap. The standard techniques comprise the clinical examination, Doppler ultrasound and Doppler sonography for healthy patients without suspected direct trauma to the vascular system, and conventional digital subtraction angiography (DSA), respectively, in case of traumatized vessels or patients with peripheral arterial obstructive disease.

Materials: We have conducted a prospective study for the comparison of the magnetic resonance angiography (MRA) to the conventional DSA. Fourteen patients were examined presurgically by means of both a conventional DSA and an MRA before undergoing planned microvascular coverage of tissue defects of the lower extremity. The surgeon, based on a questionnaire, assessed and compared both examination results according to their information content. Furthermore, the presurgically planned level and localization of the vascular anastomoses and the intraoperative findings were compared postoperatively.

Results: The MRA examination yielded sufficient information on the vascular anatomy to enable the surgeon to carry out a detailed presurgical planning. Additionally, the use of MRA showed clear advantages with regard to both patient and user comfort.

Conclusion: Taking into account the advantages for the assessment of vessels using MRA, in particular when considering the impact of the frequently varying vascular anatomy of the lower leg on reconstructive surgery, as well as the significantly lower morbidity rate of the examination itself, then the MRA must be regarded as a safe alternative to the DSA.

Key Words
Lower limb injuries · Microsurgery · Plastic and reconstructive surgery · Vascular trauma

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Introduction

Microvascular free tissue-transfer to the lower extremities is the standard method of treatment not only for open fractures (Gustillo type III b and c), but also for the coverage of chronic wounds as well as, in selected cases for esthetically and functional reasons, for severe burns [1, 2–7]. It is, however, important to differentiate between primary (emergency free flap) and secondary reconstruction by means of free flap surgery [8, 26, 27]. Proper selection of a recipient vessel is essential for the success of a free tissue-transfer [9].

We perform an average of 50 microvascular free flaps to the lower extremity annually in our hospital. As far as vascular injuries are concerned, several complications are described in the literature. Trauma, post-traumatic treatment modalities used for retention of the fracture and operative procedures damaging vessels by distraction, application of screws or intra-

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medullary nailing are the main causes for these complications [10, 11]. Among the aggravating circumstances for the operative planning are anatomical anomalies or variants, degenerative diseases [12] and the abnormal ''run-off'' of the main vessels [13]. The retrospective analysis of our presurgical decision-making between January 1995 and December 1998, with respect to whether the designated localization of the vascular anastomoses proved to be suitable showed that a digital subtraction angiography (DSA) was performed presurgically on 80% of the patients. It was, however, not performed on patients with contraindications for the administration of intra-arterial contrast agents (anti-coagulation therapy, contrast agent allergy, graft replacement) or in cases were an emergency free flap was performed, due to the magnetic resonance angiography's (MRA) minimal invasiveness on the traumatized patient and its rapid availability in our emergency room setting. Based on a previous study by Mast et al. [24], who in their study with five patients concluded that the MRA was accurate, surgically relevant and, for its non-invasive nature, desirable over DSA, we decided to conduct a prospective study comparing both diagnostic modalities in each case, by obtaining both an MRA and a DSA from each patient.

Since our radiology department has gained vast experience in the last years in the evaluation of the vascular system of the lower extremities in patients suering from peripheral arterial occlusive disease (PAOD) using MR angiography [14, 15], we have decided to evaluate the value of this procedure in the presurgical planning of surgical reconstruction of the lower extremity. For the planning of reconstructive surgery, in particular for the planning of a microvascular free tissue-transfer to the lower extremity, the DSA is considered today as the standard and safe method, alongside Doppler ultrasound and ultrasonography [16]. As the angiography, however, is generally associated with a morbidity not negligible, due to its invasive character and the necessary contrast agent administration, the presurgical duplex-sonography has already been presented by different authors as an alternative means [23]. Due to its results being evidently quality-dependent on the examiner and the difficult comprehensibility for the surgeon, the procedure in our opinion represents no genuine alternative. Several studies have already been published on the MRA as a means of evaluation for the vascular system of the lower extremity. In these publications, the comparability of the MRA and the DSA regarding the expressiveness of the vessel morphology could be assessed beyond any doubt [17–20]. We focused mainly on the issue of whether the MR angiography of the lower extremities for presurgical planning of reconstructive surgery is comparable or even superior to DSA or Duplex sonography as far as expressiveness, vascular anatomy and/or stenosis ratio of the vessels are concerned. To what extent are the diagnostic findings by the radiologist, based on the images, comprehensible for the surgeon and how does he determine whether the vessels are suitable for microvascular surgery? Should an MR angiography be integrated in the preoperative algorithm when planning microvascular tissue transfers? In addition, in the context of the present study, the occurrence of complications as well as possibly relevant risk factors was assessed in comparison to the use of Doppler ultrasound examination and Duplex sonography as described in the literature [14, 23], which are rated as very low-risk presurgical diagnostics. In the literature, the rate of complications associated with DSA [20, 21] is reported to be exceeding that attributed to MRA [22].

In comparison with the established diagnostic methods already in frequent clinical use, such as ultrasonography, Doppler examination and computer tomography, it is also important from an economical point of view, to evaluate the costs of conventional angiography, which, contrary to MRA, requires ambulatory post-interventional monitoring.

Patients and Methods

From October 1998 until October 1999, 14 patients admitted and treated at our hospital (aged 26–78 years, average age 50 ± 17.8 years, 10 men, 4 women, 13 patients after open fractures Gustillo III b, c and fixation with osteosynthesis, 1 patient with defect after chronic osteomyelitis) for whom a microvascular free flap-transfer to the lower extremity was planned, received both a presurgical MRA and a conventional DSA of the leg and lower leg arteries. The respective examiner of the MRA and DSA assessed the images, with particular attention to the vessel designated as the potential recipient of the arterial anastomosis. The potential target vessel was evaluated for the presence of vascular anomaly or vessel damage caused by a previous fracture or surgery. Afterwards, the surgeon charged with the procedure was asked to evaluate the comprehensibility of the results on the basis of the available images (on the basis of a scale of 1–6, whereby 1 = very well and 6 = insucient). The surgeons were shown the images of the MRA first. Thereafter, the surgeon would examine the images of the conventional DSA, but only after being asked in

each case whether they would still need the DSA for their presurgical planning (answer possibilities yes/no).

MR Angiography

All MRA were performed on a 1.5 T MR system (Signa EchoSpeed; General Electric Medical Systems, Milwaukee, WI, USA). The examination took place with the patient in dorsal position with a decided coil for the MRA of the pelvis and the lower extremities (Peripheral Vascular Array; Medical Advances, Milwaukee, WI, USA) with moving-table technique**.** The architecture of the coil used permits to simultaneously represent the arterial vessel system of the infra-nephric abdominal aorta, as well as the pelvis-leg-axis up to the height of the middle shank. After the acquisition of a planning sequence, two data sets were acquired during the passage of the intravenously administered gadolinium-based contrast agent (Magnevist, Schering AG, Berlin, Germany) via the arterial vessel system. The contrast agent was injected via an automatic syringe pump after the circulation time of the contrast agent was administered by means of the bolus technique. The first data set covered the region of the infra-nephric aorta to the proximal femoral third. The second data set captured the arterial system from the proximal femoral third to the level caudal of the lower leg-arteries trifurcation. Both data sets were obtained by means of a three-dimensional (3D) gradient echo sequence (TR/TE 5.2/1.5 ms; flip angle 30°; image matrix size 512×384; thickness of film 2.4–2.8 mm; visual field per data record 48 cm). From these 3D-data records the MRA was reconstructed. The accomplished MRA technology is described in detail in [11]. The MRA's documentation was done by means of Maximum Intensity Projections (MIP) on films. Additionally, the entire source data set was available on a computer workstation.

Digital Subtraction Angiography

All DSA examinations were performed by experienced angiographers with one of two units (Integris V3000 or Integris V5000, Philips Medical Systems, Best, The Netherlands). Fine-needle DSA of the examined extremity was performed in all patients: this procedure consisted of a retrograde puncture of the ipsilateral common femoral artery with a 20-gauge puncture needle that was connected with a slim tube and multiple manual injections of contrast agent (Iopromidum, Ultravist® 300 (300 mg/ml), Schering, Berlin, Germany). The runoff was imaged by multiple acquisitions encompassing the arteries of the thigh and lower extremities. The number of projections was at the discretion of the angiographer.

Results

In all cases (14 patients/100%) the surgeons rated the comprehensibility of the available MRA findings as good (Figures 1a–1c). No vascular abnormality was noted on the target vessels for the anastomosis on either MRA or DSA. The necessitiy of an additional DSA for presurgical was negated by the surgeons in all cases (14 patients/100%) after examining the MRA images. In all cases, the DSA supplied no additional information to the surgeon. None of the examined patients experienced any complication, neither during nor after the MRA. The examination was not perceived as unpleasant by the patients. As far as the DSA was concerned, no complications were noted as well. All patients examined, however, perceived the inguinal puncture as unpleasant. With regard to the costs generated by the radiology department, the following data was collected: approximately 750 Euros for the execution of a DSA, plus 250 Euros for the ambulatory post-interventional monitoring, versus 900 Euros for the execution of a MRA. Thus, there is a difference of 100 Euros in favor of the MRA. Intraoperatively, all procedures were performed according to the presurgical planning. The flap vessels were anastomosed to the intended recipient vessel, which had been designated preoperatively by means of assessing the localization of the defect.

Discussion

For the planning of reconstructive surgery, in particular for the planning of a microvascular free tissue-transfer to the lower extremity, the DSA is considered today as the standard and safe method, alongside Doppler ultrasound and ultrasonography. As the angiography, however, is generally associated with a morbidity not negligible, due to its invasive character and the necessary contrast agent administration, the presurgical duplex-sonography has already been presented by dierent authors, one being R.B. Smith, as an alternative means [23]. Due to its results being evidently quality dependent on the examiner and the difficult comprehensibility for the surgeon, the procedure in our opinion represents no genuine alternative. Since 1998, the MRA has been used in our hospital for the evaluation of peripheral arterial occlusive disease (PAOD) [14] Vessel diameters of as little as 2 mm are sufficiently assessable. Between October 1998 and October 1999, 14 patients were examined through both an MR angiography and a conventional DSA for the presurgical

Figures 1a to 1c. a) A 60-year-old male with a fixation of the tibia following a open III° fracture of the tibia and fibula, magnetic resonance angiography (MRA) of the lower extremities (overview) demonstrate patent arteries of the right leg in particular a three-vessel run-off at the level of the calf. b) Detailed view of the left calf. The vessels of the calf are well-displayed despite of the artifacts due to the fixation material within the tibia. c) Corresponding digital subtraction angiography at the level of the calf demonstrate similar findings as in MRA.

planning of a microvascular tissue-transfer to the lower extremities. The surgeon was first shown the MRA; afterwards, his evaluation was compared with the result of the DSA. Here, the MR angiography alone allowed for a sufficiently good evaluation of the vessel morphology, and also our demand for comprehensibility of the radiologist's findings by the surgeon was met in all cases. Intraoperatively, the presurgical evaluation was confirmed so far as it was assessable. In other words it did not lead to a change of the planned anastomosis location or to complications in any case.

Several studies have already been published on the MRA as a means of evaluation for the vascular system of the lower extremity. Busch et al. [17] were able to prove that in 18% of the cases, the diagnostic image quality of the MRA was higher when compared to the DSA, in 79% it was equivalent and in only 3% it was judged to be of lower quality. The vascular surgeons questioned found the MRA images equivalent in 75% of the cases, superior to the DSA results in 16% and inferior in 9% of the cases. Reimer and Landwehr [18] formulated the hypothesis that the MRA will replace the DSA in the near future due to its cost and time efficiency. The existing downsides of the MRA, for instance its flow dependence and the resulting artifacts, are considered solvable by Debatin and Hany [14]. This is also confirmed by Vosshenrich et al. [19] in their work on the CE 3D MRA. In their study, the comparability of the MRA and the DSA regarding the expressiveness of the vessel morphology could be assessed beyond any doubt. We can only confirm these findings in our own patient collective and our very specific assessment on the value of MRA in the presurgical planning of lower extremity reconstruction [1, 24, 25]. We agree with Lutz et al. [25] who describe that the clinical findings like palpation of the arterial pulse of the main arteries does not correlate to intraoperative findings of vascular lesions. We believe that especially manual palpation of the pulses at the level of the foot are insufficient, as the result can be deceiving, if the artery palpated is perfused retrogradely through the arcus plantaris. For that reason, we consider preoperative visualization of the vascular system mandatory, either with DSA or MRA. As far as their advantages and disadvantages are concerned, we fully concur with Mast's conclusions, that the MRA results are accurate, surgically relevant and desirable over DSA because of its non-invasive nature.

Disadvantages of the MRA when compared to conventional the DSA are its lack of a dynamic

component to evaluate the dynamics of the circulation, the contraindications of the MRA (ferrous magnetic metal in the examination area, cardiac pacemaker, neurostimulator and inner ear implant) as well as the necessary technical prerequisites. Regarding the restriction for claustrophobic patients, there is now a viable alternative in the form of new devices that render an examination clearly less constricting for the patient. The advantages when considering cost and time eciency are obvious, but the MRA requires a radiological centre with qualified personnel, further main advantage of the MRA lies in its lower morbidity (no X-rays, no arterial puncture, no contrast agent containing iodine). In addition, a 3D representation of all vessels is possible, thus facilitating a steric analysis of the anatomical conditions particularly in dicult situations. The overall complication rate of the DSA is stated in the literature as ranging between 0.7 and 9% [20, 21]. The use of gadolinum chelates as MRI contrast media has become well established and seems to be a safer method; as compared to other X-ray agents they are not nephrotoxic. Minor adverse reactions like nausea and hives occurred in 1% of the patients [22]; there is not yet any data available for the MRA, however, regarding relevant incidents during or after the examination. Both interventions can be readily managed in an outpatient setting, with the exception of high-risk patients. Expenditure of time associated with MRA has been stated by Busch et al. [17] not to exceed 1 h, including post-processing. Costs of material for the MRA amount to 250 Euros, compared to 200 Euros for the contrast agent used for DSA. It has also to be taken into consideration that after the execution of a conventional DSA, an ambulatory post-interventional monitoring of 6 h with proper personnel and infrastructure is necessary.

Considering the advantages for the assessment of vessels using MRA – in particular when considering the impact of the frequently varying vascular anatomy of the lower leg on reconstructive surgery, as well as the significantly lower morbidity rate of the examination itself due to its lesser invasivity and the clearly smaller contrast agent reactions and toxicity of the substance containing gadolinium opposite the substance containing iodine – the MRA must be regarded as a safe alternative to the DSA. Also from an economic point of view, the MRA compares favorably to the DSA, with a 10% lesser costs. Further studies are warranted and required, however, for a global comparison of all diagnostic means mentioned.

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