

# Contrast-Enhanced Magnetic Resonance Angiography for Control of Minimally Invasive Coronary Artery Bypass Conduits (MIDCAB/OPCAB)



Dr. Boehm

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**Dieter H. Boehm, MD, PhD<sup>1</sup>**, Bernd J. Wintersperger, MD<sup>2</sup>,  
Hermann Reichensperner, MD, PhD<sup>1</sup>, Helmut Gulbins, MD<sup>1</sup>, C. Detter, MD<sup>1</sup>,  
F. Kur, MD<sup>1</sup>, Bruno Meiser, MD<sup>1</sup>, Bruno Reichart, MD<sup>1</sup>

<sup>1</sup>Department of Cardiac Surgery

<sup>2</sup>Diagnostic Radiology

University of Munich, Klinikum Grosshadern, Munich, Germany

## ABSTRACT

**Objective:** The purpose of this study was to delineate the course and determine the patency of venous and arterial conduits in the early postoperative period following minimally invasive bypass grafting. A less invasive magnetic resonance angiogram (MRA) was evaluated as alternative to standard contrast angiography and cardiac catheterization.

**Methods:** Twelve patients (8 males and 4 females) with a mean age of 65.3 ( $\pm$  7.4) years were evaluated four to seven days following minimally invasive direct coronary artery bypass surgery (MIDCAB) or off-pump multivessel revascularization with the Octopus® stabilizer on the beating heart. Altogether 17 coronary bypass grafts were investigated: 12 left-sided mammary artery grafts to the LAD and five aortocoronary venous bypass grafts. The examination was performed with a 1.5 Tesla Magnetom Vision (Siemens AG, Erlangen) with phased array coil technology. Data acquisition was done with an ultrafast 3D gradient-echo sequence in single breathhold and sagittal and coronal views. Contrast enhancement of the vessels

was performed with automatic intravenous bolus injection of Gadolinium-DTPA after determination of the individual contrast transit time. Traditional contrast angiography was obtained in all patients during the same time period as a comparison to assess the sensitivity and specificity of the magnetic resonance imaging.

**Results:** All five venous grafts and 11 of the 12 IMA grafts were detected and shown to be patent with the MRA technique. Contrast angiography demonstrated complete patency for all 17 bypass grafts with adequate anastomoses and no evidence of stenosis. Therefore the calculated sensitivity for visualization with MRA was 92% for IMA grafts and 100% for venous grafts.

**Conclusion:** The contrast-enhanced ultrafast MRA in single breathhold technique is a reliable, noninvasive method for visualization and determination of the patency of arterial and venous coronary grafts.

## INTRODUCTION

Diagnostic investigation of previously constructed coronary artery bypass grafts is routinely performed by means of injected radio-opaque contrast with cineangiography. Standard contrast angiograms also can be coupled at the same sitting with graft interventions like angioplasty or stenting if needed. However, coronary angiography uses ionic radiation, is expensive, and has potential hazards. Contrast enhanced magnetic resonance angiography (MRA) is a recently implemented, noninvasive and fast imaging modality, although it needs some technical enhancements. Especially for less invasive methods of coronary revascularization, the method would allow a less

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*Address correspondence and reprint request to: Dieter H. Boehm, MD, PhD, Department of Cardiac Surgery, University Hospital Munich-Grosshadern, Marchioninistr. 15, D 81366 Munich, Germany, Phone: +49/89/7095-3464, Fax: +49/89/7095-8873, E-mail: [boehm@hch.med.uni-muenchen.de](mailto:boehm@hch.med.uni-muenchen.de)*

Table 1. Site of anastomoses and techniques applied

| Graft          | LAD | RCA | DA | Technique |
|----------------|-----|-----|----|-----------|
| LIMA (n)       | 7   |     |    | MIDCAB    |
| LIMA + SVG (n) | 5   | 3   | 2  | OPCAB     |

invasive assessment of graft status and assist in quality control. This report compares early postoperative MRA against standard coronary angiography to determine if the sensitivity and specificity of MRA can reach a level suitable for postoperative assessment of graft status.

## MATERIALS AND METHODS

The examination was performed with a 1.5 Tesla Magnetom Vision™ (Siemens Medical Systems, Erlangen, Germany) with phased array coil technology. Data acquisition was done with an ultrafast 3D gradient-echo sequence in single breathhold with sagittal and coronal views. Contrast enhancement of the vessels was performed with automatic intravenous bolus injection of Gadolinium-DTPA (Magnevist, Schering AG, Berlin, Germany) after determination of the individual contrast transit time. Data acquisition time was 23 and 29 seconds (sagittal and coronal views, respectively), and spatial resolution was  $0.98 \times 1.40 \times 1.60 \text{ mm}^3$ . The complete examination required



Figure 1a. MRA-visualization of a LIMA to LAD bypass (IMA: internal mammary artery; AAr: aortic arch, DA: descending aorta)

a time exposure of 20 to 25 minutes. A consecutive 3D maximum intensity projection (MIP) calculation of the data sets was also performed.

Image evaluation was performed assessing contrast enhancement, pulsation, and breathing artifacts, as well as wrap-around artifacts using a five-step scale. For patency assessment, grafts were divided into three parts: proximal anastomosis, graft course, and distal anastomosis. The mean score of image quality was good ( $2.2 \pm 0.8$ ) and all magnetic resonance (MR) data sets except one were of sufficient image quality for assessment of bypass graft patency. Subsequently the grafts were assigned to different groups: visible (which means patent) and non-visible (which means occluded). For purposes of correlation, the MR images were compared to a standard contrast angiography performed in the same patients during the same time period.

Twelve patients (8 males and 4 females) with a mean age of 65.3 years were evaluated four to seven days following off-pump coronary grafting. A total of 17 coronary bypass grafts were investigated with both techniques (see Table 1 ☉): 12 left internal mammary artery (LIMA) grafts to the left anterior descending (LAD) and five aortocoronary venous bypass grafts were performed. Seven patients received a single bypass using a LIMA graft to the LAD. The surgical approach in these cases was via a left-sided anterolateral mini-thoracotomy and cardiac stabilization with the CTS pressure stabilizing system (Cardiothoracic Systems, Cupertino, USA). In five patients, in addition to the internal mammary artery (IMA) graft to the LAD, an aortocoronary venous graft was performed: in three cases to the right coronary artery (RCA), and in two cases to the first diagonal branch. In these patients, the surgical approach was via median sternotomy and cardiac stabilization was achieved using the Octopus® suction system (Medtronic GmbH, Düsseldorf, Germany).

## RESULTS

All five saphenous vein grafts (SVGs) and 11 of the 12 LIMA grafts were shown to be patent using the MRA technique, resulting in a patency rate of 92 % for IMA grafts and 100% for SVGs. Coronary angiography demonstrated full patency for all 17 bypass grafts (see Table 2 ☉). Sensitivity for the visualization of IMA grafts with MRA was thus 92% and 100 % for SVGs. Examples of a MRA visualization of a LIMA to LAD graft and the corresponding angiography are shown in Figure 1a (☉) and Figure 1b (☉). A saphenous vein graft in addition to a LIMA to LAD

Table 2. Number of patent grafts using the different methods

| Graft    | MRA   | Angiography |
|----------|-------|-------------|
| LIMA (n) | 11/12 | 12/12       |
| SVG (n)  | 5/5   | 5/5         |

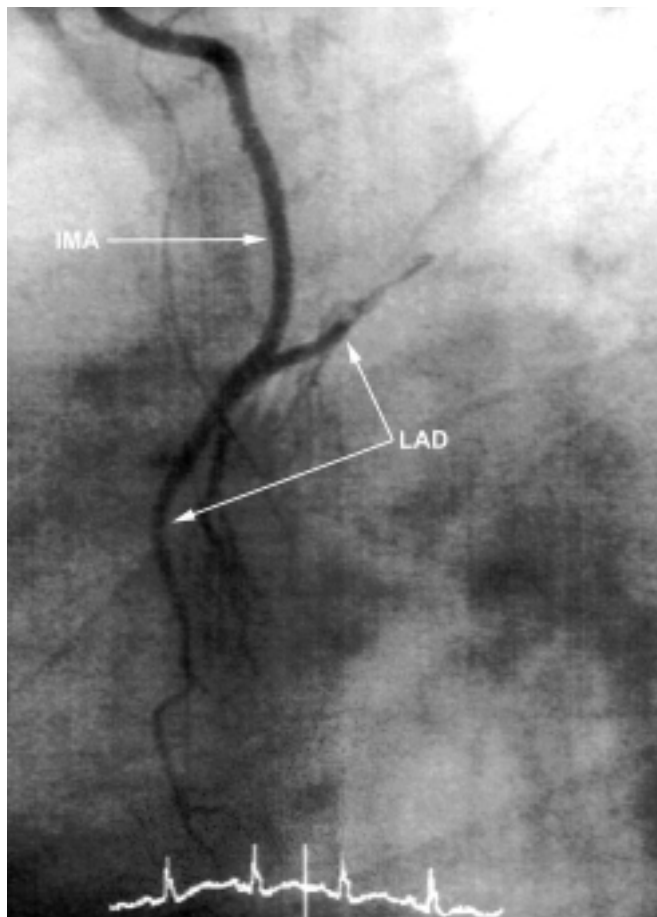


Figure 1b. Corresponding coronary angiography of LIMA to LAD bypass.

graft in MRA technique is shown in Figure 2 (⊙). Failure of MRA in detecting the one IMA graft shown to be patent by coronary angiography was due to inadequate patient compliance with the breathhold technique.

## DISCUSSION

Visualization of venous bypass grafts by means of MR imaging was reported by Herfkens in 1983 [Herfkens 1983]. Subsequent studies for assessment of IMA grafts were performed in 1987 but without comparing the results to established methods [Gomes 1987]. MR flow studies of coronary artery bypass grafts with assessment of the cyclic flow profile were published by Hoogendoorn et al. in 1995 using phase contrast MR techniques [Hoogendoorn 1995]. The contrast-enhanced ultrafast MRA in single breathhold technique is a fast, reliable and noninvasive method for visualization and determination of the patency of coronary grafts after MIDCAB. Due to the high spatial resolution, both venous and arterial grafts can be visualized. The main limitations of this method are: 1) adequate patient compliance (breathholding technique), and 2) exclusion of patients with permanently implanted pacemakers or defibrillators. Functional assessment and quantification of

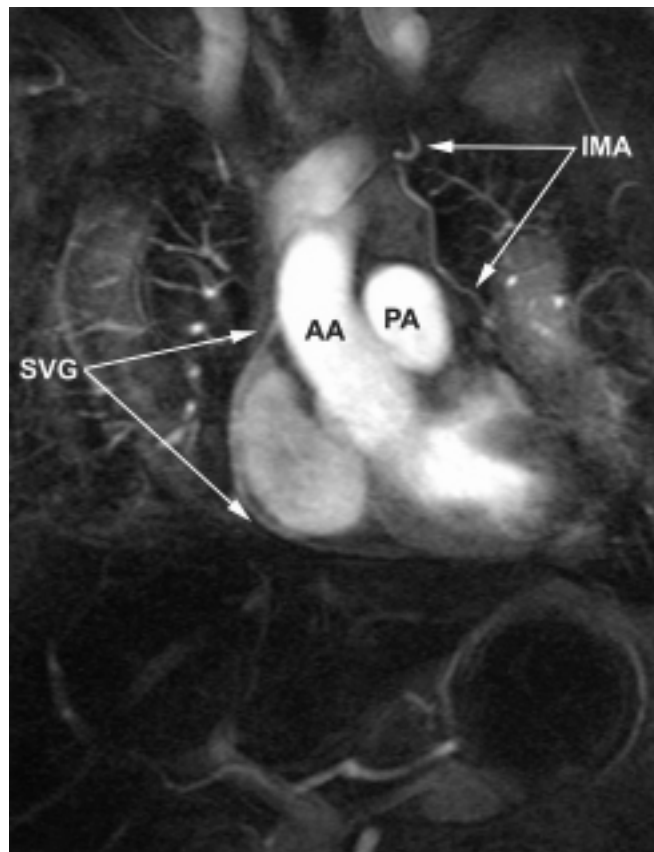


Figure 2. MRA visualization of a LIMA to LAD and SVG to RCA graft (IMA: internal mammary artery; SVG: saphenous vein graft; AA: ascending aorta, PA: pulmonary artery).

bypass-stenoses is currently not possible with this technique. In the future the combination of MRA with noninvasive MR flow measurements, making use of phase contrast technique, could demonstrate flow profiles. To allow quantification of IMA flow rates, however, further improvements in spatial resolution are necessary.

The advantage of MRA is a short procedure time, generally in the range of 20 to 25 minutes. Expensive echocardiogram (ECG) triggering is not necessary for simple bypass visualization or for a 3D data set. There are numerous possibilities for postprocessing and visualization of the entire bypass course [Manning 1993].

The disadvantage of MRA is the expense of the paramagnetic contrast medium. However, Gadolinium-DTPA has less side effects than iodine based injectable contrast medium. The evaluation of the distal part of the anastomosis, however, is not possible with the current magnetic resonance technique. MRA examination is very dependent on the collaboration between patient and radiologist to avoid artifacts caused by inconsistencies with the breathholding technique. Today, MR-angiography is available only in a few medical centers having MRT equipment and additional expensive high-performance gradient coil systems.

Contrast enhanced MRA obtained a sensitivity of 92% for the visualization of IMA grafts and 100% for visualization of saphenous vein grafts in this study, which is superior to other MRT techniques. Thus contrast enhanced 3D magnetic resonance angiography has the potential for being a reliable method for CABG visualization and patency assessment in the early postoperative period. Three dimensional postprocessing is helpful in delineating the course of grafts. For further evaluation of occluded grafts or for angioplasty, conventional angiograms are still necessary. X-ray angiography is invasive and can be associated with major complications. In comparison, contrast enhanced MRA is a noninvasive modality without iodine contrast medium or ionizing irradiation, and can be performed in less than 30 minutes with minimal risks.

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