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CASE REPORT

Iatrogenic neonatal type B aortic dissection: comprehensive MRI-based diagnosis and follow-up

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Abstract Neonatal aortic dissection is rare and most frequently iatrogenic. Decision making and appropriate imaging are highly challenging for pediatric cardiologists and radiologists. We present MRI and echocardiographic findings in the follow-up at 6 months of age of a boy with a conservatively treated iatrogenic neonatal aortic dissection (type B). To evaluate the morphology of the aortic arch and descending aorta, we carried out multidirectional time-resolved three-dimensional flow-analysis and contrast-enhanced MR angiography (CE-MRA). The MRI and Doppler echocardiographic results were closely comparable. Three-dimensional visualization helped assess details of blood flow acceleration and alteration caused by the dissection, and played a key role in our deciding not to treat surgically.

Keywords Iatrogenic aortic dissection · MRI · 3D flow analysis

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Introduction

Most children with aortic dissection present with congenital cardiovascular anomalies or connective tissue disorders [1]. Iatrogenic aortic dissection is a rare, potentially lethal complication following cardiac surgery. In general, surgical or other interventional treatment with stent implantation is mandatory in such cases. Although MRI is not the modality of choice for the initial diagnosis of acute dissection, MRI—including contrast-enhanced MR angiography (CE-MRA)—in conjunction with flow-sensitive phase-contrast techniques, is a well-established noninvasive technique and recommended in the follow-up [2].

The following report highlights the diagnostic value of MRI in making the decision for conservative treatment in an exceptional case, and emphasizes the importance of MRI follow-up in addition to echocardiography. In our patient, a flow-sensitive three-dimensional (3-D) cardiovascular protocol visualized the critical region of the aortic dissection, which could not be adequately evaluated by echocardiography.

Case report

A newborn boy (birth weight 2.9 kg) with severe pulmonary hypertension due to an atrial septal defect, patent ductus arteriosus and a large aorticopulmonary window, which was located between the ascending aorta and the pulmonary trunk, underwent corrective surgery on day 17 of life. The aortic bypass cannulation site had to be unusually far distally in the aortic arch. Due to postoperatively reduced pulses in the lower limbs, we performed digital subtraction angiography (DSA) immediately after surgery, which revealed an aortic dissection in the descending thoracic aorta ranging from the origin of the left subclavian artery to the level of the diaphragm, without re-entry (Fig. 1). Echocardiography revealed accelerated flow at the entry, indicating a hemodynamically relevant aortic stenosis. Systolic blood pressure in the upper extremities was elevated, and the blood pressure curve in the descending aorta lost its pulsatility. A systolic pressure gradient of about 35 mmHg was detectable between the upper and lower extremities. We decided on conservative treatment, including antihypertensive medication, as is suggested for type B dissection in the European Society of Cardiology (ESC) guidelines [2], because of stable cardiovascular function, unimpaired renal function and sufficient perfusion of the lower extremities.

At the age of 6 months, the boy was readmitted to our hospital for MRI and echocardiography, as we wanted to avoid further catheter manipulation in the aorta and X-ray exposure. For the MRI scan, the patient was sedated with midazolam. CE-MRA was performed on a 1.5-T MRI system (Magnetom Avanto, Siemens Medical Systems, Erlangen, Germany) with intravenous gadolinium contrast agent (Prohance, Bracco Imaging, Milano, Italy; 0.2 mmol/kg body weight; injection rate, 1.0 ml/s) to evaluate the morphology of the aortic arch and descending aorta. Balanced steady-state free-precession (bSSFP) sequences were performed for anatomical overview (Fig. 1). Imaging parameters for CE-MRA were TR/TE, 3.88/1.25 ms; spatial resolution, 0.7 × 1.3 × 0.9 mm^3 using a 3D-FLASH pulse sequence. Imaging parameters for bSSFP were TR/TE, 2.27/1.32 ms; spatial resolution, 1.1×1.5×5 mm^3. For both CE-MRA and bSSFP, data acquisition was performed during free breathing.

CE-MRA showed a contrast-medium defect in the proximal descending thoracic aorta and a stenosis of the aortic lumen at the same level with an extent of about 2 cm (Fig. 1). This matched the initial DSA results. The aortic diameter at the stenotic segment of the dissection was about 3 mm, compared with 6 mm at diaphragmatic level. The dissection membrane was clearly depicted on the sagittal bSSFP images (Fig. 1).

The MRI protocol also included a multidirectional 3-D MRI flow analysis for evaluating flow characteristics of the entire thoracic aorta, especially within the dissection. Flow-sensitive imaging consisted of a time-resolved 3-D phase-contrast velocity mapping sequence with 3-D velocity encoding (TR/TE, 4.8/2.4 ms; velocity sensitivity, 200cm/s; temporal resolution, 38.4 ms; spatial resolution, 1.9 × 2.2 × 2.0 mm^3). Measurements were synchronized with the cardiac cycle by prospective ECG gating and performed during free breathing using diaphragmatic gating. The total acquisition time for multidirectional 3D MRI flow imaging was 10 min. Three-dimensional visualization of the blood flow velocities measured in the entire aorta was performed using systolic 3-D stream-lines as described previously [3]. For further quantitative flow analysis, a plane was manually positioned in the data set, corresponding to the proximal descending

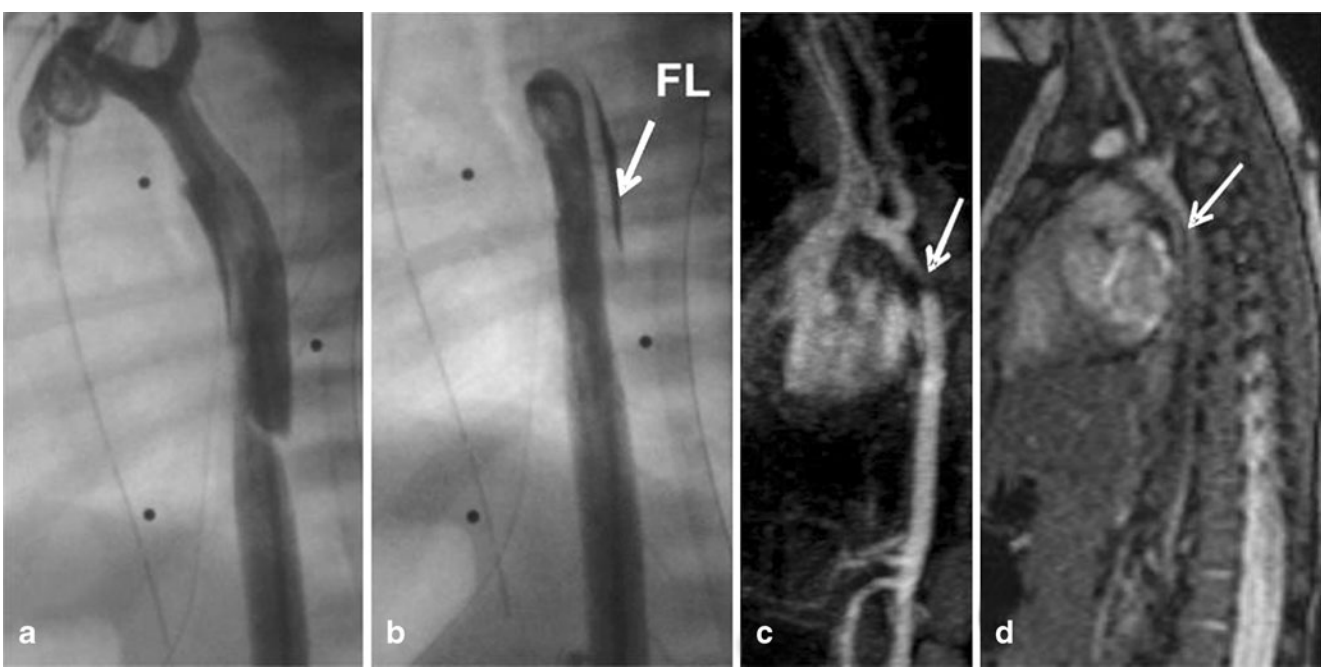

Fig. 1 Postoperative catheter angiogram and follow-up CE-MRA. **a, b** Catheter angiography reveals the aortic dissection of the descending thoracic aorta. *White arrows* depict the extent of the dissection, *FL* false lumen. Catheter position in the aortic arch (**a**) and after retraction in the descending aorta (**b**). **c, d** Follow-up CE-MRA illustrates a contrast-medium defect in the proximal descending aorta (**c**, *white arrow*). Sagittal balanced steady-state free precession MRI sequence verifies the dissection membrane (**d**, *white arrow*)

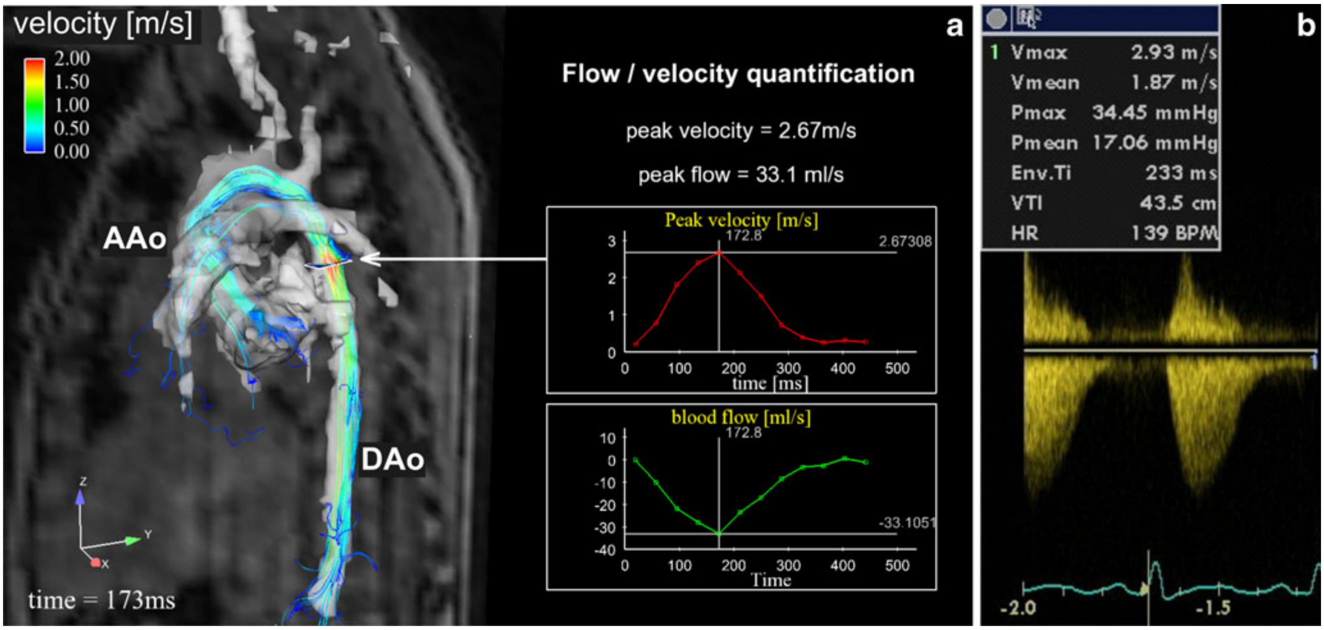

Fig. 2 **a** Three-dimensional phase-contrast velocity mapping of the entire aorta demonstrates flow acceleration in the descending thoracic aorta stenosis (*white arrow, left*). Three-directional blood flow velocities are visualized as systolic 3-D stream-lines, color-coded according to the local flow velocity. The flow and velocity measurements in the analysis plane (*diagram, right*). **b** Echocardiographic results and Doppler curve show close correlation to MRI findings. *AAo* ascending aorta, *DAo* descending aorta, *Vmax* peak velocity, *Vmean* mean velocity, *Pmax* maximum pressure, *Pmean* mean pressure, *HR* heart rate

aorta at the site of the maximum luminal narrowing (Fig. 2). This was perpendicular to the vessel. Multidirectional velocity data in this plane were extracted and evaluated with a home-built Matlab plug-in (Matlab, USA) [4]. Time-resolved blood flow and peak absolute velocities were calculated for the analysis plane as shown by the flow and velocity-time curves in Fig. 2. The time needed for post-processing of the complete multidirectional 3-D MRI flow, including 3-D visualization and flow quantification, was approximately 45 min.

This comprehensive velocity-coded acquisition revealed flow acceleration in the proximal descending aorta caused by the stenosis with a peak velocity of 2.67 m/s (Fig. 2). A Doppler study at the same segment acquired on the same day demonstrated a peak velocity of 2.93 m/s (Fig. 2).

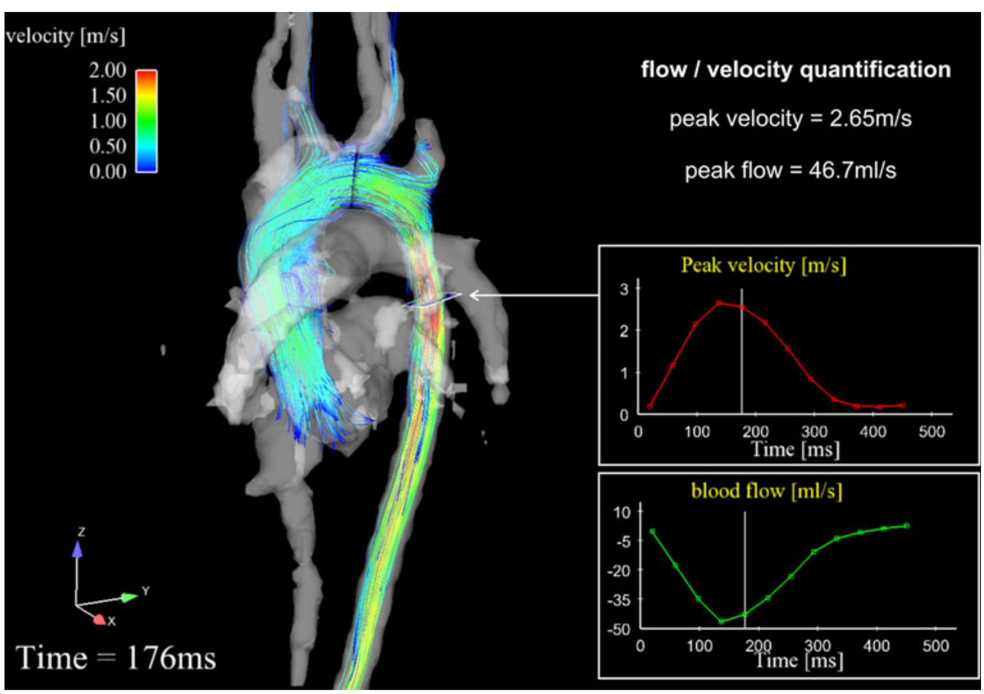

Fig. 3 Flow-sensitive 3-D MRI at follow-up. Three-dimensional blood-flow velocities in the aorta are visualized as systolic 3-D color-coded stream-lines. The flow and velocity quantification in the analysis plane reveals persistent flow acceleration in the descending aorta

Based on the imaging findings and the patient's good clinical condition, conservative treatment was continued. Blood pressure values normalized during the first 6 months of life, and the systolic gradient between upper and lower extremities dropped to less than 20 mmHg.

The boy underwent a second MRI follow-up examination 15 months later at the age of 1 year and 9 months. The aortic dissection had regressed, probably due to obliteration of the false lumen, which was confirmed by morphological sequences, and CE-MRA depicting a residual dissection membrane in the aortic arch at the left subclavian artery level. The lumen of the proximal descending aorta remained smaller than that at diaphragmatic level (ratio 5:7 mm). In spite of the morphological improvement, 3-D flow visualization revealed a persisting flow acceleration of 2.65 m/s (Fig. 3) in correspondence with the echocardiographic measurements. Additionally, a slight flow vortex formation in the left subclavian artery was detected.

Discussion

Aortic dissection in children is rare, particularly in neonates. It is usually caused by an iatrogenic injury. Aortic dissections in neonates and infants have occasionally occurred after umbilical arterial cannulation [5] or after balloon dilatation of aortic coarctation [6].

In this case of neonatal aortic dissection, we decided to treat conservatively, although a second operation or stent implantation had initially been considered necessary. Instead of using catheter angiography, follow-up examinations were solely based on noninvasive MRI to minimize the risk of dissection progression by intra-aortic catheter movements and to avoid further radiation exposure. MRI facilitated the evaluation of the development of the dissection. In particular, the 3-D flow measurements with a complete coverage of the thoracic aorta helped to clearly identify the region with minimum luminal diameter and maximum flow as illustrated in Figs. 2 and 3. The quantitative results of multidirectional flow analysis by cardiovascular MRI demonstrated a solid correlation with those obtained by established Doppler echocardiography. In addition, the comprehensive 3-D blood flow analysis and complete volumetric coverage of the entire aorta have the advantage of improving our understanding of flow alterations compared with the regionally limited information obtained by Doppler echocardiography or standard velocity-encoded cine phase-contrast MRI [7]. We chose the visualization by stream-lines in this case because the flow direction in the descending aorta was evident. In other cases, blood flow direction can be visualized by vectors or particle traces for a better understanding of hemodynamics. Recent methodological developments in flow-sensitive cardiovascular MRI protocols permit simultaneous assessment of vascular morphology and provide information on 3-D blood flow characteristics; they have proven to be a valuable addition to routine follow-up diagnostics [8]. Due to its multidimensionality, both the morphology and hemodynamics of an entire vascular system can be acquired in a single measurement. In this case, 3-D time-resolved phase-contrast velocity mapping, only performed in teenagers or adults at a 3-T scanner until now, gave us valuable insight into blood flow acceleration caused by the aortic dissection and the resulting stenosis.

This rare case of neonatal aortic dissection highlights both the feasibility and future potential of flow-sensitive cardiovascular MRI, even in small children. Flow visualization by MRI is feasible at 1.5 T and has been shown to be valuable for assessing morphology and local hemodynamics as an adjunct to CE-MRA and echocardiography.

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