3D image fusion for live guidance of stent implantation in aortic coarctation – magnetic resonance imaging and computed tomography image overlay enhances interventional technique

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Non-invasive three-dimensional (3D) imaging belongs in routine practice in diagnosis and treatment planning of many congenital and acquired cardiovascular defects. Improvements in the development of fusion imaging software have led to the introduction of 3D reconstructed images for guidance of various transcatheter therapies, with three-dimensional rotational angiography (3DRA) being the most popular tool [1, 2]. A recently available 3D roadmap based on pre-registered computed tomography (CT) or magnetic resonance imaging (MRI) data sets promises reduction in contrast and radiation exposure along with shorter procedural times [3, 4]. We present our initial experience of this application with 3D image fusion ("merging") for live guidance of stent implantation in coarctation of the aorta (CoA), using MRI applied with the HeartNavigator prototype (Philips Healthcare, Best, The Netherlands) and CT with the commercially available VesselNavigator (Philips Healthcare).

A 12-year-old boy presented to the outpatient clinic with arterial hypertension and intermittent headache already receiving β-blocker therapy. Brachiocephalic hypertension was detectable with a gradient of 47–56 mm Hg between the arms and legs, and a reduced femoral pulse quality was present. Echocardiography showed normal biventricular function and left ventricular hypertrophy. The descending aorta showed a reduced pressure profile and diastolic "run-off" with no clearly detectable gradient. An MRI scan, performed with acquisition of a 3D whole heart sequence, demonstrated subatretic CoA distal to the left subclavian artery (LSA) with increased collateral flow. The aortic arch measured 10 × 12.5 mm, CoA diameter was 5 × 5 mm and the descending aorta distal to the narrowing was 17 × 19 mm.

Interventional therapy was performed under conscious sedation via femoral artery access. The three-dimensional whole heart sequence was uploaded to the workstation (HeartNavigator prototype, Philips), automatically segmented and manually corrected (Figure 1 A). For accurate fusion with live fluoroscopy the roadmap was manually aligned with two angiographies (10–15 ml) performed at a minimum 30° difference in angulation from the anterior-posterior projection (Figure 1 B). Initial hemodynamic measurements confirmed significant stenosis with a systolic pressure gradient of 50 mm Hg. A 28 mm long covered Cheatham Platinum (CP) stent (NuMed, USA) was mounted on a 12 mm Balloon-in-Balloon (BIB) catheter (NuMed), delivered through an 11 Fr long vascular sheath (Cook, USA) and positioned without additional contrast injections (Figures 1 C, D). After post-dilation with an 18 mm sizing balloon (SJM/AGA Medical, USA), a 10 mm Hg residual gradient was left for re-dilatation 6 months later. The fluoroscopy time was 4.3 min and the dose area product was 15 940 mGray · cm².

A 7-year-old boy was referred for treatment for recently diagnosed CoA. Brachiocephalic hypertension was detectable with a gradient of 37–42 mm Hg between the arms and legs, and a reduced femoral pulse quality was present. Echocardiography showed normal left and right ventricular function with marked left ventricular hypertrophy. Distal to the origin of the LSA, flow acceleration was noted with peak gradient of 38 mm Hg (Vmax = 2.8 m/s). The descending aorta showed a reduced pressure profile and diastolic "run-off". A chest contrast CT scan confirmed

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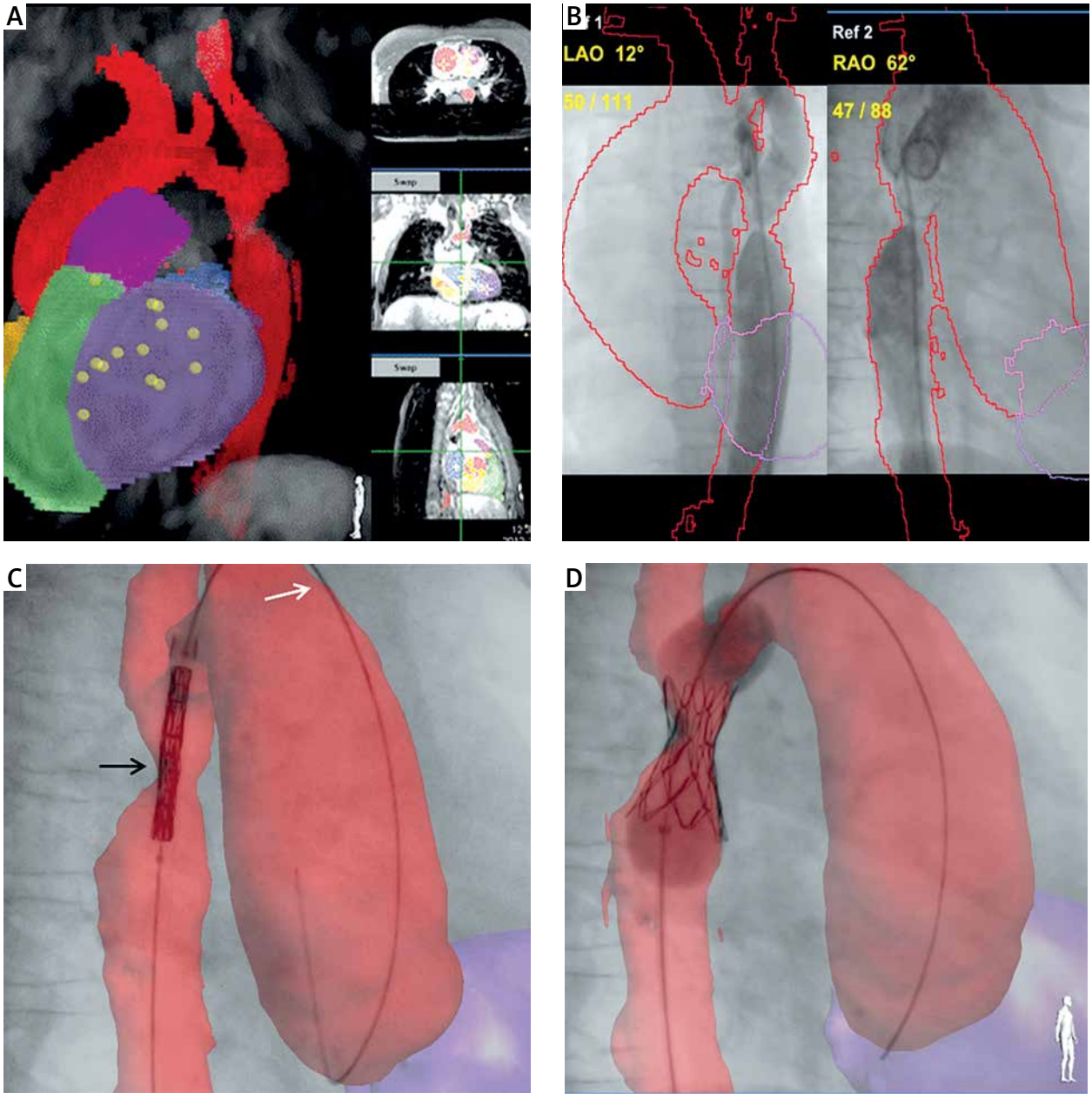

Figure 1. HeartNavigator (Philips Healthcare) assisted coarctation (CoA) stenting. Three-dimensional (3D) whole heart sequence from 1.5 T magnetic resonance imaging was uploaded to the workstation, automatically segmented and manually corrected (**A**). Highlighted with different colors, right and left-heart structures are visualized as movable 3D reconstruction (left panel) and in three perpendicular planes (right panels) with the original magnetic resonance data. To achieve accurate overlay, the roadmap was manually aligned with two angiographies (**B**). Introduction of a balloon/stent assembly through a long vascular sheath resulted in only a slight change in the anatomy (**C**). Although the stiff wire was pushed outside (white arrow) the reconstruction, the stent was contained within the narrowest part of the CoA. The stent was positioned without additional contrast injections. During balloon inflation the stent's shape correlates with the morphology of the stenotic segment (**D**)

the diagnosis of critical CoA distal to the LSA with well-developed collateral vessels. The aortic arch and the stenosis measured 11 × 12.5 mm and 2 × 2 mm, respectively.

The raw CT dataset was uploaded to the dedicated workstation (Philips Workspot), manually segmented and prepared for fusion before the patient's arrival at the catheterization laboratory (Figure 2 A). The target lesion was re-measured and ring markers were placed to indicate the ostia and define the landing zone for stent implantation.

The treatment was performed under general anaesthesia via femoral artery access. Short fluoroscopy se-

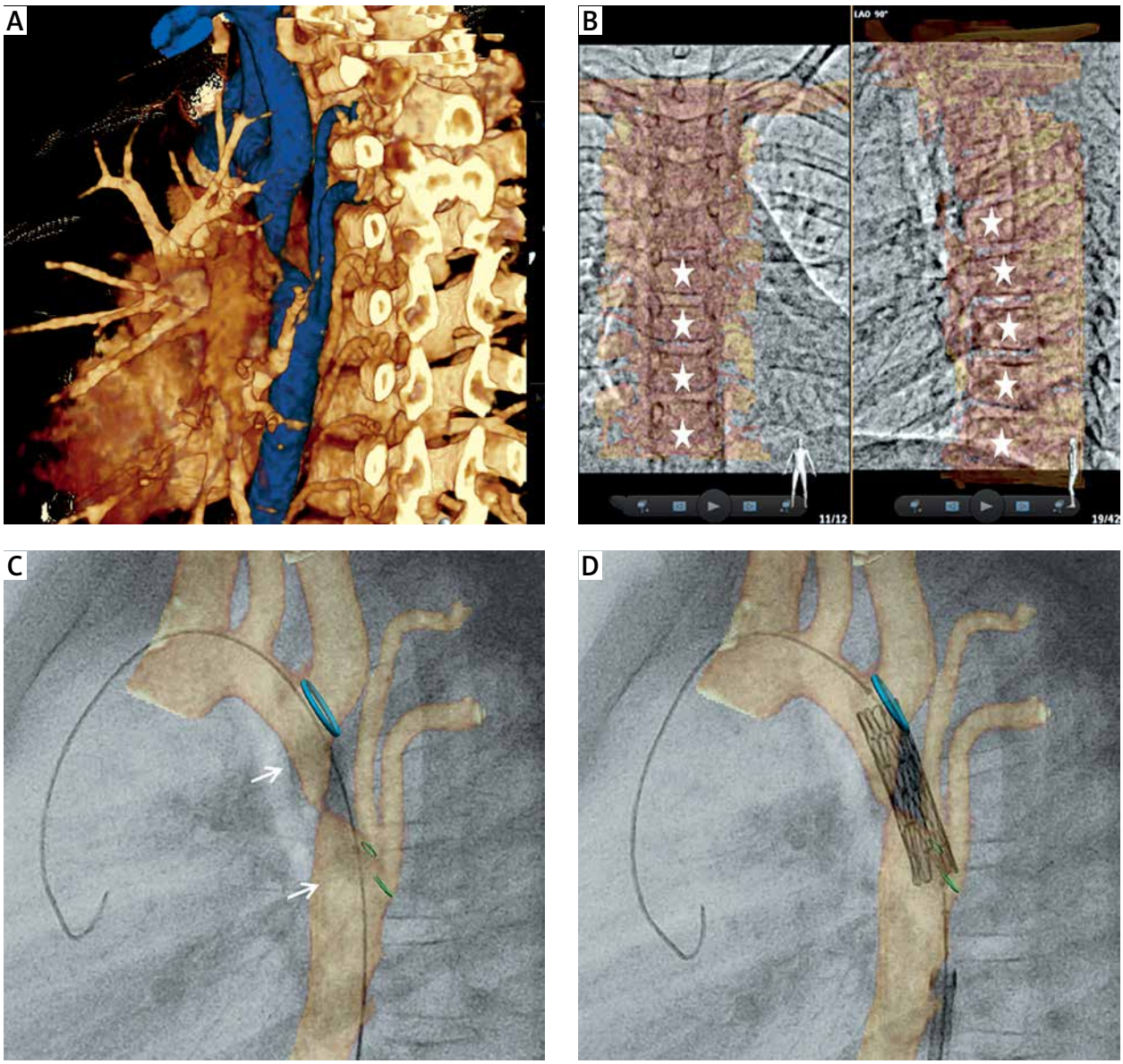

Figure 2. Philips Healthcare assisted coarctation (CoA) stenting. After uploading a raw computed tomography dataset, the application automatically creates three-dimensional (3D) reconstruction for manual vessel segmentation (**A**). Stored fluoroscopy in anterior-posterior and left lateral projections with vertebral bodies (white stars) of the mid and lower thoracic spine serving as a reference for matching the 3D reconstruction with the fluoroscopy (**B**). Prior to introduction of a large vascular sheath the lesion was predilated with a high pressure balloon (**C**, white arrows). After positioning and inflation of the inner balloon, the stent is contained between the blue marking ring and the lower yellow ring placed at the site of drainage of one of the larger collaterals (**D**)

quences in anterior-posterior and left lateral projections were used for 2D–3D fusion (Figure 2 B). Vertebral bodies (white stars) of the mid and lower thoracic spine served as reference points. Initial hemodynamic measurements showed a systolic gradient of 35 mm Hg across the stenosis. For safer introduction of a large, long vascular sheath (12 Fr, Cook) the lesion was predilated with a high pressure balloon (Figure 2 C). Next, a 34 mm covered CP stent (NuMed) was mounted on a 16 mm BIB catheter (NuMed), delivered and implanted solely under 3D guidance (Figure 2 D). The blue marking ring placed at the origin of the LSA was used as a marker for the distal end of the stent. Final rotational angiography confirmed perfect stent opposition to the walls of the aorta, without any leak and with unobstructed flow to the LSA. Hemodynamic measurements showed no residual gradient. The fluoroscopy time was 4.2 min, and the dose area product was 12269 mGray · cm².

In the majority of patients with native aortic coarctation and in almost all with recoarctation, trans-catheter

intervention is the first line of treatment. When guided with traditional 2D angiography, it is advised to acquire at least two perpendicular projections to visualize the lesion and perform pertinent measurements. In some patients, standard anterior-posterior and lateral projections may not be sufficient to completely profile the stenosis, or to precisely identify the origin of head and neck vessels. With recent improvements in imaging software, 3D mapping can be performed with CT or MRI data implementation [3, 4]. Three-dimensional rotational angiography provides a large number of "dynamic" angiographic and "static" reconstructed images for the complete evaluation of the lesion; however, it requires specific setup of the angiographic system, injection of a relatively large volume of contrast and additional radiation exposure [1, 2]. These disadvantages may be avoided with a 3D roadmap and implementation of CT or MRI data.

With recently available 3D image fusion software, both CT and MRI datasets may be used for easy segmentation and production of a 3D reconstruction of the target lesion prior to the patient's arrival at the catheterization laboratory [3, 4]. The option of 2D–3D registration eliminates the need to perform a rotational spin and therefore simplifies and shortens the registration process. Reliable overlay omits the need for diagnostic angiography and enhances precise stent positioning and implantation. Three-dimensional mapping might be supported, if it increases overall efficacy and safety of complex cardiovascular interventions. This, and the potential reduction in contrast and radiation exposure, has to be proven in larger series.

Three-dimensional mapping of congenital and structural heart disease may improve the interventional quality and process with the implementation of CT or MRI datasets to fluoroscopy. This initial experience provides proof of concept for a multi-center approach and supports the need for a prospective study. Mapping from CT and MRI can be defined as beneficial in comparison to 3DRA, which is still the standard for 3D roadmap application.

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Conflict of interest

The authors declare no conflict of interest.

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