Many metals have been used in the medical field, and we have found implanted stainless steel sternal wires to be stable for decades with minimum corrosion [1]. Titanium and its alloys are considered reliable materials. They are strong, chemically stable, corrosion-resistant, and rarely sensitized. However we found that even when using sternal wires made of pure titanium, inflammation may cause total corrosion.

A 51-year-old man presented on 162 days after undergoing open heart surgery at our hospital because of severe inflammation with reddening, swelling, and pain at the median sternotomy wound. Three of six sternal wires had been removed at 4 months after surgery because of pain and redness, and all yielded negative bacteriological examinations. The three remaining wires were removed and their surfaces were examined by scanning electron microscopy with energy dispersive spectroscopy. Most of the surface was seriously corroded at the grain boundary (Figs 1A, 1B). Scratches along the direction of extrusion were found on most grains and small crevices, while slip lines were also observed on the grains. Scanning electron microscopic examination of the surface of an unused titanium wire from the same company showed scratches from extrusion (Fig 1C). Energy dispersive spectroscopy identified titanium as the only elemental component of the explanted wire with grade 2 purity (Fig 1D), and polarization curve showed satisfactory corrosion resistance similar to commercial pure titanium (Fig 1E).

Comment

The surface of titanium sternal wires removed from a patient has never been carefully investigated. Prolonged inflammation might have caused severe corrosion of titanium in the present case.

Titanium remains in a passive state after implantation, and many implantable medical devices are made of titanium. Pacemaker contact sensitivity is rare [2–5]. However, a patch test is not reliable to detect titanium sensitivity [4, 5]. An intra-cutaneous test with serum incubated with titanium and a lymphocyte stimulation test were positive in a case of pacemaker dermatitis [4].

Titanium corrodes by contact with active oxygen in vitro [6], and inflammation activates macrophages and generates active oxygen in vivo. In the 1970s it was noticed that the soft tissue had a tendency to discolor in the presence of titanium [7]. In hip replacement cases a tendency of discoloration due to titanium dissolution and local accumulation was observed, and microscopic examination of the blackened tissue showed cells containing black granules and titanium debris [8]. Histologic analyses of areas of titanium debris showed abundant macrophages, suggesting sensitization to titanium [8]. Some early titanium medical implants, such as hip replacements, possibly failed due to corrosion of the material [8]. In a case of granulomatous dermatitis after implantation of titanium-coated pacemaker, titanium was detected in the skin biopsy by electron probe microanalysis [3]. In that case, the titanium debris was probably derived from corrosion after inflammation.

In the present case, it is surprising that continuous inflammation was associated with corrosion of grade 2 pure titanium within several months in vivo. An amount of metal ions equivalent to the volume of corrosion should have been released into the tissue. The dissolved ions from the implants possibly accumulated in the internal organs. However, the effect of dissolved titanium ions on a human is still unknown.

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FEATURE ARTICLES

Hypoplastic Circumflex Retroesophageal Right-Sided Cervical Aortic Arch With Unusual Vascular Arrangement and Severe Coarctation

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We report the case of a 12-year-old boy with a hypoplastic retroesophageal circumflex right-sided cervical aortic arch and coarctation. After the incidental finding of a heart murmur when the boy was 9 years old, cardiac magnetic resonance showed a right-sided cervical aortic

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arch, hypoplastic transverse arch, and separate origin of the left common carotid, right common carotid, right vertebral, and right subclavian arteries. The left subclavian artery arose from the proximal descending aorta next to the coarctation. An extra-anatomical ascending to descending aorta tube graft was inserted through a right lateral thoracotomy with good results.

(Ann Thorac Surg 2007;84:1014–6)

Hypoplastic circumflex retroesophageal right-sided cervical aortic arch with this vascular arrangement and severe coarctation is extremely rare. We describe our evaluation and successful surgical treatment.

A 12-year-old boy from Greece was admitted with coarctation of the aorta. This diagnosis was made by echocardiography when the boy was 9 years old after the incidental finding of a heart murmur. He was asymptomatic until 2005, when he complained of dysphagia and respiratory distress. Esophagography showed severe posterior indentation from the aortic arch.

Cardiac catheterization showed a right-sided aortic arch (rising above the level of the clavicles), hypoplastic transverse arch, and pre-ductal coarctation (gradient of 30 mm Hg). The origin and course of the head and neck vessels were unclear.

On examination the boy looked well. The systemic blood pressure was 140/75 mm Hg. He had a normal right radial pulse, but reduced left radial and femoral pulses and no other abnormal findings. Electrocardiogram showed sinus rhythm with features of a left ventricular hypertrophy.

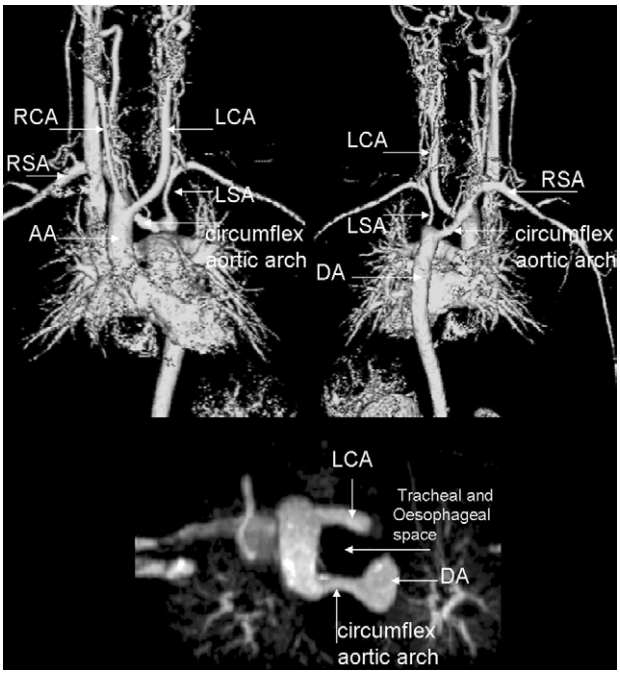

Fig 1. Preoperative cardiac magnetic resonance. (AA = ascending aorta; DA = descending aorta; LCA = left common carotid artery; LSA = left subclavian artery; RCA = right common carotid artery; RSA = right subclavian artery.)

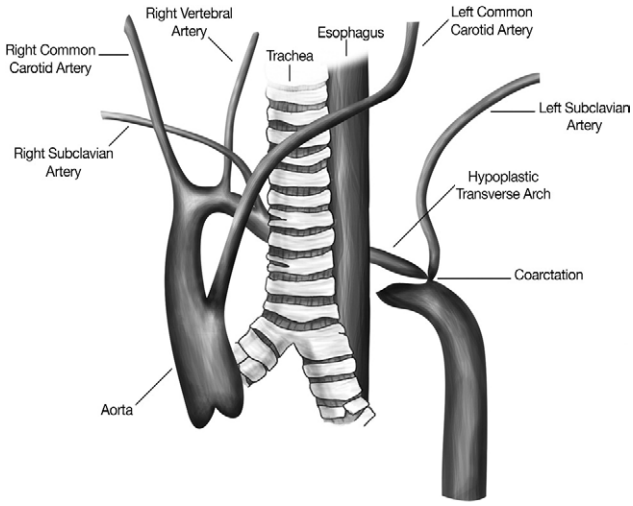

Fig 2. Diagram of aortic arch anatomy.

Echocardiography showed normal intracardiac anatomy and good left ventricular function. Coarctation was found at the distal part of the isthmus (peak gradient, 50 mm Hg) with diastolic tail and reduced pulsatility of the abdominal aorta. As the aortic arch anatomy looked unusual, cardiac magnetic resonance imaging was requested.

This showed a circumflex retroesophageal right-sided aortic arch crossing the midline behind the esophagus on the left side of the spine. The first branch was the left common carotid artery, travelling horizontally in front of the trachea, followed by the right common carotid, right vertebral, and right subclavian arteries. The transverse arch was severely hypoplastic (7 mm), with ascending and descending aortas measuring 22 mm and 17 mm, respectively. The left subclavian artery arose from the proximal descending aorta next to the coarctation (Figs 1, 2).

After multidisciplinary discussion, surgical management was decided and the patient underwent an extra-

Fig 3. Ascending to descending aorta vascular graft.

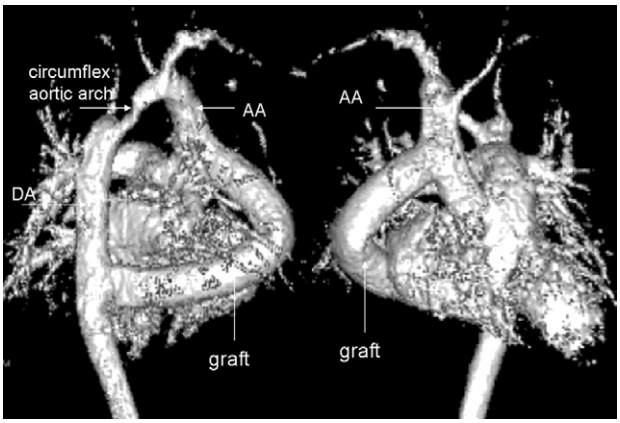

Fig 4. Postoperative cardiac magnetic resonance showing the conduit from ascending to the descending aorta. (AA = aortic arch; DA = descending aorta.)

anatomical bypass grafting from the ascending to the descending aorta without cardiopulmonary bypass. Through a right lateral thoracotomy at the fifth intercostal space, segments of the aorta were prepared and two pairs of intercostal branches were ligated. A Gelatin-impregnated knitted vascular prosthesis (Gelseal [Vascutek Ltd, Inchinnian, Scotland]) of size 18 was prepared and an end-to-side anastomosis was performed on the descending aorta using 5-0 polypropylene sutures. The prosthesis was cut to size and end-to-side anastomosis was made with the ascending aorta using 4-0 polypropylene sutures (Fig 3). Postoperative echocardiography and cardiac magnetic resonance showed a patent graft and good pulsatile flow in the abdominal aorta (Fig 4).

Comment

Cervical aortic arch formation is the result of persistence of the right or left third branchial arch and regression of the fourth [1]. Often, there are associated developmental changes including abnormal laterality, branching, and structural anomalies [2, 3]. In our case there was a hypoplastic circumflex right-sided cervical aortic arch with aberrant origin of the left subclavian artery and severe coarctation.

Right circumflex retroesophageal aortic arch describes a right-sided arch that crosses the midline behind the esophagus, and it is often elongated and reaches a higher level in the thorax.

These anomalies may present in many ways including stridor, regurgitation, and dysphagia by compressing the trachea and the esophagus. This patient experienced an episode of dysphagia at 11 years of age. He had unequal upper limb systemic pressures due to the aberrant origin of the left subclavian artery next to the coarctation.

Barium studies, echocardiography, computerized tomography and cardiac catheterization are important diagnostic tools [4], but cardiac magnetic resonance is particularly useful in accurately defining the complex anatomy [5].

Treatment options vary from no intervention to stenting or surgery. The extensive hypoplasia of the transverse arch precluded ballooning and stenting, and surgical management seemed the best option. A left thoracotomy approach, as in common coarctation repair, would be very difficult due to the high course of the aortic arch and its abnormal branching [6]. Right lateral thoracotomy with extra-anatomical bypass from the ascending to the descending aorta is safe and effective for these complex cases [7]. However, the technique used must be designed for the specific underlying anatomy [2].

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Surgical Treatment of Persistent Fifth Aortic Arch Associated with Interrupted Aortic Arch

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This study describes two cases of the rare congenital anomaly, persistent fifth aortic arch. Both cases involve

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