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# Implantable Drug Delivery Systems in Computed Tomography and Magnetic Resonance Imaging—a Comparison between Titanium and Stainless Steel

M. Krog,[1] A. Magnusson,[2] R. Nyman,[2] A. Ericsson[2]

[1]*Department of Surgery and* [2]*Department of Diagnostic Radiology, University Hospital, S-751 85 Uppsala, Sweden*

## ABSTRACT

The effect of implantable drug delivery systems on computed tomography (CT) and magnetic resonance imaging (MRI) was investigated in a phantom and in two patients. The implantable systems of identical construction consisted either of medical grade titanium alloy or stainless steel. Images of a phantom showed artefacts of the stainless steel port in both CT and MRI. These artefacts were substantially reduced in images of the titanium port. Similar results were found in situ in two patients.

## INTRODUCTION

The use of venous access ports made of various materials has increased considerably in recent years. Ports made of metallic alloys are usually preferred for reasons of inertness and biocompatibility whilst preventing needle penetration of the port housing. Furthermore, the strenght of the material facilitates a portal design that allows for greater compressive forces to be extended on the silicon septum thereby increasing the retention force for the needle in the port septum. However, metallic implantable systems cause artefacts that might severely degrade the images in computed tomography (CT) and magnetic resonance imaging (MRI), due to high attenuation and ferromagnetic properties of the material (3,8,11). Consequently implantable drug delivery systems constructed of stainless steel induce severe artefacts in the immediate vicinity of the port both in CT and MRI.

Titanium has been described as an inert and biocompatible material (1,5). It has been used for medical implants like pacemakers, prosthesis in otology and orthopaedics, surgical clips and recently in a new generation of drug delivery systems. Titanium has been described to cause little interference with CT and MRI diagnostic (2,7,9,10,11,12). This investigation was therefore initiated to evaluate the effect of implantable venous access systems consisting of titanium alloy in CT and MRI compared to ports made of stainless steel.

## METHODS

Implantable drug delivery systems, consisting of titanium (6AV-4V) (PORT-A-CATH [R] TITANIUM), Pharmacia Sweden, and of stainless steel (316L) (PORT-A-CATH [R]), Pharmacia Sweden, were investigated in CT and MRI equipments. They were examined in a phantom and in situ in two patients. In both patients the ports were placed subcutaneously on the chest wall with the catheters tip positioned in the superior caval vein (13). Both patients were treated for Crohn´s disease with short bowel syndrome. The patients were a normal-figured female of 56 years with a titanium port placed on the left pectoral muscle and a slender male of 40 years with a stainless steel port placed on the right pectoral muscle. The size and configuration as well as the quantity of metal in the two ports were identical (Fig.1).

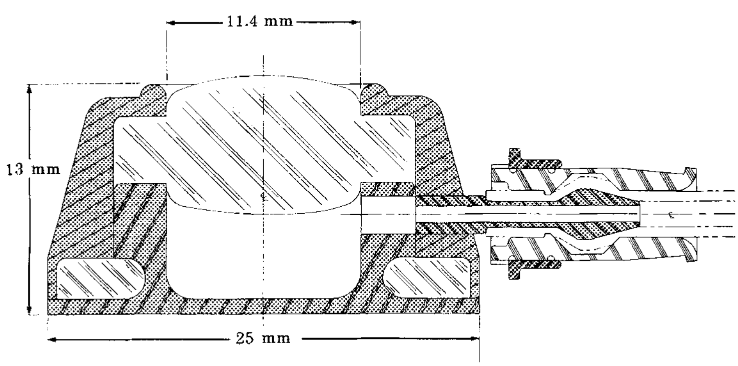


Fig.1. Specification of the Port-A-Cath.

CT was performed with a Siemens Somatom DR2, scanning time 4 s, 0.35 As and slice thickness of 8mm. For the phantom investigation respective ports were placed into a water-filled rubber bubble, and in close contact to the outside of a water filled cylinder with a diameter of 25 cm.

MRI was performed with a superconductive equipment (Siemens Magnetom) operating at 0.5 T. Transversal and frontal images were recorded with spin-echo (SE) and gradient-echo (FLASH) sequences (4). Double-echo, multisclice SE sequences with repetition times (TR) of 500 and 1500 ms and echo times (TE) of 30, 35 and 90 ms were used. The FLASH sequence was performed with a flip-angle of 40 degrees, TR of 70 ms and TE of 14 ms. The number of data acquisitions were 2 for 500/30, 1 for 1500/35,90 and 2 for the FLASH sequence. The acquisition matrix was 256x256.

Contiguous slices with a thickness of 10 mm were recorded. For the phantom study the ports were placed in a box filled with 0.9 % saline.

## RESULTS

* COMPUTED TOMOGRAPHY.

In the phantom study, streaky artefacts were observed in images containing both ports. However, the artefacts created by the titanium port were considerably smaller than those from the steel ports (Fig. 2). In vivo investigations shows these differences (Fig. 3).

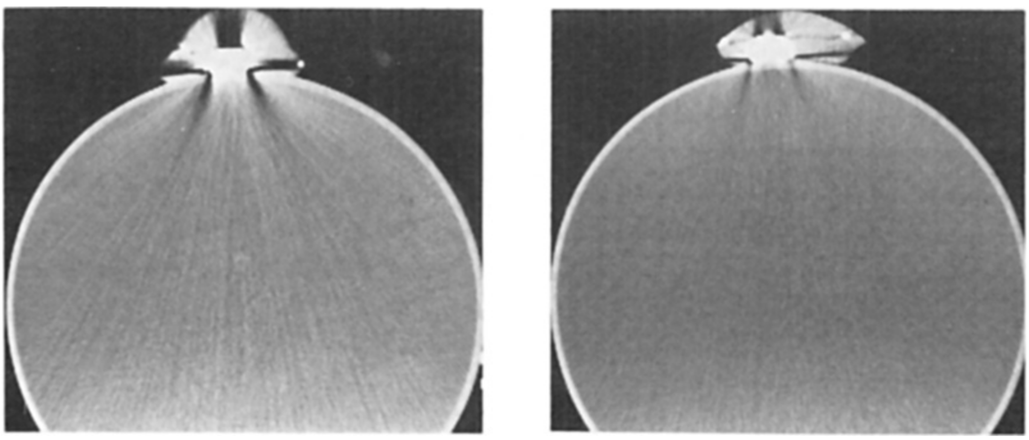

Fig 2. CT images of the phantom. Images viewed under the same conditions, window width 580 HU (Houns-field Units) and window center 40 HU.
Left: Stainless steel port. Right: Titanium port.

* MAGNETIC RESONANCE IMAGING.

In spin echo images of the phantom the artefacts were most extended in the direction of the readout-gradient. Therefore the "size" of the disturbance was measured in this direction.

The dimensions of the artefacts were independent of the type of SE sequence but slightly larger in frontal than in transverse images. A considerable increase in image distortion was observed with FLASH sequences in comparison to SE sequences with both types of ports (Fig 4). The artefacts of the titanium port measured 38-42 mm in the SE image and 59-62 mm in the

Fig 3a.
In vivo
CT images
Stainless steel port.
Same viewing conditions as in Fig. 2.

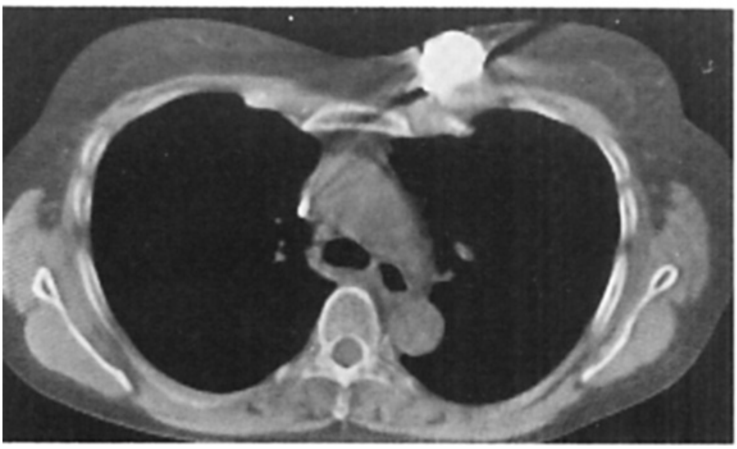

Fig.3b.
In vivo
CT images.
Titanium port.
Same viewing conditions as in Fig. 2.

FLASH image. The corresponding values for the stainless steel port were considerably larger and measured 80-95 mm and 110-130 mm, respectively. The zone of degradation in the SE images of the titanium port was only slightly larger (about 15 mm) than the size of the port. These observations were confermed in situ in the two patients. The SE 500/30 image of the titanium port showed negligable disturbance compared to a larger distortion around the stainless steel port (Fig. 5a and b). In the FLASH sequence the distorsions were considerably increased with both ports, but clearly reduced with the port constructed of titanium (Fig 5c and d).

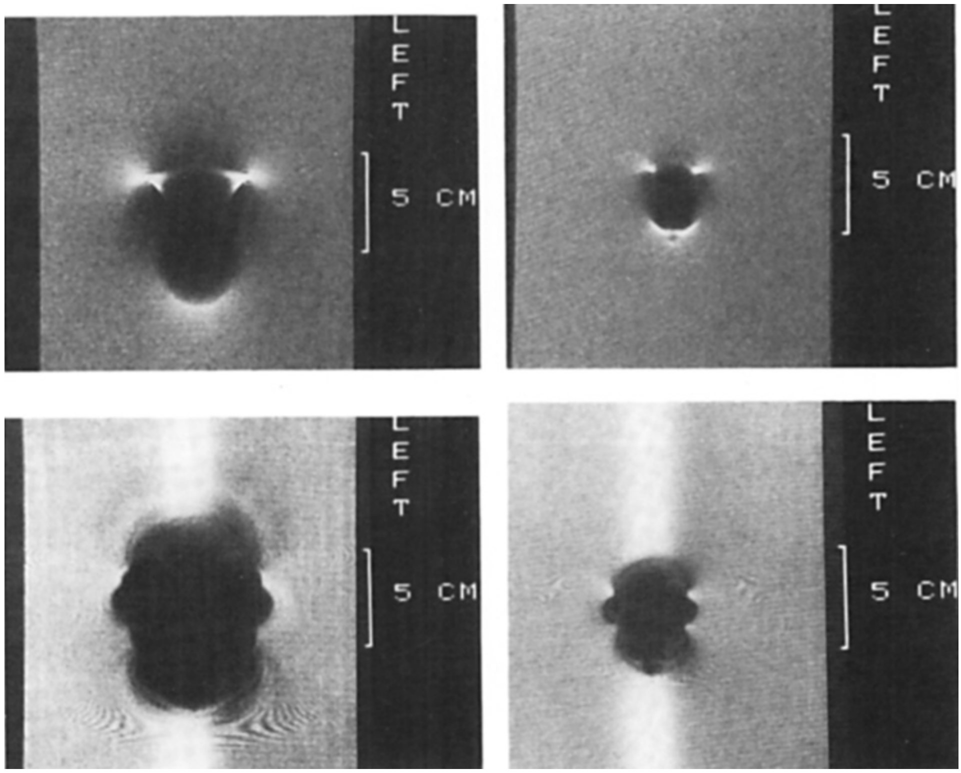


Fig 4: Frontal MR images of the phantom. The band with high image intensity, noticed in the FLASH images is inherent in the sequence.
Upper left: SE 500/30; stainless steel port. Upper right: SE 500/30; titanium port. Lower left: FLASH; stainless steel port.
Lower right: FLASH; titanium port.

## DISCUSSION

CT and MRI are used routinely for the diagnosis and the follow-up of cancer patients. In this category of patients implantable drug delivery systems are often used for the administration of drugs, blood products and for blood sampling (6). Patient safety requires these ports to be manufactured from high quality medical grade metals. For investigations of a process in the same region as the implanted port, degradation of the CT and the MR images could deteriorate the diagnostic information. In CT metallic objects produce streaky artefacts which are the result of a large attenuation difference between metal and surrounding tissue.

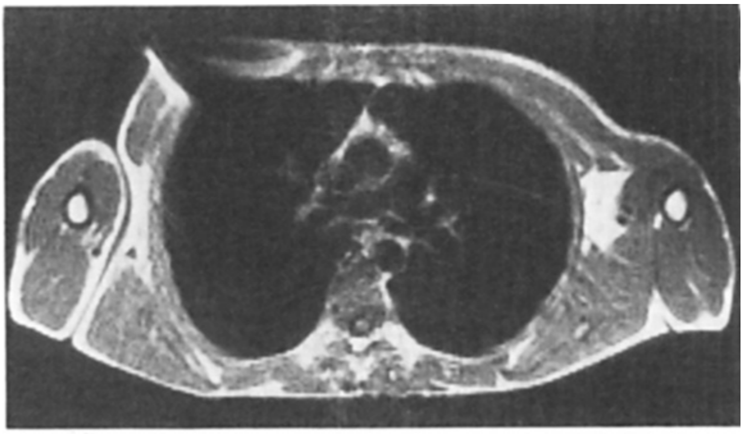

Fig.5a) SE 500/30; stainless steel port, right side.

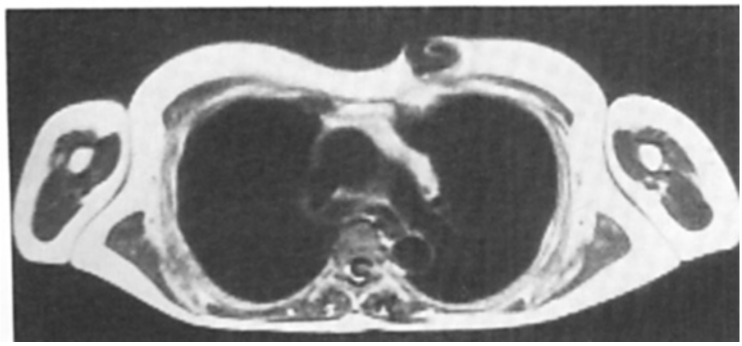

Fig.5b) SE 500/30; titanium port, left side.

Fig.5. Transverse MR images of the thorax of two patients with subcutaneously placed ports; (fig 5a and 5b spin echo sequenses, fig 5c and 5d on next page gradient-echo sequences).

The degree of disturbance by metals depend on their atomic number (3). Artefacts induced by metals are enhanced by patient movement (2). In MRI the artefacts depends on the ferromagnetic content. Consequently metallic implants made of titanium have been shown to cause moderate artefacts both in CT (10) and MRI (8) compared to those composed of stainless steel.

In this study stainless steel ports caused severe streaky artefacts in CT and considerable distortion of the signal in MRI in close vicinity of the implant. The disturbance of the titanium port in CT images was moderate. In MRI the titanium port was clearly visible and caused almost negligable disturbance in SE sequences. As expected the distortion was increased in gradient-echo sequences, but still clearly less with the titanium-compared to the stainless steel port.

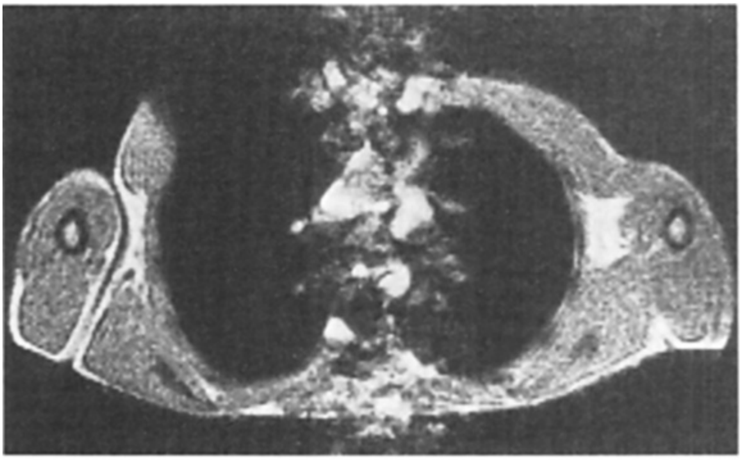

Fig.5c) FLASH; stainless steel port, right side.

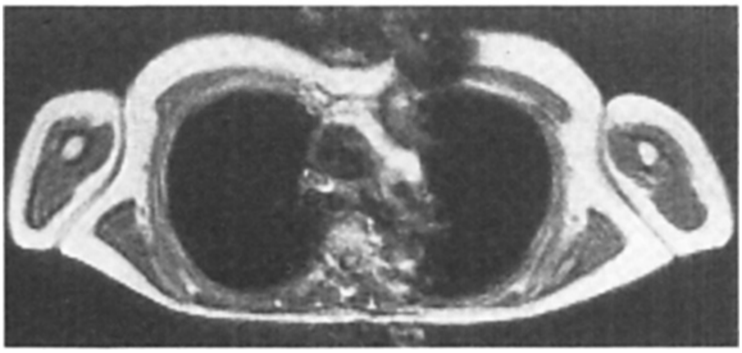

Fig.5d) FLASH; titanium port, left side.

It is therefore concluded that metallic implants made of titanium combine high medical expectance of biocompatibility with minimal interference in diagnostic imaging with CT and MRI.

## ACKNOWLEDGEMENTS

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Address for correspondence:
Michael Krog, M.D.
Department of Surgery
University Hospital
S-751 85 Uppsala
Sweden