Comparison of magnetic resonance with computed tomography angiography for preoperative localization of the Adamkiewicz artery in thoracoabdominal aortic aneurysm patients

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Objective: **Preoperative localization of the Adamkiewicz artery and its segmental supplier in advance of thoracic aortic aneurysm (TAA) and thoracoabdominal aortic aneurysm (TAAA) repair is proposed to be useful to prevent postoperative paraplegia. The diagnostic potential of magnetic resonance angiography (MRA) and computed tomography angiography (CTA) was evaluated for the preoperative localization of the Adamkiewicz artery in white TAAA patients.**

Methods: **Thirty-nine consecutive patients with a TAA(A) scheduled for elective open surgical aortic repair preoperatively underwent MRA and CTA. Objective image quality was assessed by measuring the signal-to-noise ratio and contrast-to-noise ratio of the Adamkiewicz artery and was related to patient thickness. Two independent observers scored the location of the Adamkiewicz artery and the subjective image quality of vessel-background contrast of the Adamkiewicz artery, image noise, spinal cord tissue enhancement, epidural venous enhancement, and overall image quality.**

Results: **Average detection rate for Adamkiewicz artery localization was 71% (67% to 74%) for CTA and 97% (94% to 100%) for MRA. Interobserver agreement was 82% for CTA and 94% for MRA. Signal-to-noise ratio was significantly higher ($P < .001$) and contrast-to-noise ratio was significantly ($P < .001$) lower for CTA than for MRA. Contrast of the Adamkiewicz artery ($P < .001$) and overall image quality ($P < .004$) were judged to be significantly better for MRA. Spinal cord tissue enhancement was judged stronger at CTA ($P < .03$), with significantly less epidural venous enhancement ($P < .001$). No significant difference was found in image noise. Signal-to-noise and contrast-to-noise decreased significantly ($P < .001$) with increasing patient thickness for CTA but not for MRA.**

Conclusions: **Localization of the Adamkiewicz artery in white TAAA patients is possible with both CTA and MRA. Compared with CTA, MRA is more favorable because of the higher Adamkiewicz artery detection rate, the higher contrast-to-noise ratio, and its independence of patient thickness. (J Vasc Surg 2007;45:677-85.)**

Patients undergoing thoracic aortic aneurysm (TAA) or thoracoabdominal aortic aneurysm (TAAA) repair are at risk for ischemic spinal cord injuries such as paraparesis or paraplegia. To avoid these complications, preoperative visualization of the spinal cord blood supply has been suggested and used.[1-9] The largest, and therefore considered to be the most important supplier of the thoracolumbar spinal cord, is the great anterior radiculomedullary artery, also known as the Adamkiewicz artery.[10] The Adamkiewicz artery has a calibre of <1.0 mm and derives from a posterior branch of an aortic segmental artery. Because the Adamkiewicz artery supplies the largest and most vulnerable part of the thoracolumbar spinal cord, it is the artery of interest in preoperative diagnostic imaging.

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Different imaging techniques can be used to depict the Adamkiewicz artery. The standard of reference for this purpose is intra-arterial catheter-based angiography. This technique is invasive, however, and can be technically difficult to perform in TAAA patients, which is illustrated by a highly variable Adamkiewicz artery detection rate of 43% to 86%.[1,2] Moreover, catheter angiography can be hazardous to the vascular patient, and severe complications, including paraplegia, have been described.[1] Although the risk for major complications in the largest published series of 480 patients was only 1.2%, it is significant compared with the 3% to 5% occurrence of paraplegia owing to surgery in our TAAA patient population.[11]

Noninvasive magnetic resonance angiography (MRA) and computed tomography angiography (CTA)[3-9,12-17] have been explored to investigate their potential to localize the Adamkiewicz artery and its segmental supplier. In 2006, we showed with two validation studies[13,14] that MRA is able to consistently localize the Adamkiewicz artery and its segmental supplier and differentiate it from the similarly shaped great anterior radiculomedullary vein (GARV).

We also performed a study[5] in 60 TAAA patients that revealed two important outcomes: (1) MRA can preoperatively localize the Adamkiewicz artery in up to 100% of the TAAA patients, and (2) a significant correlation exists between the location of the segmental artery supplying the Adamkiewicz artery relative to the aortic cross-clamped area and intraoperative spinal cord function. We found that when the segmental supplier of the Adamkiewicz artery was outside the cross-clamped area, no changes in spinal cord function were observed. This means that preoperative localization of the Adamkiewicz artery by MRA has a negative predictive value of 100% for a decrease in spinal cord function. Conversely, when the segmental supplier was located inside the cross-clamped area, the positive predictive value was 32% for a decline in spinal cord function. The results indicated that the Adamkiewicz artery indeed is still functional in TAAA patients and that maintenance of its direct segmental supply is crucial in one third of the patients with a temporary decrease in spinal cord function during surgery.

The use of CTA instead of MRA would be beneficial logistically because CTA is generally used to determine the aortic aneurysm's diameter, extent, and type (atherosclerotic or dissection). To our knowledge two studies, both performed in Japanese patients, have compared CTA with MRA for the localization of the Adamkiewicz artery in the same patients,[9,15] but no report has been published on the detection ratio of CTA in white TAAA patients. Thus, the aim of this study was to investigate whether MRA or CTA is the preferred technique for the preoperative visualization of the Adamkiewicz artery in white TAA(A) patients. To this end, the Adamkiewicz artery detection rate, as well as the quantitative and observational image quality, were compared between CTA and MRA.

PATIENTS AND METHODS

Patients. The study included 39 consecutive patients (20 men and 19 women) with a TAA or a TAAA scheduled to undergo elective surgical aortic aneurysm repair between September 2002 and May 2005. These patients were also included in a previous study that correlated the location of the segmental artery supplying the Adamkiewicz artery relative to the aortic cross-clamped area with intraoperative spinal cord function.[5] The 39 patients were aged a mean (± SD) 65 ± 12 years and could be divided in five different groups according to the extent of their aortic pathology using the Crawford classification: 16 TAA, 2 TAAA type I, 12 TAAA type II, 4 TAAA type III, and 5 TAAA type IV. Fourteen patients had chronic type-B dissection and atherosclerosis to some extent, and 25 patients had advanced atherosclerotic disease.

Before the procedure, all patients underwent CTA and MRA. CTA preceded MRA in all patients. The interval between these two examinations varied from 1 day to 3 weeks. CTA was performed as part of the regular clinical work-up program before the procedure to determine the extent and location of the aorta pathology.

The Maastricht University Hospital Medical Ethical Committee approved the study protocol, and written informed consent was obtained from all patients before inclusion.

Computed tomography angiography. CTA images were obtained on an Aquilion four-channel multidetector row CT scanner (Toshiba, Tokyo, Japan). The antecubital vein was used to inject 120 to 150 mL of iohexol (350 mg/mL iodine, Omnipaque, GE Health, Oslo, Norway) at a rate of 3 mL/s. The scanning range was set from the level of the apex of the lungs down to the lower edge of the sacrum.

Initially, the contrast bolus arrival timing in the ascending aorta was assessed according to the protocol of Takase et al[4] (Sure Start, Toshiba, Tokyo, Japan); however, this injection protocol did not provide satisfying depiction of spinal cord arteries (or veins) in the first six patients. These patients were not included in this study, and the contrast timing was adjusted.

A fixed scan delay of 35 seconds was used in the 39 included patients before starting the contrast-enhanced acquisition. The technical variables for the first 12 patients were as follows: collimation width, 4-mm × 2-mm; pitch, 0.875; reconstructed slice width, 2.0 mm; reconstruction increment, 1.5 mm; standard abdominal filter (FC01), x-ray tube rotation time, 0.5 seconds; tube voltage, 120 kV; and tube load, 200 mAs. For the remaining 27 patients, the variables were adjusted to increase contrast. Adjusted technical parameters in the last 27 patients were rotation time, 1.0 seconds; tube voltage, 80 kV; and tube load, 300 mAs. Only one dynamic phase was acquired with CTA to limit radiation exposure. Duration of the CTA examination was <15 minutes.

Magnetic resonance angiography. All patients underwent preoperative MRA to localize the Adamkiewicz artery and its segmental supplier. Imaging was performed on a clinical 1.5 T MRI system (Philips Intera, Philips Medical Systems, Best, The Netherlands) equipped with a phased-array synergy surface spine coil. The MRI protocol included a bolus timing scan series in which the time of contrast arrival in the distal aorta was determined. The MRA exam consisted of two consecutive dynamic phases and was performed using a three-dimensional (3D) spoiled gradient echo sequence. A centric k-space filling scheme synchronized to the arrival of the contrast agent (dose 45 mL, gadopentetate dimeglumine, Magnevist, Schering, Berlin, Germany) was used to suppress venous blood signal. The craniocaudal field of view was 50 cm, slice thickness was 1.2 mm, matrix dimensions were 464 × 512, and the number of slices (76 to 110) was individually adjusted. The two dynamic phases, each 36 to 52 seconds, allowed differentiation based on temporal intensity changes between the Adamkiewicz artery and the GARV, which have a similar spatial configuration. Details of the imaging protocol have been described elsewhere.[6,13,14] The MRA examination typically took 30 minutes.

Image analysis of Adamkiewicz artery localization. Image data sets were transferred to the image postprocessing workstation Easy Vision 4.1 (Philips). Image data sets were made anonymous by a technical assistant not involved in the analysis. Each individual examination was assigned with a unique identification number resulting in 39 MR and 39 CT 3D image data sets. The 78 examinations were randomly presented to two experienced independent observers who were blinded for the clinical details and each other's results. They attempted to localize and visualize the trajectory from the aorta via the segmental artery and Adamkiewicz artery to the spinal cord in each data set using (targeted) maximum intensity projections and (curved) multiplanar reformations. If this was not successful, analysis of signal intensity time courses of the depicted vessels had to be performed. When the signal intensity of the depicted vessel decreased in the second phase, this vessel was considered to be the Adamkiewicz artery. A vessel that showed a constant or increasing signal intensity over the two dynamic phases was considered to be the GARV. This analysis of signal intensity time courses was only possible with MRA examinations. In cases where visualization of the arterial trajectory was not successful with CTA, differentiation of the Adamkiewicz artery from the GARV was based on differences in morphologic features and craniocaudal localization. The GARV frequently has a longer intradural trajectory, is located more caudally, has a larger calibre than the Adamkiewicz artery, or a combination of these.

The segmental origin of the Adamkiewicz artery and GARV at MRA was determined using the T_2-weighted anatomic images in combination with the MR coil markers and late-phase MRA images, which showed the contrast-enhanced vertebral bodies.

For both CTA and MRA, the level could be determined by counting the vertebral bodies. The intervertebral foramen at which the spinal branch of the segmental artery entered the spinal canal and continued as the Adamkiewicz artery was interpreted as the Adamkiewicz artery level. For instance, in case the spinal branch entered between the 12th thoracic (T) vertebra and the first lumbar (L) vertebra, the localization was denoted as segmental level T12.

After each observer independently tried to localize the Adamkiewicz artery, the percentage of agreement between the two observers was calculated for CTA and MRA. Observations were considered in agreement when both observers localized the Adamkiewicz artery at the same level on the same side or when both observers did not detect the Adamkiewicz artery.

Observational image quality. The same two observers who tried to localize the Adamkiewicz artery were asked to give a subjective score on a 5-point scale ranging from 0 (zero/none), 1 (very poor/weak), 2 (poor/weak), 3 (moderate), 4 (good/significant), to 5 (excellent/strong) rating the image quality items of spinal cord tissue enhancement, epidural venous enhancement, image noise, contrast of the Adamkiewicz artery relative to the adjacent image region, and overall image quality for both image modalities and every patient. These scores were averaged per patient per image quality item.

Quantitative image quality. For objective image quality for both imaging modalities, signal intensity measurements were performed by a third independent reader to determine the signal-to-noise (SNR) and contrast-to-noise ratio (CNR). Because a spine phased-array surface coil was used, no representative air regions were available to obtain reliable noise measurements for MRI. The standard deviation of the signal intensity in the erector spinae muscle (SD_0) was therefore determined to represent the noise level. SNR was calculated as the ratio between the signal intensity of the artery and SD_0. CNR was calculated as the difference between signal intensity of the artery and the surrounding image region divided by SD_0. The signal intensity for CTA was measured in Hounsfield units and converted to attenuation coefficients in cm^2/g.

To investigate the influence of the body habitus on the SNR and CNR of the Adamkiewicz artery, the (transverse) anteroposterior diameter of the abdomen at the T12 level was measured. To assess the possible relation of SNR and CNR as a function of this diameter, regression analysis was applied to quantify the effect of the exponential decay of the radiation transmission with patient thickness.

Surgical protocol. The surgeon was informed about the localization of the segmental Adamkiewicz artery supplier and other open and occluded segmental arteries. The operation strategy for the placement of the aortic cross-clamps was not influenced by the preoperative angiography results. The surgical procedure was performed in a similar manner as described before.[11,18,19] Our spinal cord protection protocol consisted of cerebrospinal fluid (CSF) drainage, left atrium-femoral artery or femoral artery-femoral vein bypass enabling distal aortic perfusion, and spontaneous cooling to 32° to 33°C with active rewarming at the end of the procedure.

Neuromonitoring of spinal cord function was performed intraoperatively by means of motor-evoked potentials (MEPs) and has been described in detail elsewhere.[11,18,19] In general, the aorta is sequentially cross-clamped, allowing stepwise exclusion of aortic segments and assessment of changes in MEP amplitudes. If the MEP decreased after placement of the proximal clamp, the mean distal aortic perfusion pressure was increased till the MEP normalized. However, if the MEP rapidly decreased during aortic cross-clamping and was not correctable with increasing distal and mean arterial pressure, indicating that the excluded aortic segment contained crucial segmental arteries, the clamps were released and the patient was actively cooled to 32°C, affording additional neuroprotection. The aorta was then clamped again and opened.

Patent segmental arteries were reattached and perfused till the MEPs returned to baseline levels. When the origin of the segmental artery supplying the Adamkiewicz artery was inside the cross-clamped area, this segmental artery was reattached and perfused first. In cases were MEP amplitudes remained stable, several patent segmental arteries

Table I. Overview of the Adamkiewicz artery detection by two observers for computed tomography and magnetic resonance angiography

	Adamkiewicz artery	
	Found	*Not found*
CTA		
Observer 1	26	13
Observer 2	29	10
MRA		
Observer 1	37	2
Observer 2	39	0

CTA, Computed tomography angiography; *MRA,* magnetic resonance angiography.

were preventively reattached except when they arose from a severely diseased aortic wall. Revascularization of the hypogastric arteries was also performed when possible.

Statistical analysis. Statistical analysis was done with SPSS 11.0 software (SPSS Inc, Chicago, Ill). The paired-sample Student *t* test was used to test whether there were significant differences in SNR and CNR between the two imaging modalities. To test if there were significant differences in subjective image quality and Adamkiewicz artery detection rates the Wilcoxon signed rank test was applied. Statistical significance was inferred at $P < .05$. Exponential-linear regression analysis was applied to investigate the possible relation between the SNR and CNR and patient thickness for both modalities.

RESULTS

Adamkiewicz artery localization image analysis. In all 39 patients, image data sets suitable for analysis were obtained with both modalities. No examination was aborted owing to claustrophobia, and no side effects occurred during or after the injection of contrast material. The average scan delay for MRA was 27 seconds (range, 16 to 55 seconds).

The Adamkiewicz artery was more often detected by both observers with MRA than with CTA (Table I). The average detection rate with MRA was 97% (observer 1, 95%; observer 2, 100%), which was significantly ($P < .001$) higher compared with the average detection rate of 71% (observer 1, 67%; observer 2, 74%) for CTA (Fig 1, Fig 2). The Adamkiewicz artery was localized in all patients between vertebral levels T8 and L1 and derived from the left side in 64% of patients (25/39) and from the right side in 36% (14/39; Table II).

The GARV was observed in 19 patients with CTA and always covisualized with the Adamkiewicz artery. Differentiation with CTA between the Adamkiewicz artery and GARV was based on vascular anatomy. With MRA, the GARV was observed in 36 patients (Table II) and was observed 34 times in the early phase images and 36 times in the late phase images. Differentiation between the Adamkiewicz artery and GARV with MRA was possible on the basis of signal changes between the first and second phase MRA images in these 36 cases. In three patients, no GARV was depicted using MRA, but spinal cord drainage through the filum vein was detected.

With CTA, the Adamkiewicz artery was localized in 77% (20/26) by using 80 kV tube voltage compared with 31% (4/13) at 120 kV. In eight patients, none of the observers was able to detect the Adamkiewicz artery on CTA images, and in seven patients, only one of the observers was able to do so. The percentage of inter-observer agreement for CTA was 82%. For MRA, there were two cases in which only one observer was unable to localize the Adamkiewicz artery. The interobserver agreement with MRA was 94%.

Observational image quality. Contrast of the Adamkiewicz artery vs the adjacent image region ($P < .001$) and overall image quality ($P < .004$) were judged to be significantly better for MRA (Table III). Spinal cord tissue enhancement was evaluated to be significantly ($P < .03$) stronger for CTA. Epidural venous enhancement was judged to be significantly ($P < .001$) less present on CTA images. The difference in image noise between the two modalities was not significant ($P > .7$).

Quantitative image quality. Quantitative image analysis revealed that SNR of the Adamkiewicz artery was significantly higher ($P < .001$) for CTA (60.8 ± 18.6, mean ± SD) compared with MRA (10.6 ± 4.0; Table IV). The signal intensity of the image region adjacent to the Adamkiewicz artery was not significantly ($P > .5$) different for CTA (14.8 ± 22.4) compared with MRA (13.0 ± 11.1). The CNR of the Adamkiewicz artery was significantly ($P < .001$) higher for MRA (6.8 ± 2.4) than for CTA (2.3 ± 1.8; Table II). At CTA, both SNR ($P < .001$) and CNR ($P < .01$) decreased significantly with increasing patient abdominal diameter. At MRA, there was no significant relation between SNR ($P > .3$) or CNR ($P > .6$) and the patient's abdominal diameter (Fig 3).

Clinical outcome. No intraoperative death or renal failure occurred in this series of patients. Five patients (13%) died in the hospital after surgery: 1 TAA patient from respiratory failure, 2 (type II TAAA) from cardiac and respiratory failure, 1 (type III TAAA) from sepsis and respiratory failure, and 1 (type IV TAAA) from sepsis. Paraplegia developed in two patients.

Acute paraplegia became evident in one type III TAAA patient after the procedure. This neurologic deficit was anticipated because MEPs were entirely absent at the end of the procedure. Sequential clamping of the thoracic and abdominal aorta in this patient was associated with a gradual decrease of MEPs to nonmeasurable amplitudes. Despite increasing mean arterial and distal aortic pressures and revascularization of all available segmental arteries, including the one supplying the Adamkiewicz artery, MEP signals did not return.

Delayed paraplegia occurred in one type II TAAA patient. In this patient, exclusion of the entire aorta did not

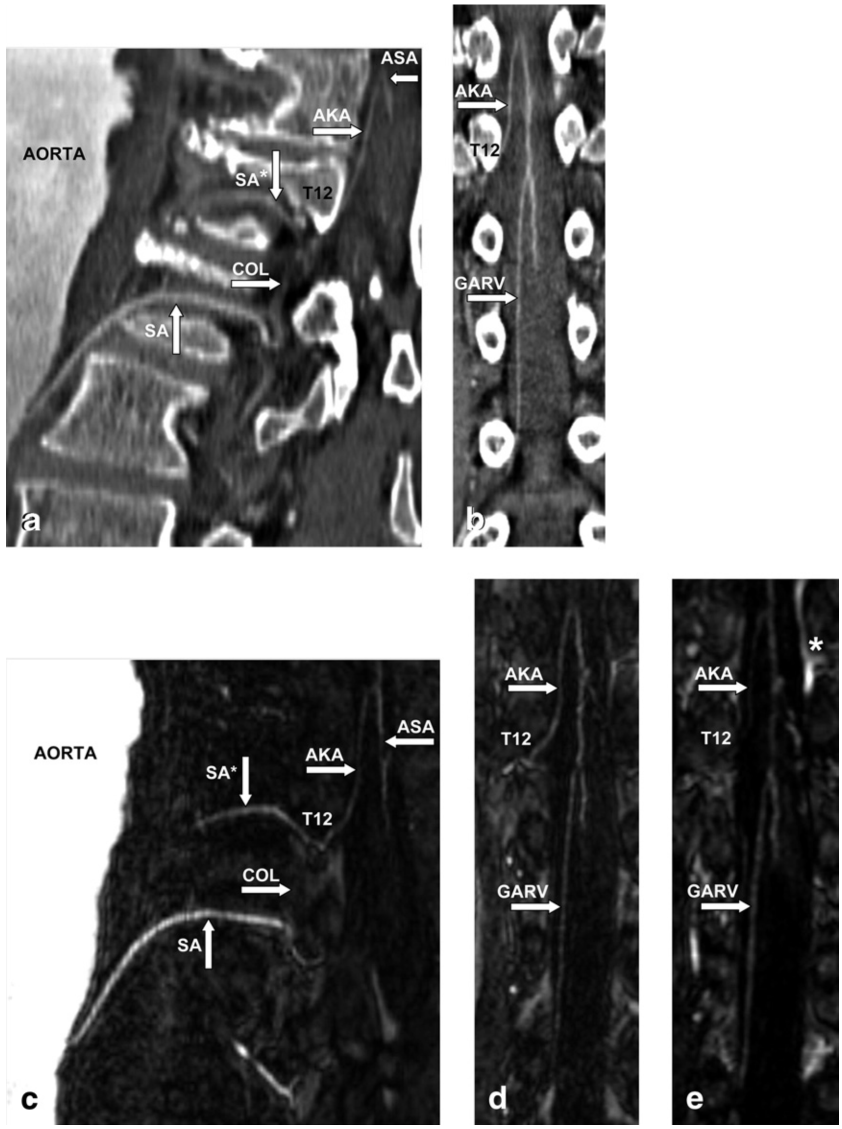

Fig 1. Preoperative computed tomography angiography (CTA) **(a, b)** and magnetic resonance angiography (MRA) **(c, d, e)** in a 63-year-old woman with a Crawford type II thoracoabdominal aortic aneurysm. The curved multiplanar reformation (MPR) of the CTA **(a)** and first-phase MRA **(c)** show the collateral segmental supply from the aorta to the Adamkiewicz artery *(AKA, arrow)* and anterior spinal artery *(ASA, arrow)*. The segmental artery *(SA*, arrow)* directly connecting to the Adamkiewicz artery is partially occluded. The Adamkiewicz artery is supplied by an intersegmental collateral *(COL, arrow),* which originates from a SA one vertebral level below. Note that in the coronal MPR of the CTA **(b)** and first-phase MRA **(d)**, both the Adamkiewicz artery and the great anterior radiculomedullary vein *(GARV, arrow)* are depicted. There is no separation of the spinal cord artery and vein in this patient in the CTA or first phase MRA. The second-phase MRA **(e)** shows decreased signal intensity for the Adamkiewicz artery, whereas the GARV becomes slightly thicker and more intense over the two phases. Note that the enhanced vasculature on the midline of the anterior cord surface is the spatially and temporally unresolved combination of the anterior spinal artery and the anterior median vein. The epidural plexus *(*)* is strongly enhanced in the second-phase image.

lead to a decline in MEPs. Because of the very poor quality of the aorta and because no MEP declines were observed during the entire operation, no attempts were undertaken to revascularize any of the encountered back-bleeding segmental arteries, including the supplier of the Adamkiewicz artery. The patient experienced a short period of hypotension in the intensive care unit, and thereafter he was unable to move his legs.

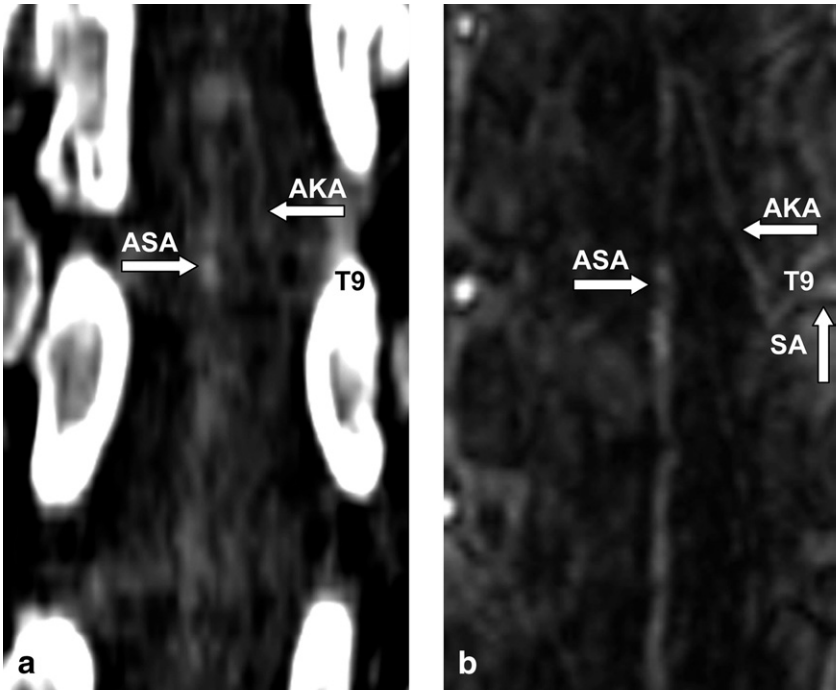

Fig 2. Preoperative computed tomography angiography (CTA) **(a)** and magnetic resonance angiography (MRA) **(b)** of the Adamkiewicz artery *(AKA, arrow)* and anterior spinal artery *(ASA, arrow)* in a 33-year-old man with a Crawford type II thoracoabdominal aortic aneurysm. Note that the Adamkiewicz artery and ASA are more difficult to depict with CTA compared with MRA owing to the lower contrast of the Adamkiewicz artery and ASA obtained with CTA.

Table II. Overview of the localizations and frequencies of the Adamkiewicz artery and great anterior radiculomedullary vein as detected by magnetic resonance and computed tomography angiography*

	Adamkiewicz artery		*GARV*	
Vertebral level	*CTA*	*MRA*	*CTA*	*MRA*
T8	2	2	0	0
T9	4	9	0	0
T10	11	13	0	1
T11	7	8	0	1
T12	6	6	1	5
L1	1	1	7	9
L2	0	0	9	11
L3	0	0	1	8
L4	0	0	1	1

GARV, Great anterior radiculomedullary vein; *MRA,* magnetic resonance angiography; *CTA,* computed tomography angiography.
*Reported are the vessels that were detected by at least one of the two observers. No Adamkiewicz artery or GARV was detected outside the indicated vertebral levels. Note that the GARV is generally more caudally localized than the Adamkiewicz artery.

Table III. Observational (subjective) image quality comparison between computed tomography and magnetic resonance angiography

	CTA	*MRA*	P
Contrast Adamkiewicz artery vs surrounding	1.9 ± 1.3	3.1 ± 1.0	<.001*
Image noise	3.5 ± 0.7	3.5 ± 0.8	>.7
Spinal cord enhancement	3.5 ± 0.7	3.2 ± 0.8	<.03*
Epidural venous enhancement	2.1 ± 0.7	2.6 ± 0.7	<.001*
Overall image quality	2.8 ± 0.8	3.2 ± 0.6	<.004*

CTA, Computed tomography angiography; *MRA,* magnetic resonance angiography.
Values are presented as mean ± SD.
*Indicates statistically significant.

DISCUSSION

This study investigated whether MRA or CTA is the best technique to visualize the Adamkiewicz artery in white TAAA patients. The higher Adamkiewicz artery detection rate revealed that MRA performed better than CTA in our TAAA patient population. The superiority of MRA was confirmed by quantitative and observational image quality analysis.

Despite recent advances in surgical techniques and intraoperative monitoring, paraplegia remains a feared and devastating complication after technically successful TAAA repair. Preoperative identification of the Adamkiewicz artery and its segmental supplier in TAAA patients has been suggested as a protective measure because it provides the opportunity to selectively reattach the spinal cord blood supplying arteries. The imaging technique used to detect to

Table IV. Quantitative (objective) image quality comparison between computed tomography and magnetic resonance angiography

	CTA 80kV	*CTA 120kV*	*MRA*	P
SNR	59 ± 15	73 ± 24	10.6 ± 3.9	<.001*
CNR	3.0 ± 1.7	2.3 ± 1.1	6.6 ± 2.7	<0.001*

CTA, Computed tomography angiography; *MRA,* magnetic resonance angiography; *SNR,* signal-to-noise ratio; *CNR,* contrast-to-noise ratio. Values are presented as mean ± SD.
*Both values are statistically significant.

the arterial trajectory to the Adamkiewicz artery should ideally have a high detection rate, be safe to perform, patient friendly, and unambiguous in the interpretation what is an inlet artery or outlet vein of the spinal cord.

In general, the standard of reference for spinal cord angiography is catheter-based angiography. This technique may provide superior image quality, but it is not recommended in TAAA patients at our institutes. Even when performed by specialists, catheter-based angiography in TAAA patients may be associated with severe complications, including paraplegia.[1] Maneuvering the catheter through the atherosclerotic aorta and hooking the tip of the catheter into the segmental arteries may induce emboli and subsequent occlusion by disrupting atherosclerotic plaques. Furthermore, injection into and maneuvering the catheter in the segmental artery can lead to vasospasm and temporary occlusion of these segmental arteries.[20]

Computed tomography versus magnetic resonance angiography. Studies have explored noninvasive imaging modalities such as CTA[3,4,9,15] and MRA[5-9,12-17] to assess their potential to noninvasively localize the Adamkiewicz artery. Both seem capable of visualizing the Adamkiewicz artery and its segmental supply. Reported detection rates of the Adamkiewicz artery vary from 68% to 90% for CTA[3,4] and from 67% to 100 % for MRA.[5,6,9] We found that MRA was superior to CTA in all the important metrics, including Adamkiewicz artery detection rate (97% vs 71%), interobserver agreement (94% vs 82%), and image quality (score, 3.2 vs 2.8). Differences between our results and those of Japanese groups [3,4,9,15] may be explained by differences in image quality related to the exact implementation of the imaging techniques and patient populations.

Contrast appears to be the most relevant image quality item to detect the Adamkiewicz artery. Visibility of small structures such as spinal cord arteries (caliber <1 mm) depends on the contrast between vessel lumen and surrounding structures. This was also noticed in the quantitative (in terms of CNR) and observational assessment of the images of the two modalities. MRA was judged to be significantly better at showing contrast between the Adamkiewicz artery and the surrounding tissue, with significantly less spinal cord tissue enhancement (darker background).

For CTA, the contrast between the iodine-containing vessel and surrounding depends on several factors. First,

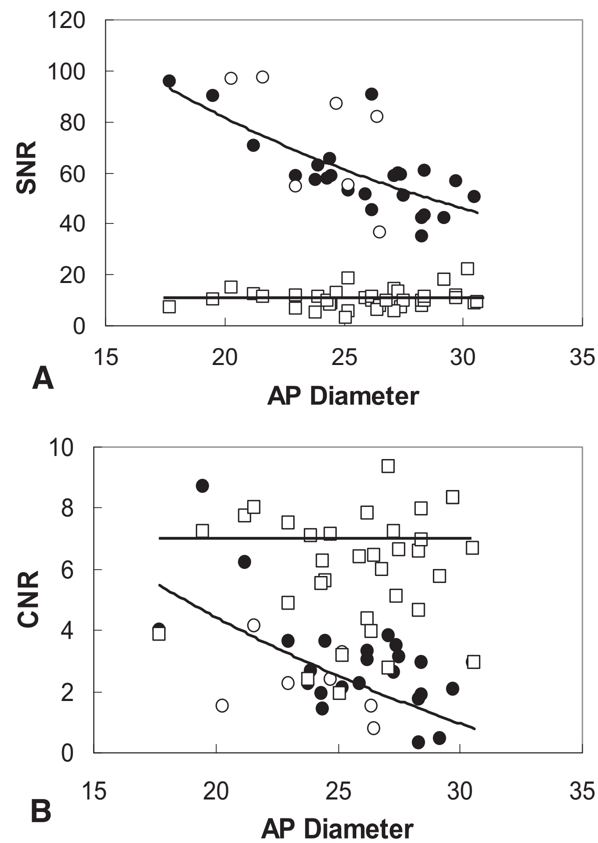

Fig 3. Signal-to-noise ratio *(SNR)* and contrast-to-noise *(CNR)* of the Adamkiewicz artery vs the anteroposterior *(AP)* abdominal diameter (measured at T12). **A,** The SNR values of both the 80 kV *(black circles)* and the 120 kV *(white circles)* computed tomography angiography (CTA) protocols lie above that of magnetic resonance angiography (MRA) *(squares)*. There is no influence of an increasing abdominal diameter on the SNR for MRA. This is in contrast to CTA where the SNR significantly decreases with increasing abdominal diameters. **B,** For the CNR, the MRA values lie above the values of both CTA protocols. Again there is no influence of an increasing abdominal diameter on the CNR MRA. This is in contrast to CTA, where the CNR significantly decreases with increasing abdominal diameters.

tube voltage (kV) is important because lower voltages will lead to stronger attenuation by intravascular contrast material compared with a higher voltage.[21] Stronger attenuation in the vessel lumen gives rise to more contrast and thus improved visualization. This was reflected by the more frequent Adamkiewicz artery detection in the subgroup of patients who were scanned with the lower kV setting.

Second, the patient's body habitus is crucial. CNR decreases significantly for patients with larger abdominal anteroposterior diameters. The thicker bodies of corpulent individuals more strongly absorb the x-rays, which results in fewer x-ray photons being transmitted through the body to the detectors. This consequently causes more noise and lower SNR and CNR values.[21] Because our white patient population is, not surprisingly, more obese than the Japanese subjects who were studied, the results of those studies may not apply to the current white patient population.

Apart from the current results in favor of MRA, it should be recalled that MRI does not involve ionizing radiation. Performing thoracoabdominal CTA is associated with a relatively high effective dose of approximately 20 mSv, which is relatively high for diagnostic imaging. Moreover, the gadolinium-based MR contrast agents used in the current study have a more favorable safety profile, with a much lower frequency of renal complications in vascularly comprised patient populations compared with the iodine-based contrast agents used for CTA.

A limitation of the current study is that we did not use a dedicated timing in our CT protocol, as opposed to MRA. However, because of the complex shape of the aortic aneurysms, timing in CTA is difficult regardless of whether a fixed scan delay or an automated trigger system is used.

One might also argue that the CT scanner used in this study was not state-of-the-art compared with the current generation of 16-slice and 64-slice machines. More detectors would allow faster imaging, possibly acquiring more data at the peak of the contrast enhancement. Boll et al[22] used a 40-slice CT system to visualize the Adamkiewicz artery in 100 nonvascular patients with a pancreatic neoplasm and achieved acquisition times of approximately 7 seconds. Although these authors claimed an Adamkiewicz artery detection rate of 100%, arteries feeding the spinal cord were not differentiated from draining veins. Definite classification of spinal vessels in terms of arterial and venous was not validated and remains highly uncertain in our opinion. It therefore remains to be proven whether this advanced technology will improve the Adamkiewicz artery visualization in vascular patients. Moreover, Takase et al[4] used an identical four-slice CT scanner and found a Adamkiewicz artery detection rate of 90% in 70 Japanese patients with vascular disease.

Implications for presurgical work-up. At our institutions, and probably in most other hospitals, CTA is used to determine the extent, diameter, and type (atherosclerotic or dissection) of the aortic aneurysm. CTA is also logistically more easily accessible than MRA. If CTA, preferably performed at 80 kV tube voltage for corpulent patients, were able to unambiguously detect the Adamkiewicz artery and its segmental supply, it would a priori be the preferred and only technique to be applied in the presurgical work-up. As this study showed, however, MRA outperforms CTA on the Adamkiewicz artery localization. In addition to the lower Adamkiewicz artery detection ratio, CTA is not yet able to unambiguously differentiate between the Adamkiewicz artery and the outlet vein. In our opinion, differentiation—answering what is inlet artery (ie, Adamkiewicz artery) and outlet vein (ie, GARV)—is of paramount importance. At present, only MRA can differentiate between spinal cord inlet artery and outlet vein.

CONCLUSION

In consideration of the foregoing, overall surgical planning should involve CTA to detect and characterize the aortic aneurysm. When CTA does not detect the Adamkiewicz artery or when the continuity of the blood supplying arterial trajectory from the aorta to the spinal cord cannot indisputably be visualized because of insufficient image quality, we suggest MRA be performed to identify the Adamkiewicz artery. The noninvasive assessment of spinal cord blood supply in white TAAA patients is feasible with both CTA and MRA. Because the detection rate of MRA and image quality is superior to CTA, we conclude that MRA is the preferred modality in white TAAA patients.

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AUTHOR CONTRIBUTIONS

Conception and design: RJN, MJJ, JMVE, TL, WB
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