CT Angiography for Anterior Lumbar Spine Access

High Radiation Exposure and Low Clinical Relevance

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Abstract

Background Some spine surgeons perform CT angiography for detailed planning of anterior access to the lumbar spine. However, the value of this imaging method and its influence on surgeons' decisions are unclear.

Questions/purposes We determined (1) the dose of radiation used in preoperative CT angiography and (2) whether CT angiography affects planning of anterior lumbar spine surgeries.

Patients and Methods We assessed preoperative CT angiograms of 28 patients undergoing anterior spine surgery. The level of aortic bifurcation, iliac vein confluence, course of the ascending lumbar vein, central sacral vessels, and any vascular variation were mapped. We determined the effective dose of radiation and recorded whether the preoperative CT angiography influenced surgical planning.

Results We observed variations in the location of the aortic bifurcation and the iliac vein confluence. In 32% of patients, there were accessory renal arteries originating from the aorta; 7% had a rudimentary persistent left-sided

caval vein. The findings did not change the plan for surgery in any patient. We detected high organ radiation dosages (mSv) for the stomach (63 mSv), liver (58 mSv), urinary bladder (47 mSv), and colon (46 mSv); other high exposure dosages involved the lungs, bone marrow, ovaries, and uterus.

Conclusions About one in 1919 men and one in 2971 women undergoing CT angiography therefore are expected to have colon cancer develop, and one in 2781 men and one in 2856 women are expected to have cancer of the urinary bladder develop. CT angiography is of low value for preoperative planning for anterior access to the lumbar spine and should be avoided to prevent radiation-induced damage.

Level of Evidence Level II, diagnostic study.

Introduction

Use of anterior access to the lumbar spine has increased owing to modern surgical procedures such as implantation of disc prostheses or cages for segmental fusion. To prepare for the surgical procedure and reduce the risk of intraoperative complications, preoperative imaging is considered crucial [2, 13]. It is particularly important to consider the large vessels. There is a wide range of possible anatomic variants of vessels, making surgical access to the intervertebral disc difficult or even impossible, especially for levels L4/L5 [11, 14, 25]. For detailed planning of the surgical procedure, preoperative CT angiography with 3-D reconstruction can show the complex vascular anatomy. The most common and important variants are those of fusion and location of the kidneys. Horseshoe kidneys are located more caudally than normal kidneys, and with a frequency of 1:400, they are not rare [12]. They are

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accompanied by many venous and arterial variants that are located even more caudally than in normal kidneys [12]. Even more complicated are the situations in patients with caudally dystopic unfused kidneys [1, 8, 10].

If CT angiography reveals a possibly complicated vascular situation before surgery, this can be included in the patient's information and consent, and an alternative posterior procedure can be planned. A vascular surgeon can be asked for assistance, if one is not available routinely, and if the orthopaedic surgeon is not familiar with vascular complications. However, the value of this imaging method and its influence on surgeons' decisions are unknown. Also, as CT angiography exposes the patient to a high dosage of radiation, it is important to know whether the advantage of better imaging of the individual anatomy outweighs the risks of probable radiation-induced tissue damage.

We therefore (1) determined the anatomic variations and presence of atherosclerosis, (2) determined whether the findings from preoperative CT angiography influenced preoperative decision making, and (3) estimated the individual radiation exposure caused by the CT angiography.

Patients and Methods

We retrospectively studied all 28 patients who underwent anterior lumbar spine surgery at the L4/L5 levels or higher between November 2005 and December 2007. All patients had preoperative CT angiography. Nine patients were planned for disc arthroplasty, six patients received an anterior stand-alone fusion cage, and 13 patients received an anterior cage plus posterior fusion (Table 1). No patient had undergone prior anterior access surgery. Patients were screened for iodine allergy, diabetes mellitus, and creatinine levels.

Table 1. Surgical procedures

Surgical procedure	Levels	Number of patients
Cage	1	2
	2	3
	3	1
Disc arthroplasty	1	7
	2	1
Cage and dorsal fusion	1	4
	2	7
	3	1
Cage and disc arthroplasty	1 each	1
Cage and dorsal fusion + disc arthroplasty	2 + 1	1

All angiographies (LightSpeed™ 16-Slice MDCT, LightSpeed™ QXi 4-Slice MDCT, and LightSpeed VCT; General Electric, Milwaukee, WI) were assessed by two experienced radiologists. The level of aortic bifurcation, iliac vein confluence, course of the ascending lumbar vein and central sacral vessels, and any vascular variants were mapped. In addition, atherosclerotic disease and vascular aneurysms were recorded. Atherosclerotic disease has been classified as mild, moderate, or severe. Interobserver and intraobserver correlation coefficients were calculated [6, 18]. The interobserver correlations for the two raters were high. The ICC regarding the levels of arteries was 0.98. The ICC regarding the levels of veins was 0.99. The intraobserver correlations also were high for both raters (ICC = 1) regarding the levels of arteries and veins. The kappa statistics regarding variants revealed correlations of 0.92 (interobserver) and 1 (intraobserver).

We used automatic tube current modulation for optimizing the dosage [23]. As contrast medium, iodixanol 320 (Visipaque™; GE Healthcare, Cork, Ireland) was injected with a flow speed of 5 mL per minute (body weight in kg $\times$ 2 = contrast agent in mL). The beginning of scanning was triggered by bolus tracking (SmartPrep software; GE Healthcare).

The slices had a thickness of 1.25 mm. Pitches were between 1 and 1.3, and the noise ratio was lower than 20 in our cases. Two scans were performed, the first during the early arterial blood flow phase and the second during the venous blood flow phase. In a second step, coronal and sagittal images were reformatted from source images and multiplanar volume-rendering reconstructions.

The effective applied dosage of radiation per CT angiography and the individual dosage for different organs were estimated with the help of the CT-Expo program, Version 1.5 [22]. In this process, the scanned area and the affected organs were identified for every CT angiography performed and for every phase. Calculations were performed taking into account the individual tube voltage and current, time for a complete rotation, collimation, and pitch factor.

All surgery was performed via a median left-sided extraperitoneal approach; one surgeon (CB) performed all the surgeries. After a midline skin incision the posterior rectus sheath was exposed and incised in the lateral portion. The psoas muscle, retroperitoneal vessels, and left common iliac artery and vein were exposed. In all cases of L4/L5 disc approaches the ascending lumbar vein also was exposed. The left common iliac artery and the venous bifurcation are retracted from left to right to expose the L4/L5 disc space. Traction on the ascending lumbar vein was carefully observed. In 18 patients the ascending lumbar vein was ligated to prevent avulsion injury. A retractor system with blunt blades (Synframe; Synthes, Oberdorf,

Switzerland) was used for retraction of soft tissue structures and vessels in all patients.

All angiograms were analyzed preoperatively, independently, by two radiologists and the surgeon. The radiologists indicated the vessel variation on a print-out of the angiogram. Based on these findings the surgeon performing the approach decided if the vessel variations identified on the CT angiogram were clinically relevant (eg, change to a transperitoneal approach for better vessel exposure, consultation of a vascular surgeon to assist during the approach, abandon the anterior approach and perform a posterior procedure).

Estimation of the lifetime attributable risk (LAR) of cancer incidence and mortality of radiation-induced colon and bladder cancer for the individual patients was performed, assuming a linear correlation between the occurrence of tumors and the effective dosage even when it was less than 100 mSv, and assuming the equation of the effective equivalent dose in J/kg and the effective dose in J/kg using tabulated values [7] and the calculated dosage for the different organs.

Estimation of lifetime relative risk (RR) of radiation-induced colon and bladder cancer was performed according to the baseline lifetime risk (LR) estimates of cancer and mortality [7]. The formula for calculating the RR is $RR = (LAR + LR)/LR$; the formula for calculating the excess relative risk (ERR) is $ERR = (RR - 1.0) \times 100$ [7].

Results

The level of the aortic bifurcation was between L1 and L5. Aortic bifurcation occurred predominately at the L4 vertebral body in 17 patients (61%), at L5 in three patients (11%), at L3 and the level of discs L3/L4 and L4/L5 in two patients (7%) each, and in L1 in one patient (4%). The iliac vein confluence occurred mainly at the L5 vertebral body (67%) and at the L4 disc (18%) and the L4/L5 disc (18%). The central sacral artery was detected in 22 patients, being at level L4 in 15 patients (54%) and at level L3 in six patients (21%). In one patient, the artery was found at the L3/L4 disc. In nine patients (32%), there were accessory renal arteries originating from the aorta (Fig. 1). Two patients (7%) had a rudimentary persistent left-sided caval vein. One patient had a connection between the ascending lumbar vein on the left side and the renal vein. In one patient, a right-sided additional internal iliac vein led to the left iliac vein at level L5 (Fig. 2). The course of the ascending lumbar veins did not show any variants. Six patients (21%) had atherosclerotic disease, with two patients having severe disease, three having moderate disease, and one having mild disease. One patient had elongation of the iliac vein, one patient had an aneurysm,

Fig. 1 The preoperative CT angiography of the prevertebral arteries shows an additional right-sided renal artery originating from the iliac artery at level L4.

Fig. 2 The preoperative CT angiography of the prevertebral arteries and veins shows an additional right-sided internal iliac vein flowing into the left iliac vein at level L5.

and two patients had ectasia of the abdominal aorta. One patient had moderate stenosis of the external iliac vein and one had hemangioma of the liver. No additional pathologic findings were revealed by the CT scans. Most of the vessel variations were clinically irrelevant because they were located outside the approach channel (eg, right-sided additional internal iliac vein or accessory renal arteries

Table 2. Applied dosage of radiation caused by CT angiography

Organ	Dosage (mSv)
Stomach	63.4 ± 24.6
Liver	58.1 ± 22.1
Urinary bladder	47.7 ± 38.7
Colon	46.1 ± 31.3
Lungs	17.4 ± 11.6
Bone marrow	27.4 ± 15.3
Ovaries	23.3 ± 29.6
Uterus	22.2 ± 28.4
Testicles	< 32.8
Mammae	< 23.4

Values are expressed as mean ± SD.

originating from the aorta). Only the rudimentary persistent left-sided caval vein was surgically relevant resulting in longer preparation and access time without causing vessel injuries.

The anterior access could be performed as planned preoperatively in all patients. The preoperative findings of the CT angiography did not influence decision-making for the planned procedure for any of the patients. However, in all cases, the printed images of the 3-D CT angiogram indicating the specific vessel variations were present in the operating theatre to provide the surgeon with additional information regarding the specific vessel situation. During surgery the vessels were exposed in a standard fashion and the variations identified on the angiograms were confirmed as far as they were located in the operating field of the approach.

The effective dosage of a CT angiography was 34.1 ± 16.5 mSv on average (range, 8.8–53.5 mSv). High organ dosages were detected particularly for the stomach, liver, urinary bladder, and colon (Table 2). We observed high exposure rates for the lungs, bone marrow, ovaries, and uterus. In some cases, the testicles were radiated with as much as 32.8 mSv, and the breasts with as much as 23.4 mSv per CT angiography.

Four patients had postoperative complications (14%): two had superficial wound infections and two had postoperative bleeding. A left retroperitoneal hematoma in one patient with factor 13 deficiency necessitated a revision procedure with removal of the hematoma. No active bleeding could be detected. The second case of postoperative bleeding involved the left inferior epigastric artery, which was treated by embolization.

Discussion

Prior studies suggest the necessity of preoperative planning using MRI [15] or CT [8] to reduce surgical risks.

Preoperative CT angiography has become a frequently used procedure before anterior access surgery to detect probable anatomic variations that might be a challenge for the surgeon [8, 9, 15]. Spine surgeons with experience in abdominal interventions may not use preoperative CT angiography as frequently as spine surgeons without this experience, however, owing to certain, rather common variants of the vessels, surgery of the lumbar spine may emerge as very difficult, or even impossible, and CTA is the preferred method to show these variants [12]. Depending on local circumstances, CT or MRI is used for preoperative imaging. The choice of the method depends mainly on cost. In some countries, modern MD-CT or MRI scanners are not available to the treating physicians. We therefore (1) determined the anatomic variations and presence of atherosclerosis, (2) determined whether the findings from preoperative CT angiography influenced preoperative decision making, and (3) estimated the individual radiation exposure caused by the CT angiography.

We raise two issues about our study, regarding first the exposure to radiation, and second the rapid evolution of scan technology, which overhauled in part the technique used here. First, precisely identifying prevertebral vascular anatomy can be difficult on axial MRI, with only 86% accuracy in predicting intraoperative findings [15]. For patients who have had prior anterior access surgery, the anatomy can differ from normal findings. Therefore, we investigated our patients by CT angiography. CT angiography is performed commonly for evaluation of vascular diseases such as aneurysms, atherosclerotic disease, and pulmonary embolisms, and for detection of substantial vascular variants of the arterial and the venous system, which could be important in planning surgical access [21, 26]. By choosing the CT, the patients were exposed to radiation. This disadvantage could have been worsened by using a large primary field in all patients. The main reason for including the liver and basal parts of the lungs or testicles in the primary field was the surgeon's request for abdominal angiography without restricting the field to a particular location. Incomplete or missing information from the surgeon may have a strong influence on the patients' radiation exposure. Another reason for choosing primary fields that are too large could be the radiologists' concern about cutting off important regions or lack of experience in choosing the correct dosage of electric current, voltage, or timing for application of the contrast medium. Second, there are rapid evolutions in the efficacy and technical nature of CT scanners, and similar rapid advances in MR technology, which are rendering lower-doses from CT and more rapid, accurate, and detailed imaging from MR. Our data in a sense represent one imaging technique and equipment, and cannot be generalized to all current or emerging CT equipment and techniques. However, CT still is a source of radiation

Table 3. Estimated lifetime risk for cancer caused by CT angiography

Organ	Lifetime attributable risk incidence*	Lifetime attributable risk mortality†	Lifetime relative risk	Excess relative risk
Colon	52.093 (male)	26.277 (male)	1.0124031 (male)	1.24% (male)
	33.653 (female)	16.135 (female)	1.0080126 (female)	0.80% (female)
Urinary bladder	35.948 (male)	8.041 (male)	1.01057 (male)	1.06% (male)
	35.002 (female)	10.406 (female)	1.03182 (female)	3.182% (female)

* Number of estimated additional cases of a specific disease per 100,000; † number of estimated additional deaths from a specific disease per 100,000.

exposure, even though modern scanners are capable of producing acceptable pictures with lower radiation exposure [4, 16].

There are several limitations of the study which should be addressed. First, the retrospective design of the study may entail an uncontrollable risk of the occurrence of bias owing to bad documentation and confounding associations among different variables. We deem this risk to be low because the documentation of the CT angiographies is complete and the surgeon noted all peculiarities regarding preoperative examinations and the course of the operations. Therefore, an underestimation of the significance of the preoperative CT angiography appears unlikely in the current study. Second, the presence of rare variations or anatomic situations, which did not occur in our study group, eg, an inverse situs, a left-sided caval vein without a right-sided caval vein, or pelvic kidneys on both sides, may cause very severe technical problems in special cases. These situations can be depicted accurately using CT-angiography preoperatively. Though we do not know such a case from our experience, it seems to be obvious that imaging may change the operative procedure. However, these instances can be diagnosed using other diagnostic measures, or may be known preoperatively, so that the CT-angiography may be indicated individually. Therefore, the CT-angiography seems not to be useless in selected cases.

In all 28 patients, the procedure was performed exactly as planned. Despite many anatomic variants, anterior access to the spine was possible without causing serious intraoperative complications. This is in contrast to prior reports on the topic. Datta et al. [8] reported a considerable influence on the surgical plan in 21% of patients, related to deformity, vascular anatomy, and anomalies, which is in contrast to our findings.

We found a substantial radiation exposure risk in our patients, which seems relevant especially for younger patients undergoing total disc arthroplasty. The younger a patient is at the time of CT [8], the higher the sensitivity to radiation and therefore the probability of having radiation-induced diseases develop, and with the increase in life expectancy, the risk of contracting a radiation-induced cancer also increases [7]. There are more serious risks than

we previously presumed [16]. However, uncertainties remain regarding which effects result from which dosage. Much information regarding the risk for radiation-induced tumors was obtained from observations and studies of victims of the atomic bombs of Hiroshima and Nagasaki [7] and from the 15-Country Collaborative Study of Cancer Risk Among Radiation Workers [5]. The main part of our knowledge regarding the risk of radiation-induced diseases derives from these two reports. One subgroup of survivors of the atomic bomb victims got an effective radiation dosage comparable to that of our patients (mean, 40 mSv; range, 5–150 mSv), leading to a measurable increase in the frequency of malignancies [3, 4, 17, 19, 20]. It should be taken into account that the applied dosage is comparable in both situations, but not the possible effect, as atomic bomb explosions produce gamma radiation of approximately 3 MeV, compared with 120 to 140 kV with CT angiography. Owing to this difference, the risk for having cancer develop that is induced by diagnostic radiographs is estimated to be two- to threefold greater as compared with the risk from the same radiation dosage with radiation of approximately 3 MeV [7]. The average dosage in radiation workers is 20 mSv [23]. Even in this population, a correlation between mortality from cancer and radiation dosage could be observed clearly. It is remarkable that 20 mSv is lower compared with most of the exposure to our patients with CT angiography. Therefore, the dosage of radiation must be considered in light of subsequent diseases that could develop. We estimated about one in 1920 men and one in 2972 women having CT angiography are expected to have colon cancer develop, whereas about one in 3806 investigated men and one in 6198 women would die from colon cancer (Table 3). One in 2782 men and one in 2857 women having CT angiography would be expected to have cancer of the urinary bladder develop, and one in 12,436 men and one in 9610 women would die from urinary bladder cancer.

The advantages of better knowledge of a patient's anatomy must be balanced with the disadvantages of the method, such as high radiation exposure and side effects of the contrast medium. CT angiography revealed a substantial number of vascular variations and abnormalities,

however, it had no influence on the surgical decision making. Patients did receive a high dosage of radiation, which can substantially increase the risk of malignancies. The indication for diagnostic methods with radiation exposure must be made considering each patient's individual situation, taking into account the patient's age, gender, and severity of symptoms [24]. In addition, the technical settings of the CT scanners must be regulated individually to prevent patients from having severe side effects.

References

- Aljabri B, MacDonald PS, Satin R, Stein LS, Obrand DI, Steinmetz OK. Incidence of major venous and renal anomalies relevant to aortoiliac surgery as demonstrated by computed tomography. *Ann Vasc Surg.* 2001;15:615–618.
- Barker R, Fareedi S, Thompson D, Saunders D. The use of CT angiography in the preoperative planning of cervical spine surgery in children. *Childs Nerv Syst.* 2009;25:955–959.
- Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. *AJR Am J Roentgenol.* 2001;176:289–296.
- Brenner DJ, Hall EJ. Computed tomography: an increasing source of radiation exposure. *N Engl J Med.* 2007;357:2277–2284.
- Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, Howe G, Kaldor J, Muirhead CR, Schubauer-Berigan M, Yoshimura T, Bermann F, Cowper G, Fix J, Hacker C, Heinmiller B, Marshall M, Thierry-Chef I, Utterback D, Ahn YO, Amoros E, Ashmore P, Auvinen A, Bae JM, Bernar J, Biau A, Combalot E, Deboodt P, Diez Sacristan A, Eklöf M, Engels H, Engholm G, Gulis G, Habib RR, Holan K, Hyvonen H, Kerekes A, Kurtinaitis J, Malke H, Martuzzi M, Mastauskas A, Monnet A, Moser M, Pearce MS, Richardson DB, Rodriguez-Artalejo F, Rogel A, Tardy H, Telle-Lamberton M, Turai I, Usel M, Veress K. The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: estimates of radiation-related cancer risks. *Radiat Res.* 2007;167:396–416.
- Cohen J. A coefficient of agreement for nominal scales. *Educ Psych Meas.* 1960;20:37–46.
- Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, National Research Council. *Health Risks From Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2.* Washington, DC: The National Academies Press; 2006.
- Datta JC, Janssen ME, Beckham R, Ponce C. The use of computed tomography angiography to define the prevertebral vascular anatomy prior to anterior lumbar procedures. *Spine (Phila Pa 1976).* 2007;32:113–119.
- Ebraheim NA, Xu R, Farooq A, Yeasting RA. The quantitative anatomy of the iliac vessels and their relation to anterior lumbosacral approach. *J Spinal Disord.* 1996;9:414–417.
- Faggioli G, Freyrie A, Pilato A, Ferri M, Curti T, Paragona O, D'Addato M. Renal anomalies in aortic surgery: contemporary results. *Surgery.* 2003;133:641–646.
- Garg J, Woo K, Hirsch J, Bruffey JD, Dilley RB. Vascular complications of exposure for anterior lumbar interbody fusion. *J Vasc Surg.* 2010;51:946–950; discussion 950.
- Glodny B, Petersen J, Hofmann KJ, Schenk C, Herwig R, Trieb T, Koppelstaetter C, Steingruber I, Rehder P. Kidney fusion anomalies revisited: clinical and radiological analysis of 209 cases of crossed fused ectopia and horseshoe kidney. *BJU Int.* 2009;103:224–235.
- Jamali AA. Digital templating and preoperative deformity analysis with standard imaging software. *Clin Orthop Relat Res.* 2009;467:2695–2704.
- Jarrett CD, Heller JG, Tsai L. Anterior exposure of the lumbar spine with and without an “access surgeon”: morbidity analysis of 265 consecutive cases. *J Spinal Disord Tech.* 2009;22:559–564.
- Kleeman TJ, Michael Ahn U, Clutterbuck WB, Campbell CJ, Talbot-Kleeman A. Laparoscopic anterior lumbar interbody fusion at L4–L5: an anatomic evaluation and approach classification. *Spine (Phila Pa 1976).* 2002;27:1390–1395.
- Mahesh M. *MDCT Physics: The Basics Technology, Image Quality and Radiation Dose.* Philadelphia, PA: Lippincott Williams & Wilkins; 2009.
- Pierce DA, Preston DL. Radiation-related cancer risks at low doses among atomic bomb survivors. *Radiat Res.* 2000;154:178–186.
- Portney LG, Watkins MP. Statistical measures in reliability. In: Portney LG, Watkins MP, eds. *Foundations of Clinical Research: Applications to Practice.* Norwalk, CT: Appleton & Lange; 1993:505–528.
- Preston DL, Ron E, Tokuoka S, Funamoto S, Nishi N, Soda M, Mabuchi K, Kodama K. Solid cancer incidence in atomic bomb survivors: 1958–1998. *Radiat Res.* 2007;168:1–64.
- Preston DL, Shimizu Y, Pierce DA, Suyama A, Mabuchi K. Studies of mortality of atomic bomb survivors. Report 13: solid cancer and noncancer disease mortality: 1950–1997. *Radiat Res.* 2003;160:381–407.
- Schmermund A, Magedanz A, Voigtländer T. The role of CT angiography in risk stratification for atherosclerosis. *Curr Atheroscler Rep.* 2009;11:111–117.
- Stamm G, Nagel HD. [CT-expo-a novel program for dose evaluation in CT] [in German]. *Rofo.* 2002;174:1570–1576.
- Tack D, De Maertelaer V, Gevenois PA. Dose reduction in multidetector CT using attenuation-based online tube current modulation. *AJR Am J Roentgenol.* 2003;181:331–334.
- The Alliance for Radiation Safety in Pediatric Imaging. Image gently: image gently and CT scans. Available at: www.pedrad.org/associations/5364/ig/index.cfm?page=614. Accessed July 22, 2010.
- Wood KB, Devine J, Fischer D, Dettori JR, Janssen M. Vascular injury in elective anterior lumbosacral surgery. *Spine (Phila Pa 1976).* 2010;35:66–75.
- Zimmet JM, Miller JM. Coronary artery CTA: imaging of atherosclerosis in the coronary arteries and reporting of coronary artery CTA findings. *Tech Vasc Interv Radiol.* 2006;9:218–226.