SPINE Volume 32, Number 1, pp 113–119

The Use of Computed Tomography Angiography to Define the Prevertebral Vascular Anatomy Prior to Anterior Lumbar Procedures

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Study Design. Prospective cohort.

Objective. To determine the efficacy of a single-slice computed tomography (CT) angiogram to define the prevertebral anatomy in patients undergoing an anterior lumbar spine procedure.

Summary of Background Data. Preoperative planning with precise prevertebral anatomic details can help in mini-open anterior lumbar approaches.

Methods. A total of 76 consecutive patients undergoing a minimal incision approach for anterior lumbar surgery were evaluated before surgery with CT angiography. The prevertebral anatomy was documented, and the patients were observed during treatment.

Results. There were no complications related to CT angiography. This study directly influenced surgical decision making and the treatment options in 21% of patients. The vena caval confluence limited access to the L5–S1 disc in 3% of patients and at the L4–L5 disc in 92% of the patients. Prevertebral anatomic anomalies were found in 11.8% of patients. Atherosclerotic disease was discovered in 17% of the patients. The major complication rate was 7.5%. CT angiography correlated with intraoperative vascular anatomy in all cases.

Conclusion. Preoperative CT angiography before anterior approaches was determined to be effective in evaluating the prevertebral vascular anatomy.

Key words: computed tomographic angiography, anterior lumbar surgery, lumbar disc replacement, anterior lumbar fusion, lumbar disc revision, prevertebral anatomy. **Spine 2007;32:113–119**

The oldest written document still in existence describing anatomic structures is an Egyptian papyrus believed to be written around 1600 BC. However, Hippocrates (400 BC) is credited as the creator of the science of anatomy. Although our anatomic knowledge has vastly improved since the time of Hippocrates, our definement of the prevertebral surgical anatomy has only been slightly improved on in recent textbooks. Each individual has subtle variations that can present significant surgical challenges. The anatomy described in books is simply the ideal positioning and size.[1] Variants of the human internal anatomy can be dramatic and cause serious health issues in the surgical field.

As spine surgery evolves, anterior access to the lumbar spine becomes more prevalent in our practices. Surgical anatomy textbooks describe the aortic bifurcation to be at the left side of the fourth lumbar vertebral body and the confluence of the common iliac veins to be at the right side of the fifth lumbar vertebral body.[1] Unnoticed anatomic variations can add additional risks in the setting of minimal access surgery that make preoperative planning more essential. Large incision approaches allow for a good view of the great vessels and the ability to work around previously unrecognized aberrancies in the anatomy. Smaller incisions or "mini-open" approaches and laparoscopic techniques are more favorable for patient pain, recovery, and cosmesis. Unfortunately, these approaches limit the ability to adapt easily to anatomic challenges that some patients present. Complications as a result of an anterior approach are infrequent but include bowel injury, ureteral injury, epidural hematoma, disc herniation, retrograde ejaculation, and large vessel injury.[2–8]

Computed tomography (CT) angiography is commonly used to identify pulmonary embolisms, visualize blood flow in the renal arteries, detect aneurysms, and identify arthrosclerotic disease. CT angiography procedures are performed routinely in the United States for the evaluation of vascular disease. It can be a powerful tool in our preoperative planning for anterior spine surgery by mapping the aortic bifurcation and iliac vein confluence. The anatomic positioning of the aortic bifurcation and iliac vein confluence is described to be anterior to the L4 and L5 vertebral bodies, respectively, with near perfect alignment to each other. However, deviations in this anatomy are very common (Figure 1).

Many authors that perform anterior laparoscopic and minimal incision procedures have already shown the significant difficulty and morbidity the anatomic relationships of the prevertebral vascular structures pose to the surgeon.[4,9,10] This study's goal was to review prospectively a consecutive series of patients that underwent CT angiography before minimal incision anterior spinal surgery and its ability to define effectively each patient's vascular relationships to the anterior spine. These additional data could then be analyzed prospectively to determine if the cost, morbidity of the CT angiography, and the influence on preoperative planning justify its routine use in the minimal anterior access setting.

From the Spine Education Research Institute, Denver, CO.
Acknowledgment date: February 20, 2006. First revision date: March 13, 2006. Second revision date: March 16, 2006. Acceptance date: March 17, 2006.
The manuscript submitted does not contain information about medical device(s)/drug(s).
No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.
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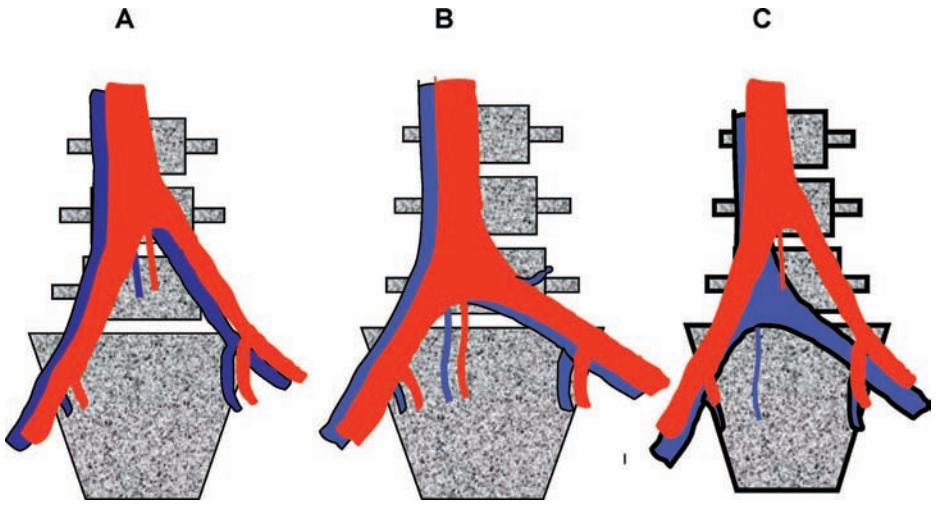

Figure 1. Typical anatomical positioning of the aortic bifurcation (red) and iliac vein confluence (blue). The first drawing (**A**) is considered normal, the second positioning (**B**) is lower than normal, and the last (**C**) depicts the great vessels not aligned.

■ Methods

Seventy-six consecutive patients requiring anterior lumbar surgery, either a disc replacement or arthrodesis, between June 2004 and March 2005 underwent CT angiography before surgery. Patients were screened for iodine allergy, diabetes mellitus, and normal blood urea nitrogen and creatinine levels.

Helical CT scans were taken from the upper abdomen to the pelvis at 0.7 seconds per rotation to collect anterior-posterior and lateral views. Similar to nonhelical CT scans, the machine operated at approximately 300 mAs (range 280–440) and 120 KV (range 100–140). A contrast medium consisting of Omnipaque 300 (125 cc; Amersham Health, Buckinghamshire, UK) and a saline flush (25 cc) at 4.0cc/second were administered intravenously during the evaluation. Optimal settings of the CT were determined to be: pitch 1.375:1; speed 13.75; thickness 2.5 mm; and interval 2.55. Scans were collected at 20 and 115 seconds to obtain visual mapping of the arterial and venous blood flow. Three-dimensional data reconstructions were rendered to develop spatial resolution of the vascular structures (Figure 2).

The scans obtained mapped the level of aortic bifurcation and iliac vein confluence, as well as any atypical vascular orientation. The presence of atherosclerotic disease and retroperitoneal adenopathy were recorded. Atherosclerotic disease was characterized as mild, moderate, or severe (Figure 3). Significant vascular aneurysms were documented and referred to a vascular specialist for evaluation. Intraoperative and postoperative complications were recorded as the patient was cared for.

Accessibility of the L3–L4, L4–L5, and the L5–S1 discs in relation to the aortic bifurcation and common iliac vein confluence were determined for each patient (Figure 3). For the disc to be accessible, the central portion and adjacent 30% of the disc width should be uncovered by overlying vessel.[10] This central access to the disc space is critical for proper placement of a disc replacement prosthesis or a central bone graft. The surgeon evaluated the scan and determined if the "mini" anterior approach was suitable for the patient, and if the preoperative plan at the levels in question would be altered by the CT angiography.

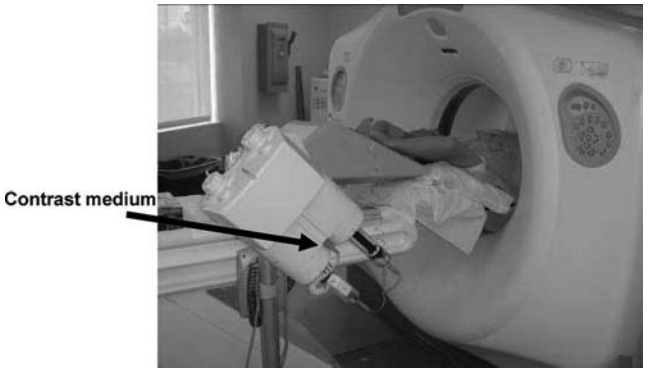

Figure 2. Patient positioning and contrast medium administration for CT angiography.

■ Results

The patients in this series were planned for anterior lumbar surgery before this assessment by CT angiography. Of the 76 patients, 44 were offered total disc replacement surgery. Twenty-two patients were set up for an arthrodesis, and the remaining 10 had not determined the type of surgery to undergo. Fifty-three of the patients went on to have the preplanned surgery, 44 arthroplasties and 9 anterior fusions.

Incidental findings consisted of one patient with a renal mass subsequently identified as a renal cell carcinoma, surgery was cancelled for medical intervention. Two patients each were found to have previously undocumented ovarian masses and renal cysts, respectively. An enlarged prostate, liver hemangioma, gallstones, and diverticulosis were seen in individual patients.

Prevertebral anatomic anomalies were found in 11.8% (9 of 76) patients scanned. Vascular anomalies consisted of 2 large centrally placed sacral arteries, 4 tortuous vessels, one left retroaortic renal artery at the level of surgery, and one duplicate left iliac vein. Significant prevertebral lymphadenopathy at the operative level was detected in one patient.

Thirteen patients (17%) were determined to have atherosclerotic disease, with one patient being described as severe, one as moderate, and 11 as mild (Figure 3).

Figure 3. Characterization of atherosclerotic disease.

The level of the aortic bifurcation (Figure 4) and iliac vein confluence (Figure 5) were described from L3 to S1. Aortic bifurcation occurred predominately at the L4 vertebral body in 39 of 76 patients (52%). The bifurcation was at or cephalad to the L4 body in 69 of 76 patients (92%). Iliac vein confluence occurred mainly at the L4–L5 vertebral disc in 36 of 76 patients (48%). The vein confluence began at the L5 vertebral body level in another 26 of 76 patients (35%). Mapping showed the variations in the positioning and congruency of the vessels (Figure 6). The position and condition of the great vessels were evaluated and determined during surgical approach, and all correlated well with preoperative CT angiography.

The ease of access to the disc space between the aortic bifurcation and vein confluence was determined for each level. Ease of access for a disc space was defined as the central one third of the disc space that was free of vessel coverage so it could be accessed without significant vessel retraction.[10] This evaluation will allow determination of the amount of lateral dissection needed and retraction for proper access to the center of the disc space required for total disc prosthesis placement and anterior interbody grafting. Uniformly, the L5–S1 allowed the easiest access with minimal dissection and retraction. The aortic bifurcation allowed access to the L5–S1 disc space in 100% of our patients. The only limitations to L5–S1 were by the vein confluence or a large aberrant left iliac vein seen in 7% of patients. The L4–L5 disc level access was limited by the arterial anatomy in 33% of patients and by the venous anatomy in 92% of patients (Figure 7). In only one patient was there a high enough bifurcation to allow access to the L3–L4 disc space but was limited by the venous confluence.

The operating and access surgeon performed planning. Of patients, 21% (16 of 76) were determined to have alterations or significant aid to presurgical planning. In 5 patients, it was determined that anterior lumbar plating was not an option because of vessel position. Two patients had scoliotic deformities that altered relationships of the prevertebral anatomy (Figure 8). In these cases, moving to the right side of the prevertebral vasculature to approach the apex vertebra and a slightly larger vertically orientated incision was used. Two patients had previous anterior surgery with scarring of the vessels, and the scan confirmed the correct position of the vessels for the approach surgeon. One of these patients had an anteriorly displaced disc prosthesis against the patient's ureter. This required the preoperative placement of a ureteral stent to help prevent injury. Variations in the

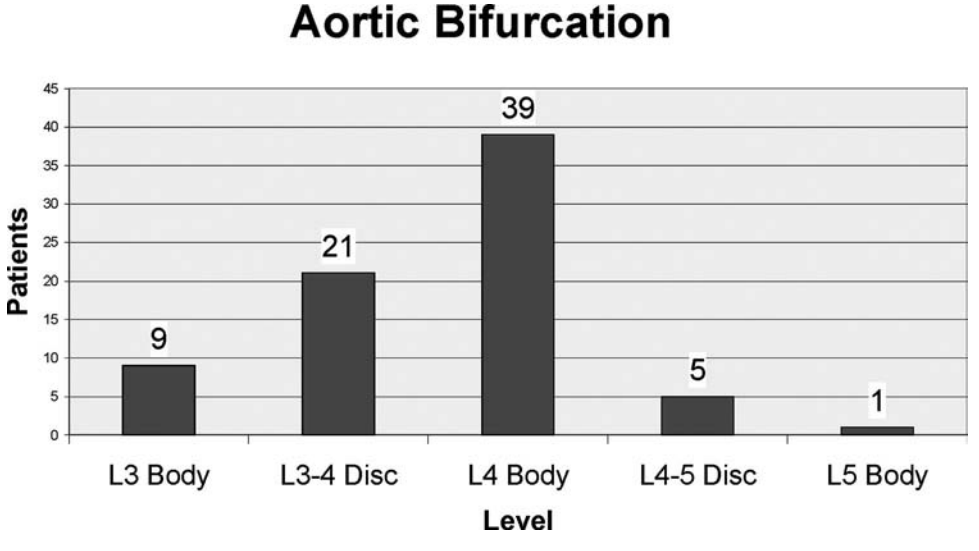

Figure 4. Level of aortic bifurcation.

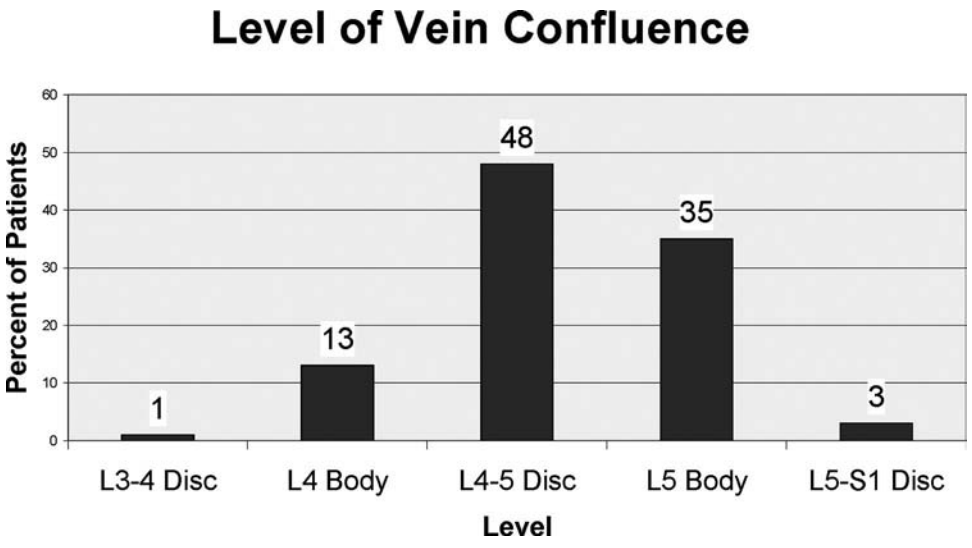

Figure 5. Level of iliac vein confluence.

vascular anatomy affected the preoperative plans. Severe atherosclerosis at the affected level caused the patient to refuse surgery after discussing the risk of tears with vessel retraction. A large central sacral artery required ligation because of the position over the operative level of L5–S1. Four large oblique left iliac veins covering the disc space required an approach between the iliac artery and vein (Figure 6D). One patient had a left retro-aortic renal vein at the approach level that was protected during the case. This anomaly can be disastrous if the vein is avulsed with unknowing vigorous retraction because its posterior position makes repair extremely difficult. Significant lymphadenopathy was seen at the involved disc space in one patient that limited a more lateral approach to the L3–L4 level, requiring a more direct anterior approach and interbody fusion, instead of the traditional more lateral approach to this space.

Thirteen patients were morbidly obese. The approach surgeon felt that the CT angiography confirming the position of the prevertebral vascular anatomy allowed him more confidence in recommending a "mini" open anterior surgery for the patient. No patient underwent a formal open procedure after CT angiography review before surgery.

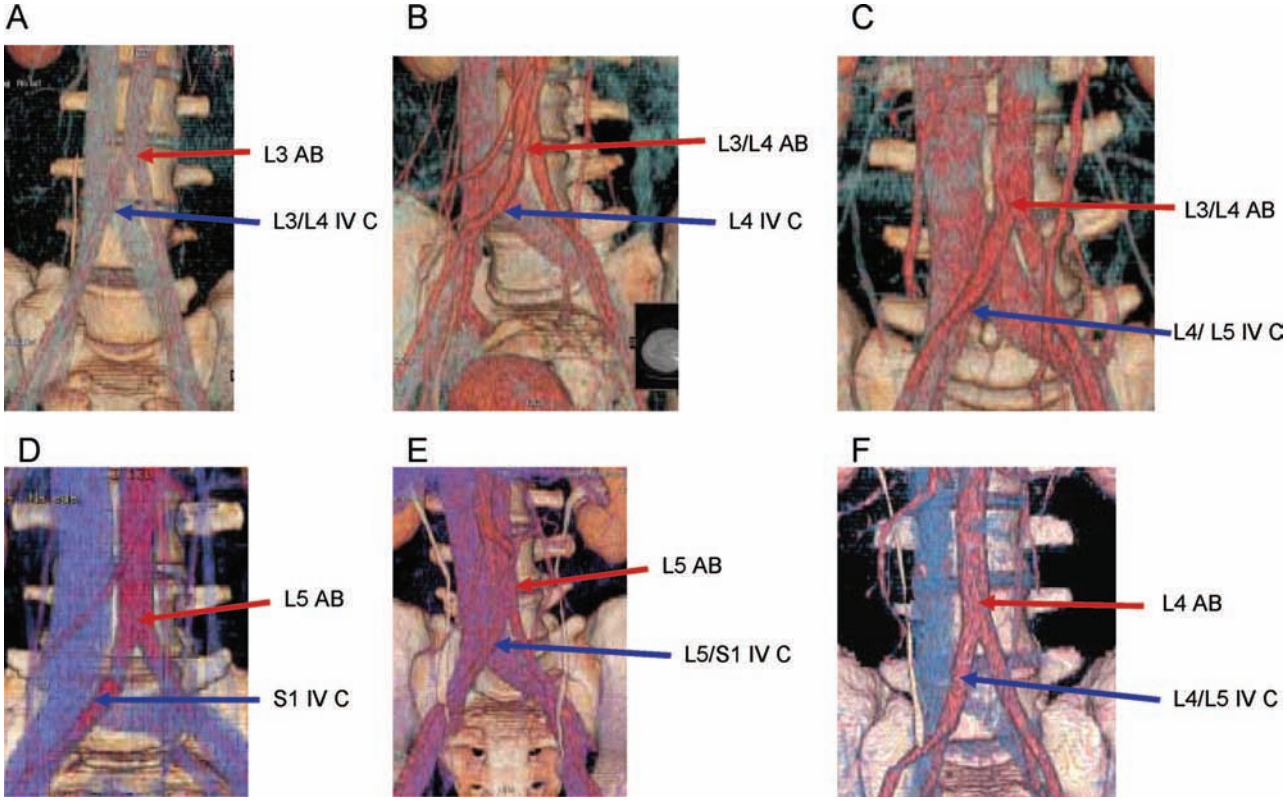

Figure 6. Representative CT angiography mappings of patients in series showing aortic bifurcation (AB) and iliac vein confluence (IV C).

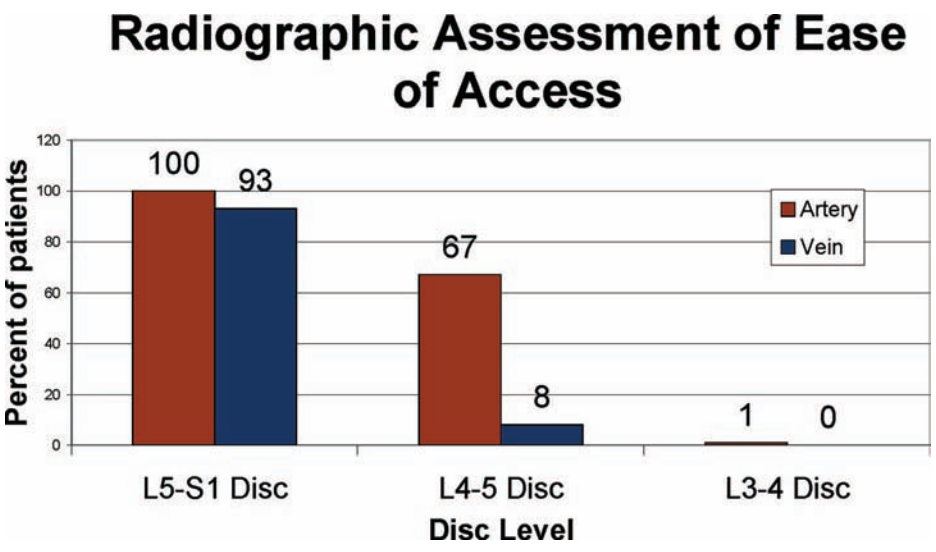

Figure 7. Ease of access for each level in regards to the bifurcation and confluence. Ease of access is determined by evaluating if the disc space's central one third is accessible without significant retraction.

Complications were seen in 21% (11 of 53) of the patients operated on. There were 2 venous tears and no arterial injuries, resulting in a vascular complication rate of 3.8%. Two patients had persistent incisional pain >2 weeks and resolved by 6–8 weeks. One patient each had a wound dehiscence and superficial infection. The remaining complications included a retroperitoneal hematoma requiring readmission, peritoneal sac tear with repair, retrograde ejaculation, erectile dysfunction, and bipedal edema. There were no incidences of deep venous thrombosis, arterial thrombosis, bowel injuries, or compartment syndromes.

None of the patients operated on were converted from a "mini" open approach to a formal open incision. All vessel injuries were directly repaired through the original incision.

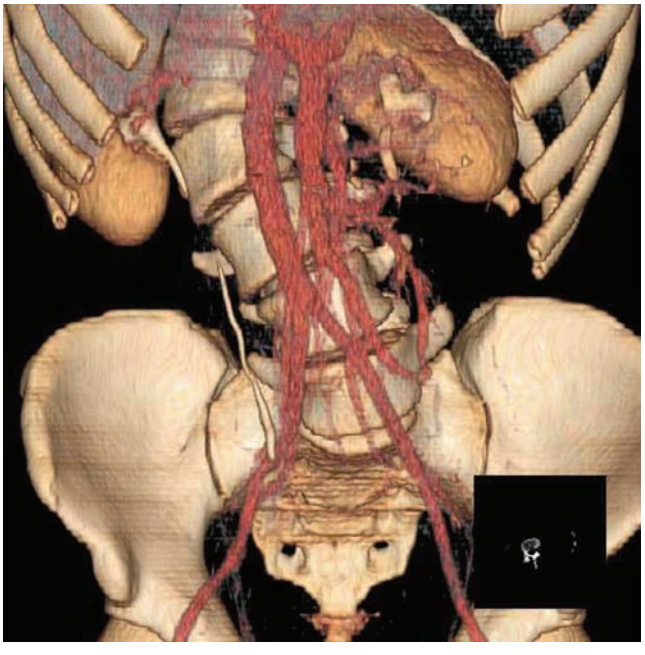

Figure 8. CT angiography in a patient with scoliosis.

■ Discussion

Precise anterior mobilization of the vessels is essential to anterior lumbar spine surgery. However, only 8% of patients were found to have "ideal" positioning of at least one of their great vessels for easy surgical approach to the center portion of the L4–L5 disc space required for proper placement of a total disc replacement or anterior bone graft.[10] Most patients, therefore, had slight variations from the described anatomy, possibly elevating their risk assessment for anterior surgery. The aortic bifurcation was found to be at the level of the L3–L4 disc and L4 vertebral body in 80% of patients, and only 8% being distal to the L4 level. The bifurcation in most patients did not block access. The venous confluence was found to be at the L4 vertebral body or L4–L5 disc in 82% of patients, which placed a significant challenge to access of this level in 92% of our patients. This finding was higher than that of Vraney *et al*,[10] who found that the venous anatomy blocked anterior central access to the L4–L5 disc in only 27% of patients, but their study looked at only 22 patients with venograms for unrelated conditions. Although the ease of access radiographic ratings were the same in both studies, the block to access in our study was greater. The number of patients was greater in this study, and the scans allowed us to evaluate venous and arterial anatomy in one study, and only in patients being considered for anterior surgery.

The L4–L5 level is usually covered by the prevertebral vasculature, and for this reason, we found that the CT angiography helped determine our strategy for vessel mobilization to access the central portion of the disc that is necessary to place properly a disc prosthesis or anterior graft; Figure 9 demonstrates the ideal visualization of the disc space. In Figure 6A, an approach would be best between the right and left iliac veins and arteries. The anatomy in Figure 6D would require an approach between the left iliac vein and the left iliac artery. The anatomy in Figure 6F would approach L4–L5, the best

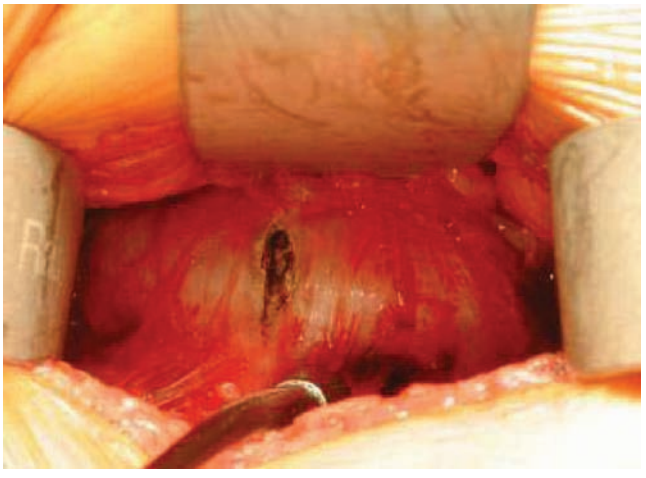

Figure 9. Proper anterior visualization of the disc space required for disc replacement surgery. The center of the disc has been marked with cautery.

by dissecting lateral to both the left iliac vein and artery.

There was a significant influence on the surgical plan in 21% of patients evaluated in this study related to deformity, vascular anatomy and anomalies, and a displaced arthroplasty. The direct association between adequate exposure and rate of overall major complications were found in 16% of patients evaluated by Zdeblick and David[8] in a study comparing laparoscopic and mini-anterior exposures. Our overall major intraoperative complication rate during mini-open surgery, which included vascular injury, retrograde ejaculation, and retroperitoneal hematoma, was only 7.5%. The overall complication rate in our study was 21%.

The current study had 2 venous tears, resulting in a vascular complication rate of 3.9%. This was at the lower end of rates reported for minimally invasive anterior approaches to the spine, which ranged from 1.4% to 7.7%.[2–8] Interestingly, both injuries occurred during the placement of an anterior plate to the lumbar spine. This may be related to increased manipulation of the vessels required for the proper placement of the plate and application of the screws compared to uninstrumented arthrodesis or disc replacement surgery.

As we move toward smaller incisions and mini-open approaches, it becomes more challenging to identify intraoperatively vascular orientation. Retraction of the vessels always leaves the patient vulnerable to tears and avulsions. Preoperative planning to reduce surgical risks becomes more vital. Kleeman *et al*[4] showed the need for preoperative planning by evaluating the prevertebral vascular anatomy using preoperative magnetic resonance imaging (MRI). This study found that having to dissect lateral to the iliac vessels increased the rate of retrograde ejaculation. Knowing the position of the vessels could help lower other complications by having a good preoperative plan, especially at the L4–L5 disc level. The only problem is that the MRI only showed an 86% accuracy in predicting intraoperative findings. The vascular anatomy in the current study correlated with preoperative CT angiography in all 53 patients operated on. It can be very difficult on axial MRI to define the prevertebral vascular anatomy precisely. The advantages of preoperative CT angiography for planning include one sheet with a single 3-dimensional representation of the anatomy that is easily read by the average spinal and approach vascular surgeons. The scan can be placed on the view box and reviewed during the case without difficulty. The disadvantage of this study is that smaller soft tissue structures, such as the sympathetic trunk, are not well visualized with the current technology. CT angiography offers a potential solution to help reduce risks associated with complex vascular anatomy and other prevertebral anatomy by simply and effectively evaluating these structures before surgery.

This imaging was beneficial in the patient with an anteriorly extruded disc prosthesis. This study demonstrated the prosthesis' position behind the prevertebral vascular structures and facilitated accurate preoperative planning for mobilization. The CT angiography was better than MRI at demonstrating that there were no large vertebral body defects and no anteriorly displaced boney fragments. The CT angiography showed less artifact distortion of the surrounding anatomy, better boney architecture evaluation, and the ability to evaluate more of the prevertebral anatomy than MRI. This patient required placement of a ureteral stent before surgery because of the close proximity of the extruded disc prosthesis. The CT angiography for this patient is shown in Figure 10; note the absence of ureteral fill distal to the prosthesis and dilatation of the proximal portion. This was not seen on the preoperative MRI. This imaging modality, in the future, may prove to be an essential imaging modality in

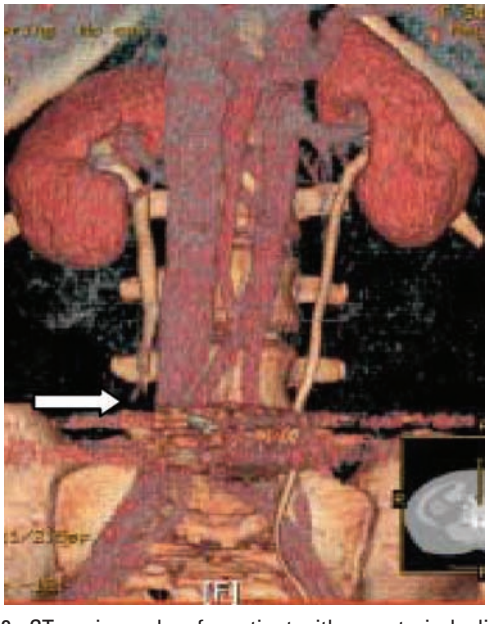

Figure 10. CT angiography of a patient with an anteriorly displaced disc prosthesis. Note the loss of distal fill (arrow) of the right ureter and proximal dilation from compression from the prosthesis.

this subset of patients as more experience with these cases are reported and future CT software is able to suppress metallic artifact more effectively.

The cost of this procedure will vary from institution to institution but is commonly covered by insurance and Medicare; at our institution, the total cost was between $800 and $1000. We believe that the value of this test for planning can counter the monetary cost in certain cases.

This study demonstrates that this technology accurately and efficiently defines the prevertebral vascular anatomy in patients considered for anterior lumbar surgery. The L4–L5 disc level in the majority of patients requires vessel mobilization, and CT angiography allows accurate presurgical planning that may prove to help lower complications related to the anterior approach required for total disc replacement or anterior interbody grafting. CT angiography can reliably define the altered anatomic relationships that are present in patients with scoliosis (Figure 8) and other deformities of the spine, where adaptation to these anatomic relationships is critical for successful surgery. As more experience is reported, CT angiography may also prove to be a valuable asset in preoperative planning for revision anterior spine surgery for a failed disc replacement.

■ Key Points

- CT angiography is a safe, inexpensive, and effective examination to evaluate the prevertebral vascular anatomy before an anterior approach to the lumbar spine.
- Preoperative CT angiography influenced the surgical plan in 21% of operative cases.
- CT angiography was most useful in presurgical planning for an approach to the L4–L5 disc space and in complex cases.

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