Comparison of Three Display Methods for Evaluating CT Angiography Data for the Vascular Assessment of Renal Donors

Maria E. Pace, Thorsten L. Krebs, Jade J. Wong-You-Cheong, Barry Daly,
Steve M. Pomerantz, and Eliot L. Siegel

VARIANT RENAL arterial anatomy is common, occurring in up to 32% of potential renal donors. The pre-operative identification of variant anatomy is critical prior to donor nephrectomy. Computed Tomographic Angiography (CTA) has been demonstrated to be useful for the vascular assessment of potential renal donors. There has been limited investigation in determining the best method to evaluate the acquired CTA data. We compared three soft copy display methods: stack mode axial, cine axial, and 3-D maximum intensity projection (MIP). These results were correlated with anatomy found at surgery.

MATERIALS AND METHODS

Forty renal donors underwent CTA prior to laparoscopic donor nephrectomy. Retrospective analysis of the three CTA data sets were independently evaluated by two radiologists specialized in cross-sectional imaging blinded to the surgical results. Imaging findings were agreed upon by consensus. All exams were performed on a High Speed Advantage CT scanner (General Electric Medical Systems, Milwaukee, WI). Preliminary unenhanced 10 mm slices were obtained to evaluate the area of coverage. Patients were hyperventilated prior to a thirty second breathhold angiographic phase study. An enhanced helical scan was obtained from above the kidneys to 3 cm below the aortic bifurcation, following intravenous injection of 150 cc Omnipaque 300 via an 18 g peripheral IV at a rate of 4 cc per second with a 14 to 20 second delay. The scans were obtained with 3 mm collimation, a pitch of 1.5-1.8, and a small FOV (18-25 cm). As soon as tube cooling permitted, delayed 10 mm slices through the abdomen and scout were obtained.

The raw data was reconstructed using a standard algorithm at 1 mm intervals. The reconstructed axial data sets were transferred to a G.E. Advantage workstation, where they were viewed as three soft copy displays. At the workstation, a radiologist edited the data sets using the three dimensional editing tool, which was used to generate targeted coronal plane 3-D MIP display models which were projected at 20 degrees between views. Additionally, individual data sets were viewed as individual stack axial images and an axial plane cinematic loop with a reader selectable frame rate ranging from 4-6 frames per second.

Evaluation was limited to the left kidney which was laparoscopically removed in all cases. Assessment of arterial and venous anatomy was limited to evaluation of normal anatomy (single vessel) versus variant anatomy to include multiple or accessory vessels. Venous anatomy was not assessed on the 3D-MIP data sets. Sensitivity, specificity and accuracy rates were derived for the three data sets. In addition, T-test analysis

was performed on the data sets utilizing Excel (Microsoft, Redmond, CA).

The demographics of our patient population included 27 females and 13 males with an age range of 23-68 years (mean = 38 years).

RESULTS

For the evaluation of renal arterial anatomy, the cinematic loop was found to have the highest sensitivity, specificity, and accuracy of 92%, 100%, and 98%, respectively (Table 1). This display method was significantly better than stack axial or 3-D MIP datasets ($P < 0.05$). The 3-D MIP had the lowest sensitivity overall of 76% when compared to the other methods. The stack axials were found to have an intermediate sensitivity of 85% compared to the other methods, and the lowest accuracy (88%).

For the evaluation of renal venous anatomy, the cinematic loop was also found to have the highest sensitivity, specificity, and accuracy of 80%, 100%, and 98%, respectively (Table 2). No statistically significant difference was found between the data sets ($P > 0.05$). Surgery found thirteen accessory arteries in 40 cases (33%) and five venous anomalies (13%) (Table 3).

DISCUSSION

There has been limited investigation in determining the best CTA display method for evaluation of renal vascular anatomy. Our study demonstrated that the cinematic loop yielded a significantly higher sensitivity, specificity, and accuracy for evaluation of renal arterial anatomy compared to stack axial and MIP studies. Additionally, the

From the Department of Diagnostic Radiology University of Maryland Medical Center Baltimore, MD.

Address reprint requests to Maria E. Pace, M.D., Department of Diagnostic Radiology, University of Maryland Medical Center, 22 S. Greene Street, Baltimore, MD 21201.

*Copyright © 1998 by W.B. Saunders Company
0897-1889/98/1103-1044\$8.00/0*

Table 1. Renal Arterial Anatomy

	Sensitivity	Specificity	Accuracy
Stack Axial	85%	89%	88%
Cine Loop	92%	100%	98%
3D-MIP	76%	96%	90%

Note: For evaluation of renal arterial anatomy, cinematic loop had the significantly highest overall sensitivity, specificity, and accuracy when compared to the other display methods ($P > 0.05$). 3-D MIP had the lowest sensitivity overall and stack axial had results which were intermediate that of the other display methods.

cinematic loop had the highest sensitivity, specificity, and accuracy for evaluation of venous anatomy when compared to the stack axial images although this was not found to be statistically significant. Figure 1 demonstrates an example from our study where a small accessory artery to the left upper pole was missed on the stack axials however was correctly identified on the cinematic loop and 3-D MIP. Figure 2 demonstrates a small left upper pole accessory artery that was seen on both axial studies. This vessel was not correctly identified on the 3-D MIP, even in retrospect, because of its small size. Sometimes it can be difficult to correctly identify small accessory arteries despite an optimized CT technique and corrected editing. There is always the potential for editing errors when performing MIP reconstructions as variable information may be excluded from the final data set. MIP datasets can be configured in any three dimensional plane and displayed at variable angles. The lowest sensitivity of 76% suggests that tiny vessels may not be adequately displayed or even inadvertently removed from the 3D model. Although 3D reformatted images are visually appealing, 3D models should always be evaluated in conjunction with the axial images.

Tiny accessory renal arteries can be difficult to detect and interpret even with optimal technique. Figure 3a demonstrates a tiny linear enhancing

Table 2. Renal Venous Anatomy

	Sensitivity	Specificity	Accuracy
Stack Axial	57%	97%	90%
Cine Loop	80%	100%	98%

Note: For evaluation of renal venous anatomy, cinematic loop had the highest overall sensitivity, specificity, and accuracy when compared to the stack axials. This was not found to be statistically significant ($P > 0.05$). Venous anatomy was not assessed by 3-D MIP.

Table 3. CTA vs Surgery

	Stacked	Cine/Tiled	3D-MIP	Surgery
NL ART	24	27	26	27
VAR ART	11	12	10	13
NL VEN	32	35	—	35
VAR VEN	4	4	—	5

Note: Comparison of normal and variant anatomy as interpreted on the three display methods when compared to anatomy found at laparoscopic donor nephrectomy. Surgery found 13 variant arterial vessels (33%) and 5 venous variants (13%).

structure extending from the aorta to the left kidney upper pole which was thought to represent an accessory renal artery but was not identified at laparoscopic nephrectomy. Figure 3b demonstrates a similar appearing structure adjacent to the left upper pole which was correctly identified as an accessory renal artery radiographically and at surgery. Although surgery was used as our gold standard, small accessory vessels may potentially not be visualized at laparoscopic surgery.

For 3-D interpretation in the assessment of renal donors, Rubin, et al demonstrated in 11 patients a 100% sensitivity and specificity for identifying 7 accessory arteries on stack axial and corrected 3-D renderings.¹ The axials were not independently evaluated from the 3D renderings, however, and were used to correct and edit the finalized 3-D renderings used for interpretation. In a larger more recent study by Platt et al, 5 accessory renal arteries in 154 patients were better assessed by axial images than by 3-D methods.²

To the best of our knowledge, there has been no study to date evaluating the use of cinematic loop for assessment of renal donors. Gur et al suggested that for the evaluation of abdominal masses on axial CT, sequential viewing of image sets is significantly better when the individual readers selects his own viewing rate as compared to pre-set fixed rates.³ As suggested by our results, the cinematic loop may allow for a more contiguous visual image that allows for easier reader perception and interpretation. Our readers felt most comfortable when viewing images at a frame rate ranging from 4 to 6 frames per second. Cinematic loop provides a smoother transition between image slices and visually facilitates the progression of a vessel throughout its course. In contrast, stack axial images are viewed independently of each other and the reader's eye must repeatedly adjust to a new

MISSED ACCESSORY ARTERY ON STACK AXIALS

Fig 1. A small accessory artery is seen just superior to and paralleling the main left renal artery which was prospectively identified on the 3-D MIP (left image) and the cine loop, but was missed on the stack axial as it was felt to represent an early branching main renal artery (right image).

MISSED ACCESSORY ARTERY ON MIP

Fig 2. The axial section (right image) demonstrates a tiny upper pole accessory artery piercing the renal parenchyma which was also correctly identified on the cine axial loop. This small vessel was not identified on the 3-D MIP, even in retrospect, because of its small size (left image).

Fig 3. This figure demonstrates the difficulty with correctly identifying small accessory vessels. The axial image on the left demonstrates a tiny linear enhancing structure extending from the aorta to the left upper pole which was not seen at laparoscopic nephrectomy and was considered a false positive. The adjoining case on the right show a similar appearing vessel which was also difficult to identify but was a true positive at surgery.

location image by image when tracking a vessel. This may have accounted in part for stack mode axial viewing having the lowest overall accuracy of 88%.

CONCLUSION

In conclusion, CTA display methods are useful when evaluating renal vascular anatomy. Cinematic loop appears to be the most useful display method and is significantly more sensitive, specific, and

accurate than the 3D-MIP or stack axial when identifying renal arterial anatomy.

REFERENCES

1. Rubin GD, Alfrey EJ, Dake MD, et al: Assessment of living renal donors with spiral CT. *Radiology* 195:457-462, 1995
2. Platt JF, Ellis JH, Korobkin M, et al: Helical CT evaluation of potential kidney donors: Findings in 154 subjects. *AJR Am J Roentgenol* 169:1325-1330, 1997
3. Gur D, Good WF, Oliver JH, et al: Sequential viewing of abdominal CT images at varying rates. *Radiology* 191:119-122, 1994