Published in final edited form as:
J Vasc Surg. 2010 January ; 51(1): 38. doi:10.1016/j.jvs.2009.08.044.

Postoperative Renal Function Preservation with Non-Ischemic Femoral Arterial Cannulation for Thoracoabdominal Aortic Repair

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Abstract

Background: Renal failure after thoracoabdominal aortic (TAAA) repair is a significant clinical problem. Distal aortic perfusion for organ and spinal cord protection requires cannulation of the left femoral artery. In 2006 we reported the finding that direct cannulation led to leg ischemia in some patients, and that this was associated with increased renal failure. Following this finding, we modified our perfusion technique to eliminate leg ischemia from cannulation. Here we present the effects of this change on postoperative renal function.

Methods: Between February 1991 and July 2008, we repaired 1464 TAAA, 1088 using distal aortic perfusion, and only those receiving distal perfusion were studied. Median age was 68 years and 378/1088 (35%) were female. In September 2006 we began to adopt a sidearm femoral cannulation technique that provides distal aortic perfusion while maintaining downstream flow to the leg. This was used in 167 (15%) patients. We measured the joint effects of preoperative glomerular filtration rate (GFR) and cannulation technique on highest postoperative creatinine, postoperative renal failure and mortality. Analysis was by multiple linear or logistic regression with interaction.

Results: Preoperative GFR was the strongest predictor of postoperative renal dysfunction and mortality. No significant main effects of sidearm cannulation were noted. However, for peak creatinine and postoperative renal failure, strong interactions between preoperative GFR and sidearm cannulation were present, resulting in reductions of postoperative renal complications in the range of 15-20% when GFR was below 60. For normal GFR, the effect was negated or even reversed at very high levels of GFR. Mortality, though not significantly affected by sidearm cannulation, showed a similar trend to the renal outcomes.

Conclusion: Use of sidearm cannulation is associated with a clinically important and highly statistically significant reduction in postoperative renal complications in patients with low GFR. Reduced renal effect of skeletal muscle ischemia is the proposed mechanism. Effects among patients with good preoperative renal function are less clear. A randomized trial is needed.

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Introduction

Renal complications following thoracoabdominal aortic surgery are a significant source of morbidity and mortality (1-3). The postoperative renal effects of aortic surgery have long been believed to arise from direct end-organ ischemia during aortic crossclamping, but the perfusion techniques that have proved beneficial for spinal cord protection have been variable and largely disappointing for protection of the kidneys (4-6). Distal aortic perfusion for protection of the spinal cord requires cannulation of the femoral artery, with perfusion pressure and peri-cannula hemostasis maintained traditionally by securing the cannula into the artery with a tourniquet (Fig 1) In a previous publication, we reported that patients who experience loss of the local leg-channel somatosensory evoked potential (SSEP) distal to the cannulation site during surgery are at increased risk for postoperative renal dysfunction, compared to patients who do not demonstrate this sign of functional ischemia (7). We found in a further follow-up study that serum myoglobins are also markedly increased in patients who experience postoperative renal dysfunction (8). These two findings have provided strong enough circumstantial evidence of a role for rhabdomyolysis in the etiology of renal failure, that our team has gradually modified our perfusion technique to reduce ischemia to the leg downstream of the cannulation site by use of a sidearm graft (Fig 2). In this paper, we report our experience with the sidearm graft, and the effect of this cannulation technique on renal outcome following thoracoabdominal aortic repair.

Methods

Between February 1991 and December 2008 we repaired 1464 thoracoabdominal aortic aneurysms. Of these, 1088 required femoral cannulation for distal aortic perfusion, and this group of 1088 comprised the study population we report here. As we reviewed our previous experience, we felt that cannulation-related loss of the SSEP signal was sufficient evidence of functional leg ischemia to justify an alternative approach to femoral access, which we began to adopt occasionally in the Fall of 2006. As we gained experience with the technique, we employed it more widely, and since April 2007, we have used it in every case that requires distal aortic perfusion. Data were collected prospectively by a trained Masters' level research nurse as part of our ongoing IRB-approved clinical research / quality improvement database.

For purposes of the present study, we evaluated highest postoperative creatinine occurring in the first five postoperative days, renal dysfunction, and postoperative mortality as response variables by which to estimate the effects of sidearm vs. standard femoral cannulation. We defined renal dysfunction as an increase in creatinine above the preoperative baseline of 1 mg/dl/day for two consecutive days postoperatively, a clinical diagnosis of renal failure, or requirement for hemodialysis. This is consistent with the “I” category of the RIFLE criteria, which are used by the American Kidney Foundation to standardize assessment of renal function (9). Mortality was defined as any death occurring within 30 days of operation, whether in-hospital or out.

We compared these three outcome variables in patients with direct femoral cannulation, in which the artery is totally occluded during cannulation, to those with sidearm cannulation, in which blood enters the femoral artery through a short Dacron graft anastomosed end-to-side, and flows to both the distal aorta and also to the leg below the graft (Fig 2). We also measured other variables known to affect postoperative renal function, including preoperative glomerular filtration rate (GFR), age, gender, preoperative serum creatinine, history of hypertension and aortic crossclamp time. Preoperative GFR was calculated by the method of Cockcroft and Gault (10).

We computed univariate main effects of sidearm technique for each of the three response variables, as well as effects adjusted by stratification and multivariable regression techniques. We computed a propensity score that evaluated all the preoperative risk factors listed in Table 1, and we examined the effect of propensity for sidearm cannulation on the adjusted odds ratio for renal failure according to group. We also evaluated interaction effects of cannulation technique with respect to GFR, which is known to have strong effects on postoperative renal outcome and mortality. Postoperative creatinine, because of its non-normal distribution, was log transformed prior to parametric regression analysis. Data were analyzed using SAS software version 9.1.3 (SAS Institute Inc, Cary NC).

Results

Sidearm cannulation was used in 167/1088 patients (15%). Women comprised 378/1088 (35%) of our sample, and the median age was 64 (range 17-94). Median calculated preoperative GFR in the population was 68.8, with an interquartile range from 49 to 96 ml/min 1.73 m^2. Univariate descriptive statistics for the two groups are detailed in Table 1. Briefly, estimated GFR was somewhat lower, and coronary disease was more common in the direct cannulation group. Conversely, hypertension and extent 4 aneurysm were more common in the sidearm cannulation group. Otherwise, the groups were comparable. An attempt to balance the groups using propensity scores did not affect the sidearm cannulation effect estimates, so the propensity score variable was not included in further multivariable analyses. Preoperative GFR was the strongest univariate predictor of postoperative renal dysfunction, and was also the only statistically significant risk factor variable in simple linear multivariable analyses. Aortic crossclamp time did not have a significant effect on renal outcome once GFR and sidearm cannulation were considered. Univariate effects of sidearm cannulation were not significant for any of the three outcome variables. However, interaction model effects of sidearm cannulation with preoperative GFR were highly significant for both highest postoperative creatinine and for postoperative renal dysfunction (Tables 2 and 3, respectively). When preoperative GFR was low, patients receiving sidearm cannulation had lower creatinine values and renal dysfunction rates than patients who received standard cannulation. For GFR in the normal range, the sidearm cases had values that were the same as or higher than those in the standard technique group (Figs 3 and 4). For mortality, GFR was also the primary multivariate predictor, and even in interaction models the terms for sidearm graft and interaction were not statistically significant, although they moved in the same direction as the two renal outcome variables. Table 4 and Figure 5 show the effects of sidearm cannulation and preoperative GFR on mortality.

Discussion

The important new finding of this study is that, when patients have reduced preoperative renal function as measured by glomerular filtration rate, sidearm femoral arterial cannulation appears to produce a significant improvement in the preservation of renal function. In patients with normal GFR, with respect to the two measures of postoperative renal function, the effect of sidearm cannulation is reduced or even reversed. At a GFR of 40, peak postoperative creatinine in the conventional cannulation group is about 2.7 mg / dl. In patients receiving sidearm cannulation, this value is reduced to 2.2. But at a GFR of 90, direct cannulation produces a maximum creatinine of 1.8, compared to 2.0 for the sidearm method (Fig 3). In an almost identical relationship, probability of postoperative renal dysfunction is 38% in the direct cannulation group at a preoperative GFR of 40, compared to 30% in the sidearm group. But at a GFR of 90, renal dysfunction falls to 21% in the direct cannulation group and 28% in the sidearm group (Fig 4). These crossover effects are undoubtedly responsible for the strong interactions seen in the statistical models, and the highly significant terms for them.

In contrast, at a preoperative GFR of 40, mortality in the direct cannulation group is 25%, compared to 17% in the sidearm group (Fig 5). At a GFR of 90 however, the values are each only about 8%. The smaller effect size and lack of a major crossover effect likely contributes to the lack of statistically significant effects for mortality. Although not statistically significant, the apparent mortality reduction without overshoot on the high-GFR end is a tantalizing finding, and one that invites more research.

The results of our experience with sidearm femoral cannulation generally bear out our previous observation that an ischemic leg during thoracoabdominal aortic repair is associated with increased probability of postoperative renal complications. The strong crossover effects seen in the renal outcome data are somewhat difficult to interpret. Sidearm cannulation adds very little time to the procedure (under 10 minutes), and this is non-ischemic time since the pump has not been started at this point and normal antegrade flow is still present. Our general impression is that the clinically important effects are at low GFRs, and that with normal GFR short term leg ischemia is inconsequential. It appears that sidearm cannulation reduces the slope of the relationship between GFR and postoperative renal complications, effectively reducing the contribution of GFR to outcome. This impression is by no means a certainty, however, and we believe that more research is needed.

Open surgery is not the only type of aortic procedure under which substantial cannulation-related leg ischemia can occur. Endovascular thoracic aortic repairs require introduction of very large sheaths into the femoral arteries, and as these repairs become more complex, very long periods of leg ischemia may result. So the issue may well have implications that extend beyond those of the relatively limited indication for which we describe it here. A randomized controlled trial of sidearm vs. conventional femoral cannulation is warranted. A clinical trial would serve not only to demonstrate or refute our observational findings about the effects of leg ischemia during open thoracoabdominal repair, but would also serve as a proof-of-concept regarding muscle ischemia products and renal function in patients with vascular disease more generally, that may be important for other extensive vascular and endovascular procedures as well.

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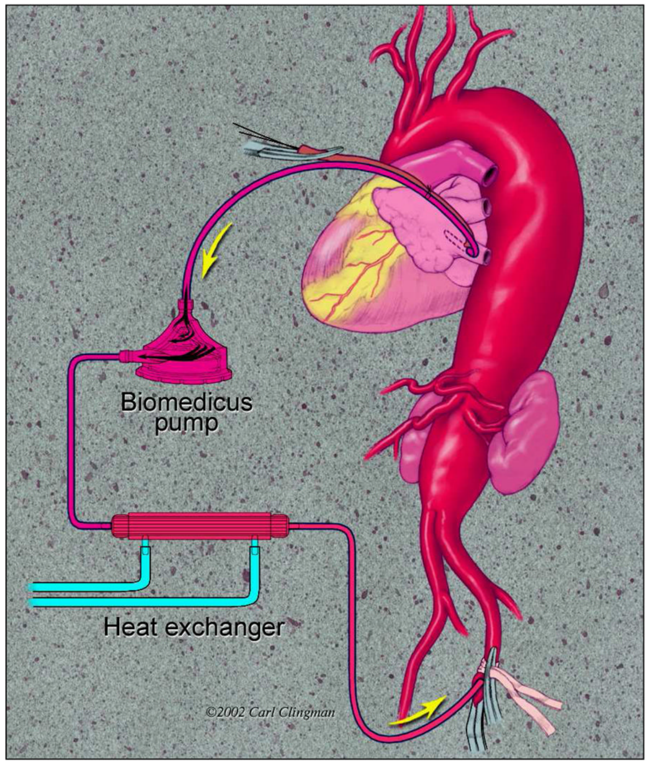

Figure 1.
Standard cannulation technique. The femoral artery is cannulated and the cannula is secured with a tourniquet, occluding the artery for distal antegrade flow below the tourniquet.

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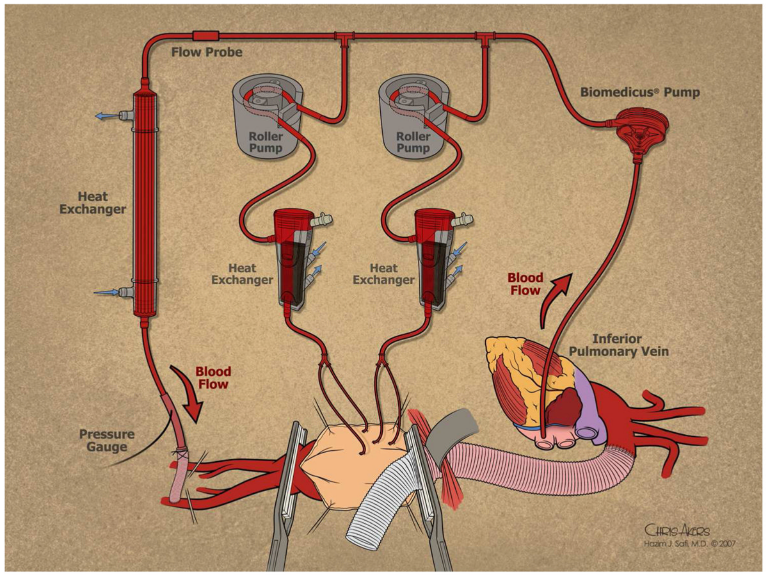

Figure 2.
Non-occlusive sidearm technique. Note that the sidearm graft allows blood flow to pressurize the artery both proximal (retrograde flow) and distal (antegrade flow) to the sidearm cannulation site.

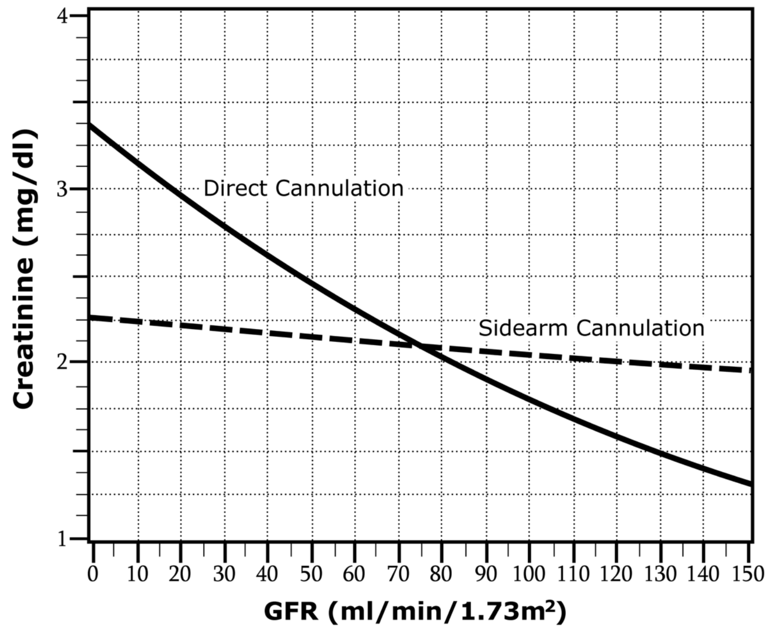

Figure 3.

Peak postoperative creatinine relationship to preoperative GFR by cannulation technique. when GFR is low, sidearm technique reduces peak creatinine, and flattens the relationship between preoperative GFR and postoperative creatinine.

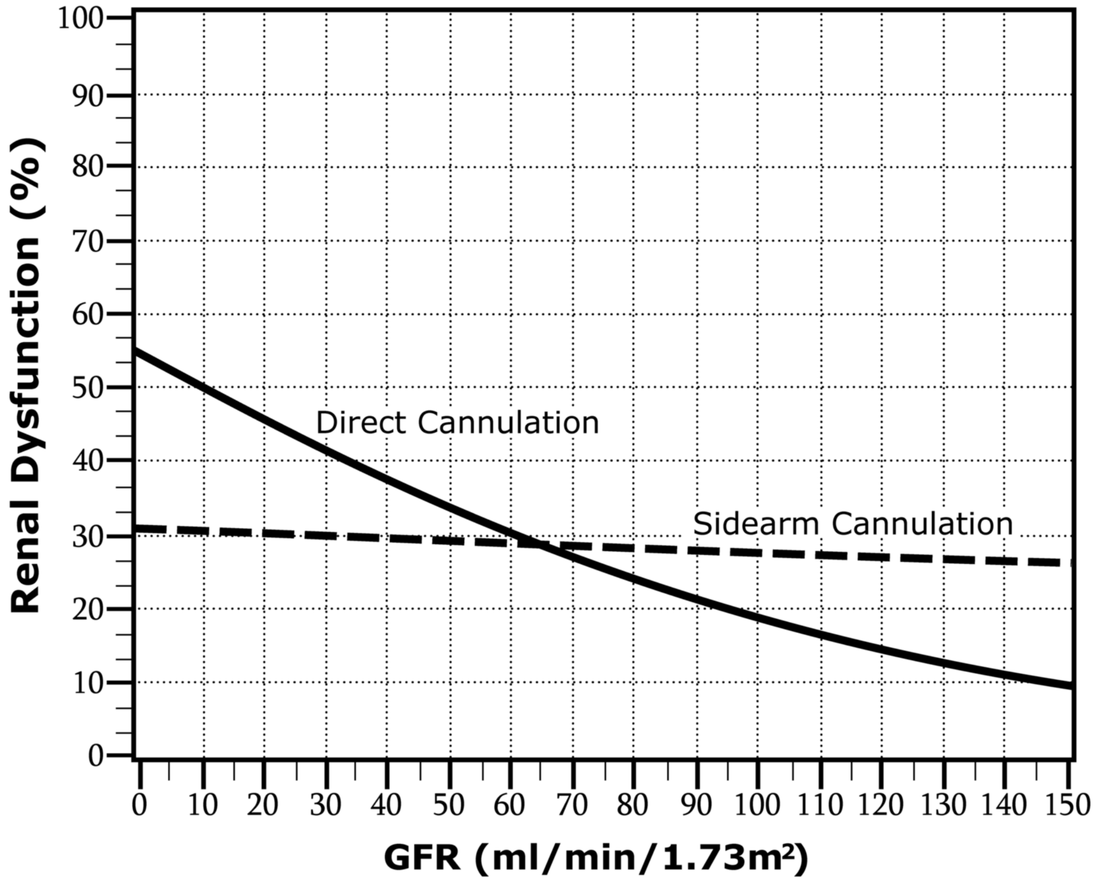

Figure 4.
Probability of postoperative renal function as it relates to preoperative GFR by cannulation technique. Sidearm cannulation reduces the effect of preoperative GFR on postoperative renal dysfunction at low GFR values.

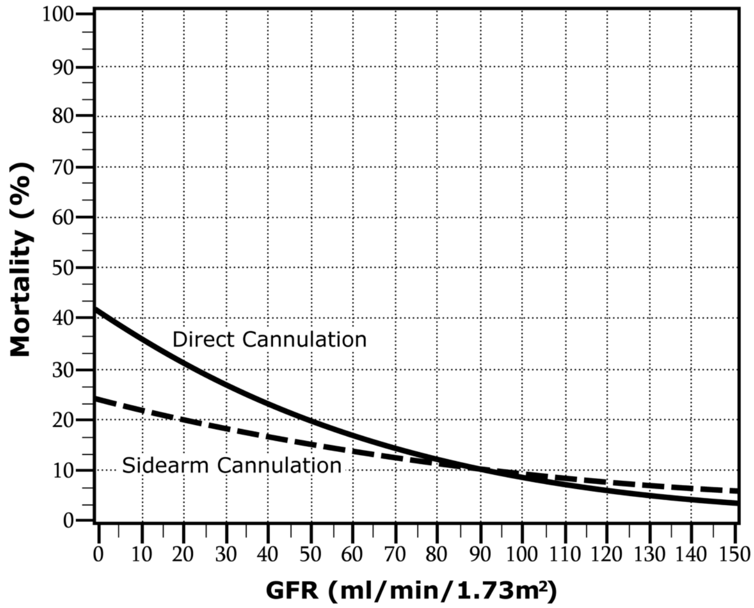

Figure 5.

Mortality related to preoperative GFR by cannulation technique. Similar pattern to renal variables. Not statistically significant at current sample size.

Table 1

Descriptive Statistics

	Direct Cannulation		Sidearm Cannulation		
Variable	**#**	**%**	**#**	**%**	**p**
Total	921	(100)	167	100	
Age					0.19
≤ 58	231	(25.1)	54	(32.3)	
59 – 68	230	(24.9)	34	(25.7)	
69 – 74	221	(24.0)	47	(21.0)	
≥ 75	239	(26.0)	54	(21.0)	
Female	325	(35.3)	53	(31.7)	0.43
Hypertension	747	(81.1)	154	(92.2)	0.01
Coronary Disease	291	(31.6)	38	(22.8)	0.03
Peripheral Vascular Disease	138	(15.0)	27	(16.2)	0.73
Emergency	41	(4.5)	6	(3.6)	0.84
Aneurysm Extent					
1	180	(19.5)	22	(13.2)	0.06
2	182	(19.8)	24	(14.4)	0.11
3	81	(8.8)	18	(10.8)	0.39
4	112	(12.2)	35	(20.9)	0.01
5	61	(6.6)	9	(5.4)	0.61
Descending	305	(33.1)	59	(35.3)	0.60
GFR					0.03
≤ 49	225	(24.4)	32	(19.2)	
50 – 68	253	(27.5)	34	(20.4)	
69 – 96	222	(24.1)	47	(28.1)	
≥ 97	221	(24.0)	54	(32.3)	
Crossclamp Time					0.09
≤ 30	202	(22.4)	41	(24.6)	
31 – 44	228	(25.2)	40	(23.9)	
45 – 60	230	(25.4)	29	(17.4)	

	Direct Cannulation		Sidearm Cannulation		
Variable	**#**	**%**	**#**	**%**	**p**
≥ 61	244	(27.0)	57	(34.1)	

For continuous variables, p values represent a chi square test across all quartiles. Other comparisons are confined to proportions on the same row. GFR was lower and more coronary disease was present in the direct group. The sidearm group had proportionally more hypertension and more extent 4 aneurysms. Otherwise the groups were comparable.

Table 2

Effects of GFR and Sidearm Graft on Creatinine*

Parameter	Estimate**	S.E.	p
Intercept	1.2099	0.0555	<0.0001
Preoperative GFR	−0.0063	0.0006	<0.0001
Sidearm Graft	−0.3984	0.1172	<0.0008
Interaction	0.0053	0.0012	<0.0001

*Creatinine values were log transformed for the analysis.

**Linear regression

Table 3

Effects of GFR and Sidearm Graft on Postoperative Renal Dysfunction

Parameter	Estimate*	S.E.	p
Intercept	0.1508	0.1730	<0.38
Preoperative GFR	−0.0166	0.0024	<0.0001
Sidearm Graft	−0.9812	0.3836	<0.02
Interaction	0.0150	0.0042	<0.0004

*Logistic regression. Odds ratios not computed due to interaction

Table 4

Effects of GFR and Sidearm Graft on Mortality

Parameter	Estimate*	S.E.	p
Intercept	−0.3663	0.2093	<0.08
Preoperative GFR	−0.0214	0.0033	<0.0001
Sidearm Graft	−0.8334	0.6122	<0.17
Interaction	0.0097	0.0080	<0.22

*Logistic regression. Odds ratios not computed due to interaction.