Management of infected prosthetic dialysis arteriovenous grafts

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Background: **Hemodialysis access is one of the most common vascular procedures that is performed by vascular and general surgeons. Prosthetic arteriovenous graft (AVG) infections pose potentially life-threatening septic and bleeding complications, as well as loss of dialysis access. Strategies employed to preserve some grafts, prevent morbidity in those with major infections, and maintain access are presented.**

Methods: **Between July 1, 1995 and August 1, 2002, 1441 AVG procedures were performed at a single institution. Fifty-one (3.5%) prosthetic AVG infections in 45 patients were identified. Twenty-seven graft infections occurred at a prior incision for placement or revision of a graft. The other 24 infections were located within the body of the graft, and 14 of these were documented to be at a recent puncture site for hemodialysis access. The most common presentation (47% [24/51]) was an exposed graft or a draining sinus tract. Management included total graft excision (TGE) when patients presented with sepsis or the entire graft was bathed in pus; subtotal graft excision (SGE), when all of the graft was removed except an oversewn small cuff of prosthetic material on an underlying patent artery; and partial graft excision (PGE), when only a limited infected portion of the graft was removed and a new graft was rerouted through adjacent sterile tissue to maintain patency of the original graft.**

Results: **None of the 45 patients died or developed hand ischemia. A uniformly successful outcome was achieved in all patients who were treated with TGE (13/13: 8 vein patches, 4 primary closure, 1 arterial ligation) or SGE (15/15). However, these treatments necessitated placement of a central venous catheter for temporary dialysis access and a new AVG later. All of these 28 wounds healed by secondary intention, including all 15 cases in which an oversewn cuff of prosthetic material remained. Graft patency and wound healing were achieved in 74% (17/23) of infections treated with PGE, and placement of a temporary dialysis access catheter and new AVG were avoided. The 6 failures of PGE ultimately required TGE because of nonhealing wounds, but there were no acute hemorrhagic or septic events.**

Conclusions: **Systemic sepsis caused by prosthetic AVG infections mandates TGE. SGE and PGE can be safely employed in selected patients with infected prosthetic AVGs. SGE maintains patency of the underlying artery and avoids a difficult and time-consuming dissection. PGE offers the advantage of minimizing extensive dissection of well-incorporated uninfected graft segments and allows continued dialysis access at the incorporated portion of the graft. (J Vasc Surg 2004;39:73-8.)**

Dialysis access is one of the most common procedures performed by vascular and general surgeons in the United States. It is estimated that more than 250,000 persons in the United States currently require hemodialysis.[1] Access-related morbidity represents a significant problem in the care of these patients. Infection of PTFE grafts is second only to thrombosis as a complication of graft placement. It is estimated that 20% to 36% of all deaths in the dialysis population occur as a result of infectious complications, although the mortality rate specifically for infected prosthetic hemodialysis grafts is much lower.[2] The cost to our health care system is considerable and is estimated to exceed $1 billion per year, with >17% of this spent toward the care of access-related morbidity.[3] It is difficult to determine the exact cost that is attributable specifically to infected prosthetic hemodialysis grafts, but it is considerable, considering the need for prolonged length of hospital stay, repeated operations, antibiotics, and other factors in patients who suffer these complications.

Of all potential access morbidity, prosthetic vascular graft infection may be the most challenging and life threatening. The patient is at risk for life-threatening sepsis or hemorrhage and often must endure multiple procedures to manage the problem. Historically, this has mandated complete graft removal, a large open wound, and placement of temporary central venous access.[1,4,5] Although excision of infected prosthetic hemodialysis grafts frequently can be accomplished with shorter incisions and skin bridges, with closure of some wounds over drains, the operation can still be extensive and difficult. Once the infection is resolved, new permanent access is obtained at a separate site, and temporary access is removed once the new permanent access matures and is functional. Given the limited number of peripheral access sites, partial salvage of grafts represents an appealing option in this difficult group of patients.[6] We review our experience with prosthetic hemodialysis graft infection and present our results specifically addressing selective use of graft preservation techniques.

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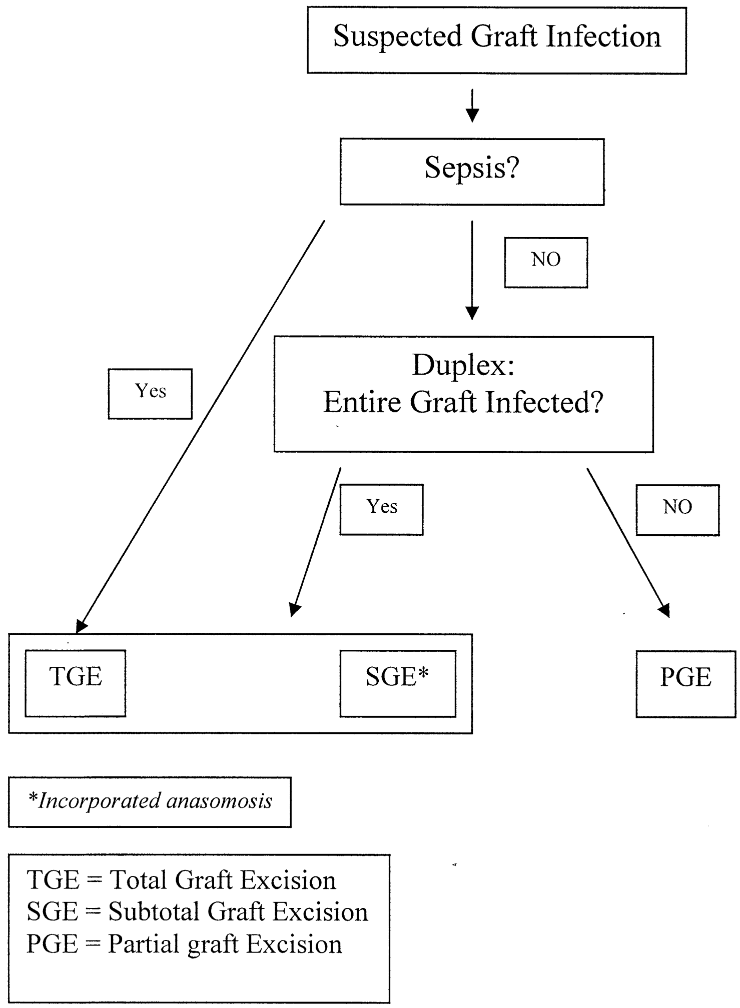

Management of suspected prosthetic arteriovenous graft infections.

PATIENTS AND METHODS

Between July 1, 1995 and August 1, 2002, 1441 prosthetic AVG procedures were performed at Pennsylvania Hospital. Fifty-one (3.5%) prosthetic (polytetrafluoroethylene [PTFE]) AVG infections in 45 patients were identified. This figure represents the lowest possible incidence of prosthetic AVG infections at our hospital; the actual rate may be higher, because some patients were followed at other dialysis centers or moved out of our area. Therefore, follow-up of all patients with prosthetic AVGs was not complete. Data collected included graft location, number of revisions before infection, interval period between intervention and infection, and location of the infection on the graft. Graft location was categorized according to the recommended standards for reports dealing with arteriovenous access.[7] Infection location was defined as occurring at a recent incision or within the body of the graft, with or without a recent dialysis puncture site. Clinical presentation was categorized as systemic sepsis, a draining sinus tract, exposed graft, purulent drainage, erythema, pain overlying the graft, hemorrhage, or a combination of the above (ie, weakened graft with a number of puncture holes with hemorrhage, false aneurysm with skin erosion resulting in graft exposure or hemorrhage). In a few cases, unexpected purulence was encountered during a thrombectomy or revision in an otherwise symptom-free patient. Stat Gram stains and wound cultures were routinely sent from the operating room. These grafts were treated as infected grafts either because the Gram stains or cultures returned as positive for bacteria or because grossly purulent fluid was found. None of these grafts had been recently placed, and they were removed solely on the basis of poor incorporation. All patients who were admitted to the hospital for graft infections were started on broad-spectrum antibiotics, typically vancomycin and gentamycin. Once culture and sensitivity results were obtained, more specific antibiotics were administered for appropriate coverage. In most cases, the nephrologists dosed the antibiotics at each dialysis session for a period of 6 weeks after surgical treatment.

Surgical management of dialysis graft infections included the following strategies. First, total graft excision (TGE) was undertaken when infection was responsible for systemic sepsis or hemorrhage at the anastomosis. The entire graft was removed, and the arterial defect was patched with autologous vein or primarily repaired. Rarely, the underlying thrombosed or diseased artery was ligated. Involved veins were routinely ligated or oversewn. The wounds were left open to heal by secondary intention, or a drain was placed within the subcutaneous tunnel if the graft could be removed through multiple short incisions. TGE mandated placement of a temporary dialysis catheter. Days or weeks after the patient recovered from the septic episode, placement of a new AVG was carried out at another location. Ultimately, the temporary venous catheter was removed.

When a patient presented with an infected prosthetic dialysis graft but without sepsis (stable hemodynamic parameters, a mildly elevated or normal white blood cell count, low grade or absent fever), graft preservation techniques were considered.

Subtotal graft excision (SGE) was defined as removal of all of the graft with the exception of an oversewn cuff of prosthetic material on an underlying patent artery.[8-10] Similar to our experience with infected peripheral bypass grafts, this strategy was employed if the arterial anastomosis was intact and encased in scar tissue.[8] By oversewing a 2- to 3-mm cuff of the original prosthetic graft on the underlying artery after excising the remainder of the graft, we avoided the need for placing an autogenous patch and dissecting an artery encased in scar tissue. This strategy preserved patency of the underlying artery and minimized the risk of nerve damage and bleeding during a hazardous dissection. Aggressive debridement of the wound and frequent dressing changes were mandatory for promoting granulation tissue to incorporate the oversewn prosthetic patch and ensure successful wound healing.

Partial graft excision (PGE) was employed if the infection was localized to one segment of the graft and a preoperative ultrasound was negative for the presence of fluid around the remaining uninfected portions of the graft. After preparing the arm, the area of exposed graft or isolated infection was covered with occlusive dressings. Segments of sterile graft that were proximal and distal to the infected area were dissected free. If these segments were not well incorporated, then the strategy was abandoned, and TGE or SGE excision was performed. If the adjacent segments were well incorporated, new graft was tunneled in adjacent sterile tissue and anastomosed to the proximal and distal uninfected portions of the graft. The sterile end of the intervening infected graft segment was partially resected toward the area of infection and was ligated to allow closure of the tunnel with a purse-string subcutaneous suture, with care taken not to violate the area of isolated infection within the tunnel. Once the new graft was placed, the wounds were closed, and sterile dressings were applied. Next, the infected portion of the graft was removed through the infected wound without violating the previous sterile incisions. The main advantages of PGE were that incorporated portions of the graft were available for immediate dialysis, temporary venous access was not required, and the location of the graft was maintained.

Table I. Presentations of 51 PTFE AVG infections

Presentation	*n*
Exposed graft/sinus tract	23
Purulent drainage	6
Sepsis	5
Unexpected purulence	5
Erythema	4
Hemorrhage	4
Hematoma	3
Pain	1

RESULTS

Mean age of these 45 patients with 51 prosthetic AVG infections was 58.3 years (range, 42 to 78 years). About half (23/45, 51%) of the patients had diabetes mellitus. Thirty-two (62.8%) grafts were prosthetic brachial-antecubital forearm loop–access grafts, 4 (7.8%) were prosthetic radial-antecubital forearm straight-access grafts, and 15 (29.4%) were prosthetic brachial-brachial upper arm loop–access grafts.

The most common presentations of prosthetic AVG infection in this series were an exposed graft or a draining sinus tract (23/51, 45.1%; Table 1). Overt sepsis was relatively uncommon, occurring in only 5 patients (9.8%) and without other signs of infection. The graft was found to be the source of sepsis, on the basis of duplex ultrasonography showing fluid around the graft, which was confirmed by graft exploration and excision and absence of any other foci of sepsis such as pneumonia. In patients who presented with erythema or hematoma, wound or fluid cultures were positive, or fluid suspicious of infection was found during surgical exploration. In one case, pain overlying the graft was the only manifestation of infection.

Twenty-seven graft infections (53.0%) occurred at a prior incision for placement or revision of a graft. These initial or re-do incisions were all closed with a running subcuticular absorbable suture, and retractors were not placed during graft thrombectomy. Instead, angled clamps were applied across each end of the graft that was exposed in the wound, and these clamps functioned as retractors to expose the graftotomy. The other 24 infections (47.0%) were located within the body of the graft where the graft had been tunneled but where there were not any prior incisions, and 14 (27.4%) of these were documented to be at a recent puncture site for hemodialysis access. Twenty-four infections (47.0%) presented within 1 month of a revision or placement, 20 (39.3%) presented within 2 to 6 months, and 7 (13.7%) presented more than 6 months after surgical revision or placement. The majority of the infec-

Table II. Partial graft excision: location versus success

Location of infection	*n*	*Successful outcome (n)*
Incision	12	9
Body	4	4
Body with puncture site	7	4
Total	23	17 (74%)

tions that presented within a month of a recent revision (18/24, 75.0%) were associated with the incision, and the majority of the infections that presented more than 1 month after surgery (21/27, 77.7%) were in the body of the graft where the graft had been tunneled under the skin and where a prior incision had not been made.

There were no deaths in this series as a result of a graft infection. There were no clinically apparent ischemic hand complications or episodes of life-threatening hemorrhage during long-term follow-up (0.5 to 48 months; mean, 9.6 months; median, 8.1 months; 39% followed for >1 year).

Thirteen patients were treated with TGE. As mentioned previously, duplex ultrasound examination of the graft revealed fluid around the graft in a few systemically septic patients without other clinical signs of infection, which prompted TGE. When patients demonstrated critical sepsis, we believed that TGE was necessary so that there was not any graft remnant to serve as a potential source of infection. If we believed that patients were not truly septic, then SGE was performed. A successful outcome was achieved in all patients who were treated by TGE in that all wounds healed and patients survived. Eight patients underwent vein-patch closure of the arteriotomy, 4 underwent primary arterial closure because of sufficient arterial caliber, and 1 underwent ligation of a thrombosed radial artery.

In 15 patients, SGE was performed. In these patients, the infection involved the majority of the graft, precluding PGE, but the area of the arterial anastomosis remained well incorporated by dense scar tissue where sharp dissection proved very difficult. A small oversewn cuff of prosthetic tissue was left on the arterial anastomosis. In all 15 cases, the wounds healed by secondary intention entirely or, rarely, by muscle mobilization to cover the prosthetic cuff (when possible) without sequelae, and remained healed without evidence of hemorrhage or recurrent infection during follow-up.

In almost half (23/51, 45.1%) of infected prosthetic grafts in this series, PGE was attempted. Preservation of a significant part of the incorporated graft was possible, thereby enabling these patients to be dialyzed immediately, without the need for a central catheter. Ultimately, six patients required TGE because of nonhealing wounds, for an overall success rate of 74% (17/23). The location of the initial infection did not appear to be predictive of success of partial excision, but the number of cases was small (Table II). There were no episodes of life-threatening hemorrhage or sepsis when a strategy of PGE was attempted, including unsuccessful cases.

Purulent fluid was encountered in five patients (9.8%) without clinical evidence of a graft infection during a planned thrombectomy. One of these patients had the entire graft removed, and four of these patients were treated with either subtotal (2) or partial (2) graft excision. Both of the PGE cases healed without complication.

Bacterial cultures were positive in 38 (75%) cases and negative in 13 (25%) cases, despite fluid or pus surrounding the graft and with other manifestations of infection such as erythema, a draining sinus tract, or sepsis. This high incidence of negative cultures was due to problems in retrieving bacterial culture results from the hospital microbiology laboratory because of frequent changes in data computer storage and was also due to the fact that many patients were started on intravenous antibiotics before cultures were taken in the operating room. Of the 38 culture-positive wounds, the most common organism was *Staphylococcus aureus* (23; 60%), with *Staphylococcus epidermidis* (15), *Streptococcus viridans* (11), *Streptococcus faecalis* (10), *Pseudomonas aeruginosa* (8), and *Zanthoma maltophilia* (1) also cultured (many cultures were polymicrobial). Correlation of bacterial cultures with success of treatment applied only to patients who were treated by PGE, because the wounds of patients who were initially treated by TGE or SGE healed without any complications. TGE was ultimately required after failure of PGE in 6 cases; *Staphylococcus aureus* was cultured from these wounds in five cases and *S viridans* in one case. Because of these small numbers of failures, it is difficult to determine whether a certain type of bacteria was more likely associated with success or failure of any strategy.

DISCUSSION

Dialysis prosthetic graft infection has been treated by total graft removal at some centers, regardless of presentation. When patients presented to us with evidence of systemic sepsis, heralded by fever, leukocytosis, or hypotension, TGE was performed. This strategy was successful in the 13 patients we treated, in that wounds ultimately healed and patients survived, but with significant morbidity. This strategy mandated placement of temporary hemodialysis access; removal of the graft with the potential risk of bleeding, ischemia, or nerve injury; and loss of that site for future permanent grafts. Most of these patients were left with large open wounds to heal by secondary intention. The morbidity associated with this strategy and the relatively infrequent presentation of overt sepsis prompted us to attempt graft salvage techniques in selected patients.

When most of the graft was infected, but the arterial anastomosis remained well incorporated, leaving a small cuff of PTFE on the artery simplified treatment, reducing the risk of nerve injury and hemorrhage. For peripheral bypass grafts, we have described leaving an oversewn cuff of prosthetic graft on the femoral artery when removing infected bypass grafts, with success rates of >90%.[8-11] Similarly, Gifford et al[12] removed grafts in 15 hemodialysis patients, leaving a prosthetic cuff on the arterial anastomosis. Fourteen of 15 healed without sequelae. One patient developed a pseudoaneurysm, which was treated without further complication. However, there is not consensus on this strategy, and other surgeons do not generally recommend this approach. Investigators at the University of Miami recommended removal of all graft material after they found that 17% of the infections in their series were the result of infected cuffs.[13] The overall failure rate of all patients who were treated with SGE in their series was not mentioned, but possibly those investigators oversewed an infected prosthetic cuff of a poorly incorporated graft remnant. In our series, a cuff was left only if the anastomosis was well incorporated. Postoperative wound debridements were carried out as necessary, and wet-to-dry dressing changes were performed at least twice daily. With this technique, all patients healed without evidence of continued infection. We did not favor closing the wounds over suction drains for fear of recurrent infection. We believe that this technique, when used appropriately, is safe, reduces potential morbidity, and simplifies graft excision.

Graft preservation techniques, first introduced by Bhat et al[6] at Montefiore Medical Center, remain controversial but may be ideally suited in the hemodialysis population, in which localized infection often occurs. A strategy of PGE relies on the presence of localized infection and a good portion of remaining incorporated graft for bypass. A segmental bypass technique, similar to our proposed PGE technique, was employed by Raju[14] at the University of Mississippi in 44 patients, with only 5 failures. Similar to our findings, Taylor et al[15] reported an 80% success rate with the use of segmental bypass that was attempted in 60% of patients who presented with an infected AVG. Palder et al[16] successfully employed segmental bypass in 22 selected patients who had localized AVG infection. It is noteworthy that failure of this strategy in our series was not associated with life-threatening complications, such as bleeding or sepsis. Furthermore, the incorporated portions of the graft were available for immediate hemodialysis and thus obviated the need for temporary venous access.

These techniques require careful patient selection and, at times, willingness to abandon the technique if extensive infection is found at the time of operation. We propose an algorithm for the treatment of a suspected prosthetic fistula infection (Fig). If clinically apparent sepsis is present, heralded by high fevers, leukocytosis, or hypotension, the infected graft should be immediately and completely removed. If the infection is localized by clinical examination and a preoperative ultrasound is negative for the presence of more extensive infection, PGE can be attempted. Although occasionally preoperative ultrasound will not detect fluid around an infected graft, a positive finding almost always correlates with infection. We frequently have diagnosed patients who do not have clinical evidence of graft infection but in whom ultrasound has confirmed the presence of fluid and infection has been documented. If in the operating room the graft is not well incorporated or the entire graft is infected, then an SGE (well-incorporated anastomosis) or TGE should be performed.

Almost half of the infections in this series were from a recent incision (24/51, 47%), whereas the remainder presented within the body of the graft, not at a recent incision (27/51, 53.0%). A significant number of graft infections arose at the site of a previous incision for graft thrombectomy and revision, probably for the same reasons that re-do wound explorations in other areas of the body, namely scar tissue resulting in relatively ischemia and poorer wound healing. Preventing these complications may potentially be avoided by careful dissection and meticulous wound closure, but the best method is to perform graft revisions through virginal skin and subcutaneous tissue. The majority of infections (21/27, 77.7%) that occurred more than 1 month after surgery were not associated with an incision. Similarly, Schild et al[13] found that 50% of the infections in their series were attributable to routine dialysis, which they defined as infections that occurred more than 1 month after surgery. Although the development of AVG infection is clearly multifactorial, our data emphasize the need for strict attention to sterile technique not only by surgeons and interventional radiologists but especially by dialysis nurses when performing AVG needle insertions. Overlying skin can erode after multiple needle punctures and can lead to graft exposure and infection. Clearly dialysis nurses need to avoid these areas of skin breakdown when performing future needle punctures of the graft.

In addition to a functioning AVG, it is not uncommon for dialysis patients to have thrombosed, abandoned dialysis grafts. Typically, it is not necessary to remove thrombosed grafts once the decision is made to abandon them, so long as they remain uninfected. In our series, four patients had infections in thrombosed, abandoned grafts, all of which were apparent on physical examination. It is clear from this study and others that abandoned grafts continue to pose an infectious risk and may not often be apparent by physical examination. In a series of 87 patients from the University of Miami, infections involving 30 abandoned grafts were found.[13] Nassar and Ayus[1] reported 20 patients with infected thrombosed, abandoned PTFE grafts who presented with fevers only (15) or with sepsis (5) and in whom the source of infection was not clearly associated with the abandoned AVG. Blood cultures in 15 of 20 patients were positive. Indium scans were positive in all 20 patients, and purulent material was found surrounding the grafts in all cases. A comparison was performed with 21 symptom-free patients with abandoned, thrombosed PTFE grafts, and 15 were found to have positive indium scans. Subsequent removal of the AVG in these patients revealed purulence surrounding the graft in 13 of 15 patients. These studies emphasize the importance of maintaining a high clinical suspicion for infection in abandoned, thrombosed grafts.

Hemodialysis graft infection management requires a balance to achieve eradication of infection and continued means to achieve hemodialysis with reduced overall morbidity. In carefully selected patients with an infected hemodialysis AVG infection, PGE and STE represent an improved strategy that can be expected to achieve a high likelihood of success with minimal morbidity and with greater salvage of involved grafts.

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DISCUSSION

Dr David K. W. Chew (West Roxbury, Mass). As recently as one month ago we had a patient who had an infected dialysis graft; the proximal anastomosis was very densely incorporated, and so the surgeon left a cuff of the graft and did a subtotal excision. The patient promptly blew out 2 weeks later from that stump of prosthetic graft that was left behind. I think it had to do with the virulence of the infection, which was gram-negative *Klebsiella*. I was wondering whether you have any data on the type of bacteria in your series—whether there is any influence on the safety of the management that you adopted.

Dr Sean Ryan. That's a good question. The majority of our cultures were staph species. We also had some *Pseudomonas*, *Streptococcus viridans*, and *Enterococcus.* In a large portion of our patients, about 25%, the cultures were negative. There is no way for us to predict success on the basis of microbiology because the subgroups of patients were treated in different ways and that dilutes any analysis. I think that certain bacteria, such as *Pseudomonas*, based on other studies we and others have published, are more worrisome.

Dr Peter J. Pappas (Newark, NJ). I want to congratulate you on tackling a very difficult group of patients. Your data indicates that you do approximately 200 prosthetic grafts a year. At our institution we've found that the best way to avoid a prosthetic graft complication is to minimize the use of prosthetic grafts for dialysis access and maximize the use of autogenous fistulae. I would therefore like to ask how many autogenous arteriovenous fistulae were performed at your institution during the same time period.

The second question is, of those patients who required a total graft excision, did you place another prosthetic graft or did you look to see if the patient had an autogenous option for access? We have found that over 50% of our patients who had a prosthetic graft that failed or had to be removed were candidates for a fistula, if you investigate their extremity veins, utilizing duplex ultrasonography.

Dr Ryan. We have a strategy at Pennsylvania Hospital where we perform autogenous primary fistulae whenever possible. We routinely perform preoperative duplex scan vein mapping of both upper extremities.

Dr Paul J. Gagne (New York, NY). I congratulate you on your careful analysis. My question is, you describe using subtotal graft excision to avoid complications related to total graft excision. In the patients in whom you performed total graft excision, did you see the complications that you were trying to avoid with subtotal graft excision?

And the second part of my question is, a number of the patients who had partial graft excision went on to total graft excision. Did they have complications that could have been avoided if you had done a subtotal excision to begin with?

Dr Ryan. Almost all patients treated by total graft excision did well and indeed did not suffer the complications we were trying to avoid by selectively using subtotal graft excision. But remember that the patients treated by total graft excision often had poorly incorporated grafts at the anastomosis. Therefore, the dissection was easier and inadvertent injury to the adjacent veins and nerves was less likely than if the graft was well incorporated, which were the situations in which we employed subtotal graft excision. The six patients who ultimately required total graft excision after failing partial graft excision also did well.

Dr Dean J. Wickel (San Antonio, Tex). I have a question about how you and Dr. Calligaro handle patients who are admitted by the nephrologist for bacteremia, maybe not overtly septic. You do a CT scan or an ultrasound, you don't find any obvious fluid around the graft, and then they order that tagged white cell study which lights up a little something around your graft. How do you handle those patients?

Dr Ryan. It really depends on the clinical situation. We agree that you must aggressively look for other sources of infection. If none are found and you have a positive white cell scan, the study is very sensitive for the presence of infection. So I think that you should treat those aggressively in the absence of any other source of infection.