maining kidney. Nevertheless, long-term, follow-up studies of renal function and anatomy in patients with renovascular hypertension underscore the frequently progressive nature of the disease both in the ipsilateral and in the contralateral kidney.[8,9] For this reason, aggressive use of revascularization rather than nephrectomy in patients with favorable characteristics predictive of functional retrieval should provide improved long-term management of such individuals. Application of the predictors identified in this report to this decision should allow more accurate selection of the appropriate operation and thereby limit the frequency of either unnecessary nephrectomy or inappropriate attempted revascularization.

References

1. Dean RH, Lawson JD, Hollifield JW, et al. Revascularization of the poorly functioning kidney. Surgery 1979; 85:44–52.
2. Dean RH, Krueger TC, Whiteneck JM, et al. Operative management of renovascular hypertension: results after 15–23 years follow-up. J Vasc Surg 1984; 1:234–242.
3. Moses LE, Emerson JD, Hosseini H. Analyzing data from ordered categories. N Engl J Med 1984; 311:442–448.
4. Morris GC Jr, DeBakey ME, Cooley DA. Surgical treatment of renal failure of renovascular origin. JAMA 1962; 182:113–116.
5. Novick AC, Pohl MA, Schreiber M, et al. Revascularization for preservation of renal function in patients with atherosclerotic renovascular disease. J Urol 1983; 129:907–911.
6. Dean RH, Rhamy RK. Split renal function studies in renovascular hypertension. *In* Ernst CB, Fry WJ, Stanley JC, eds. Renovascular hypertension. Philadelphia: WB Saunders, 1984:135–145.
7. Zinman L, Libertino JA. Revascularization of the chronic totally occluded renal artery with restoration of renal function. J Urol 1977; 118:517–521.
8. Dean RH, Kieffer RW, Smith BM, et al. Renovascular hypertension: anatomic and renal function changes during drug therapy. Arch Surg 1981; 116:1408–1415.
9. Dean RH. Renovascular hypertension. Curr Probl Surg 1985; XXII: 6–67.

Discussion

DR. JAMES C. STANLEY (Ann Arbor, Michigan): Until a few years ago, improvement in renal function following renovascular reconstructive procedures was considered anecdotal and viewed with appropriate caution, albeit perhaps from an overly conservative perspective. The Vanderbilt experience clearly defines a number of issues regarding this topic, although a few comments regarding certain similarities and differences with other series deserve mention.

Small kidney size alone seems to be an unreliable basis for deferring operative intervention in patients with renovascular hypertension and impaired renal function. Many small kidneys can be revascularized with the resultant improvement in renal function, if the reduced renal mass is due to vascular rather than parenchymal disease. In certain cases, improved renal function may be related more to better control of the hypertension than to preservation of renal mass. For instance, in the Michigan experience with 42 chronic occluded renal arteries, there were nine nephrectomies performed as the only treatment for renovascular hypertension, and four of those had improved postoperative renal function (Surgery 1981; 89:753–763). This was considered due to improved postoperative control of hypertension with reversal of nephrosclerotic changes in the remaining contralateral kidney. This event is uncommon but underscores the complexity of improved function following revascularization procedures. An arbitrary decision to perform nephrectomy with kidneys less than 9 cm in length would seem unreasonable. In fact six of 22 patients with total occlusion of their renal arteries who were revascularized in our experience had kidneys less than this size, with all but one having a beneficial response regarding blood pressure control and half exhibiting improved postoperative renal function.

There also may be functional improvement in less azotemic patients than those described by the authors. In our same experience with totally occluded renal arteries, using serum creatinine levels of 1.8 mg/dl as a dividing point, those above that value demonstrated decreases in serum creatinine from a mean of 3.1 to 2.1 mg/dl after surgery, a significant change with the p value < 0.01. Individuals having creatinine levels lower than 1.8 demonstrated a fall from a mean of 1.3 to 1.1 mg/dl after surgery, not a very impressive change, although, with few exceptions, the direction of change was nearly always the same, with a resultant p value < 0.005. Perhaps Dr. Dean could comment on the effect of revascularization in patients with lesser degrees of impaired renal function and more importantly offer his perspective on what happens to these individuals if no operation is offered—something that carried a real risk to patients in our series.

Another point of departure in the Michigan experience was that the preoperative absence of angiographically demonstrable renal vasculature meant performance of intraoperative arteriography or some other method of assessing reconstructive operability before nephrectomy was undertaken. Only 47% of our patients with totally occluded renal arteries had preoperative demonstration of distal renal vessels noted by what most of us would consider very excellent arteriographic studies. More than half these patients were successfully revascularized.

Lastly, in these times where cost containment is an important influence in our practices, one must realize that if one of 15 patients experiencing severe renal failure due to renovascular disease can be kept off of dialysis by renal revascularization, then one can justify the cost in both dollars and morbidity for operating on the other 14. Dr. Dean's paper has given us some clear directions in identifying those patients who might benefit most from our surgical efforts.

DR. GEORGE C. MORRIS, JR. (Houston, Texas): Two overlapping groups can be distinguished for study: one, patients undergoing revascularization for azotemia, and two, treatment of the totally occluded renal artery.

Our original report on the treatment of renal failure of renovascular origin in eight patients published in 1962 showed that all patients had either extreme bilateral occlusive disease or marked unilateral renal artery stenosis with absence of the contralateral kidney.

(Slide) Two patients are illustrative: A 38-year-old male had albumin in the urine since childhood and hypertension since early adulthood. During the year before operation, hypertension became resistant to treatment with congestive heart failure and blood urea nitrogen ranging from 200–300 milligrams per cent. This aortogram showed an atrophic right kidney and a normal left kidney supplied by a large left renal artery with extreme proximal stenosis. (Slide) A remarkable diuresis followed spleno-renal shunt with resolution of hypertension and heart failure.

(Slide) This 66-year-old female presented with hypertension and progressive azotemia. An aortogram showed proximal high-grade stenosis in the right renal artery and an occluded left renal artery with atrophic left kidney. Following left nephrectomy and right iliac-to-renal bypass, renal function improved with a salutary blood pressure response. Subsequent experience has confirmed that success in treating azotemia by revascularization is premised on the presentation of severe bilateral disease.

(Slide) In 1980, we published a review of 40 hypertensive patients as a guide to determine which patients should undergo reconstruction of a totally occluded renal artery. This patient had a totally occluded left renal artery with a normal-sized nonfunctioning kidney. (Slide) Revascularization restored function and normotension. (Slide) While the presence of a nephrogram, renal excretions, and visualized distal artery are

comforting, these factors were not good predictors of outcome. We show here that renal size is the best guide for management.

(Slide) In summary, kidney size is the best predictor of long-term success for revascularization of totally occluded arteries. Nephrectomy and contralateral reconstruction had a 100% success rate for hypertension when a small kidney was present. In complicated situations where one kidney is revascularized, small kidneys supplied by totally occluded renal arteries can be left untreated. Revascularization of small kidneys is feasible sometimes when preservation of renal function is important. However, there is a 50% chance that subsequent nephrectomy will be required for severe hypertension, especially if the graft is patent.

I would like to ask Dr. Dean if his work showed significant correlation between renal mass and polar lengths, and request any reflections he might have with respect to age, associated pathology, and primary pathology.

DR. RONALD J. STONEY (San Francisco, California): My remarks concern the patient who has impaired renal function. These patients, in the past, have not often been considered for renal revascularization, because the possibility of functional recovery was not well defined. Today, the beneficial response to revascularization is well documented in the results from the Vanderbilt study. Most patients experienced a significant fall in serum creatinine and a rise in overall renal function. This has been our own experience, namely that more than 80% of the patients derive a substantial benefit following renal revascularization in terms of function as well as cure or control of hypertension.

Since all of Dr. Dean's cases were selected on the basis of a satisfactory revascularization, I hope he will tell us how he made this determination. We have used intraarterial ultrasound recently, rather than an intraoperative arteriogram, to determine the adequacy of renal revascularization. I think this is crucial information prior to closure, since thrombosis is likely to result in renal infarction and, of course, a worsening of the renal functional impairment or hypertension. The ultrasound is safe, simple, and avoids the problems of reclamping the aorta or the introduction of potentially nephrotoxic dye. I wonder if Dr. Dean has had experience with this in the intraoperative assessment of his renal reconstructions.

He emphasized the reduced renal length as a marker of ischemia in his patients, and an increase in renal length is one of the markers of a successful revascularization. I noted however, that five of the 17 patients who had successful revascularization did not demonstrate an enlargement of the kidney. Was this because of severe preexisting ischemic damage, such as atrophy or infarction? Perhaps he can tell us his reasons why he thinks these patients fail to show improvement in renal length.

This paper will serve as a standard on the benefits of revascularization, particularly in retrieving renal function in severely ischemic kidneys.

DR. CHARLES E. LUCAS (Detroit, Michigan): The work of glomerular filtration is performed by the heart. During the early postoperative period, multiple factors independent of the renin and angiotensin system are operative.

I wonder if all the postoperative studies were performed after the patients had fully recovered, were on diet, and off intravenous fluids.

DR. RICHARD H. DEAN (Closing discussion): Dr. Lucas, we were concerned about the effects of operation on data obtained in the immediate postoperative period. For example, serum creatinine levels obtained within the first 12 hours are always better irrespective of what you have done. Therefore, we built in delays between operation and the initial test result used in the data. At least 3 weeks delay for serum creatinine and at least a week for the remainder of the data were used in this analysis.

In regard to Dr. Stoney's questions, a successful repair was determined on postoperative angiography with the identification of a patent graft without technical error. We felt that, to come up with some preoperative predictors, we would make the assumption that the response, or lack of response, was based on preoperative predictors rather than the failure of the surgeon. Therefore, we excluded all technical failures from data analysis. Thankfully, we had relatively few patients excluded on this basis.

Although we have no experience with intraoperative ultrasound and have routinely measured graft flows, we continue to use angiography to clarify technical success.

In regard to the five kidneys that responded without increase in length after successful revascularization, we believe it reflects the heterogenicity of intrarenal disease in these patients and the natural history. Specifically, some of these kidneys have progression of intrarenal disease and shrink even in the face of a patent graft. We did not see any significant difference between the patients who had total occlusion and those who had subtotal occlusion before surgery in regard to response to operation in any of the parameters evaluated.

I certainly appreciate Dr. Morris' comments, for, I think, his Center has been a leader in the field of identifying the salutary effect of revascularization in the severely azotemic patient. I stress, however, there are two groups of people: the patient who does not have serious azotemia and has a poorly functioning kidney, and the severely azotemic patient.

Certainly nephrectomy of the relatively small kidney will provide a significant benefit by providing better blood pressure control. Nevertheless, because of the frequency and progression of disease in the contralateral kidney, we feel that revascularization can be potentially beneficial even in a small kidney, and that, overall, those patients will be significantly helped. Within the confines of the kidneys revascularized in our study, there was no difference in the response relative to improving function in the small kidney *versus* the large kidney. Thus, we, in contrast to Dr. Morris, would feel that renal length is not a useful predictor and that other parameters are more useful. These more useful positive predictors simply are less frequently positive in the very small kidney.

With regard to the relationship between renal length and renal mass, the kidney is an oblate ellipsoid and a 10% loss in renal length is equal to about a 30% loss in renal parenchymal mass. Therefore, relatively small changes in renal length have great significance relative to changes in mass available for function.

I certainly appreciate Dr. Stanley's points. Basically, the point of this paper is, that having taken a very aggressive attitude regarding attempted revascularization of all kidneys, how can one identify those patients who would best be served by primary nephrectomy. We were encouraged by the results of this. Although Dr. Stanley's group showed a significant benefit in patients with less severe creatinine elevations before surgery, in our subgroup with serum creatinine ranging from 2 to 3 milligrams per cent, a benefit that was barely insignificant, $p = 0.051$, was identified.