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Surgical Renovascular Reconstruction for Renal Artery Stenosis and Aneurysm: Long-Term Durability and Survival

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WHAT THIS PAPER ADDS

This long-term study, with a median follow up of >10 years, has demonstrated excellent durability, low mortality, and fairly low morbidity in association with open surgical renal artery reconstruction, and provides an important reminder of the feasibility of open surgical repair in selected patients, such as if the lesion is situated close to the renal artery bifurcation, in case of multiple renal arteries and in young patients, as well as after failed endovascular intervention or recurring stenosis. In patients with atherosclerotic renal artery disease there is a particular need for improved criteria for invasive therapy.

Objective: To study functional outcome, mortality, and dialysis free survival in patients undergoing open primary surgical repair of renal artery stenosis (RAS) or aneurysm (RAA).

Methods: This was a retrospective single centre study of patients undergoing open surgical renal artery reconstruction from 1993 to 2007. Blood pressure, renal function, dialysis dependence, vessel patency, and mortality were registered. Survival was investigated by cross matching with the population registry, yielding up to 20 years of follow up.

Results: Of the 40 patients operated on, 25 (63%) were women. RAS was the indication for reconstruction in 31 patients; 23 had atherosclerotic aetiology (ARAS), and eight had fibromuscular dysplasia (FMD). Nine patients had RAA. Patients with ARAS were older ($p = .008$), had more extensive peripheral arterial disease ($p = .004$), and inferior renal function ($p = .003$) compared with patients with FMD or RAA. In FMD and RAA, the right renal artery was affected in 13/17 (76%) cases, whereas in ARAS the disease was evenly distributed. In patients with ARAS, 15/25 (60%) stenotic renal arteries (two bilateral procedures) were managed by aorto-renal bypass, and 2/25 (8%) through ilio-renal bypass. In 8/25 (32%) endarterectomy was performed. In FMD, all but one patient underwent aorto-renal bypass. Early mortality was 2.5% (one patient with ARAS). One patient with ARAS required dialysis post-operatively. Systolic blood pressure was significantly reduced in patients with ARAS, from 180 mmHg (median) pre-operatively to 155 mmHg at one month ($p = .003$) and 160 mmHg at one year ($p = .03$). Need for medication decreased from three or more drugs to two drugs at one month ($p = .01$). In FMD, there was a similar tendency. Three patients underwent re-intervention for restenosis: two endovascularly and one by open surgery. The overall 5 year survival was 88%. Median follow up was 10.6 years.

Conclusion: Open surgical renal arterial reconstruction was performed with low mortality, fairly low morbidity, and excellent durability. Open surgery should still be considered a therapeutic option in complex renal artery disease.

Keywords: Fibromuscular dysplasia, Hypertension, Long-term follow up, Renal artery aneurysm, Renal artery stenosis, Renovascular, Survival
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INTRODUCTION

The demonstration by Goldblatt in 1934 that renal ischaemia was associated with persistent hypertension was the starting point for the era of surgical and subsequent endovascular management of renovascular disease.[1] Since then, renal arterial stenosis (RAS), which is most commonly the result of atherosclerotic disease (ARAS) or fibromuscular dysplasia (FMD), has been recognised as an important cause of non-essential hypertension and renal insufficiency; however, particularly in the elderly, it may be asymptomatic.[2,3]

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The earliest method applied as an attempt to cure renovascular hypertension was nephrectomy, which was later followed by the use of reconstructive techniques, endarterectomy or bypass, and the ensuing introduction of balloon angioplasty, percutaneous transluminal renal angioplasty (PTRA), with or without stent placement. However, the indications and patient selection criteria have varied widely over the years and across procedures. In spite of the lack of a clearly defined patient group that derives benefit from renal revascularisation, the number of percutaneous procedures rose steadily until 10 years ago. Before the results of the Angioplasty and Stenting for Renal Artery Lesion (ASTRAL)[2] trial and the Cardiovascular Outcomes in Renal Atherosclerotic Lesions (CORAL)[3] study were published, treatment of RAS was thought to reduce the overall risk of cardiovascular morbidity and mortality, but no such clinical benefit was found in the two randomised trials comparing renal artery revascularisation plus medical therapy to medical therapy alone. During the last decade the numbers have decreased considerably.[4,5] An important limitation, however, is that no trial has compared all three treatment modalities: best medical therapy (BMT) alone vs. PTRA + BMT vs. surgery + BMT. Two randomised trials on open surgical reconstruction vs. PTRA showed excellent durability and low complication rates associated with surgery, but neither of the studies showed any significant difference between PTRA and surgery with respect to improvement of hypertension or renal function.[6,7]

An additional, but rare, condition that may contribute to renovascular hypertension by causing functional RAS is renal artery aneurysm (RAA). Such aneurysms are usually diagnosed incidentally, but carry a risk of rupture and thromboembolism. Repair, either surgical or endovascular, has commonly been advocated for diameters >2 cm, RAA in women of childbearing age, and in patients with associated resistant hypertension.[8–11]

The aims of this study were to analyse long-term survival and early and mid-term outcomes with respect to blood pressure, renal function, and dialysis free survival in patients undergoing open primary isolated surgical repair of RAS or RAA.

MATERIALS AND METHODS

This was a retrospective single centre study of consecutive patients undergoing open surgical renal artery reconstruction for ARAS, FMD, or RAA during a 15 year period (1993–2007) at Uppsala University Hospital, Sweden. The treated patients were identified through the Swedish Vascular Surgery Registry (Swedvasc), and the medical records of all the patients were reviewed. Demographic data, operation variables, and early and long-term outcomes were registered, with particular emphasis on blood pressure, renal function, and survival. Swedvasc started as a regional registry in southern Sweden in 1987. Since 1994, all departments performing vascular surgery in the country enter their data prospectively into the database. The registry has been investigated on several occasions, showing high external validity (few missing cases), as well as internal validity (correct registration compared with data from case records).[12–14]

Through Swedvasc, 59 patients were found to have undergone open surgical renovascular reconstruction during the study period. However, four of them had previous open renal artery surgery and were registered in association with re-operations. The primary operation in one case was open thoraco-abdominal aortic aneurysm repair with bypass to the left renal artery; the second patient had undergone previous endarterectomy of the abdominal aorta including one renal artery; and two patients had undergone prior renal artery bypass surgery. In 12 patients simultaneous abdominal aortic aneurysm repair was carried out, two patients were operated on for traumatic renal artery injury, and finally in one case no hospital records were found, rendering a total of 40 patients undergoing primary isolated renal artery surgery, thus constituting the study group. In 31 patients, the reason for surgical repair was RAS; in 23 cases the stenosis was of atherosclerotic aetiology, and eight patients presented with FMD. The remaining nine patients were treated for RAA. In comparison, during the period 1996–2003, 152 patients underwent a total of 203 PTRA procedures with or without stenting for ARAS at the same tertiary referral centre.[15] Meanwhile, during that eight year period, 13 primary isolated operations for ARAS were carried out. Subdivision of the whole study period into five year segments indicated a tendency towards a slight gradual decrease in the number of open procedures: 17 cases done during the period 1993–1997, 13 operations from 1998 - 2002, and 10 between 2003 - 2007.

Several modalities were used for the pre-operative diagnostic work up to assess renal artery pathology and kidney function. The two predominant methods were duplex ultrasound with assessment of the peak systolic velocity and resistive index, and renal angiography. Of the 23 patients with ARAS, 22 underwent renal angiography with pressure measurement, 14 were additionally examined by duplex and nine patients also had renal scintigraphy. All of the eight patients with FMD had a duplex examination; six also underwent renal angiography. Additional magnetic resonance angiography ($n = 3$), scintigraphy ($n = 2$), and renal venous renin measurement ($n = 2$) were used in patients with FMD. Several RAA cases were discovered accidentally; five of the nine patients with RAA had undergone computed tomography, and the investigation was supplemented by either duplex ($n = 4$) or angiography ($n = 6$) or both. No patient underwent surgical repair based on ultrasound alone.

The indication for operative repair in RAS was the presence of a haemodynamically significant renal artery stenosis, with >70% diameter narrowing in at least one projection and a pressure gradient of >15 mmHg between the aorta and the renal artery distal to the stenosis on the renal angiogram, with concomitant resistant hypertension (uncontrolled hypertension despite use of three or more antihypertensive medications) or renal failure. Hypertension was defined as systolic blood pressure ≥140 mmHg or

diastolic blood pressure ≥90 mmHg, or the taking of antihypertensive medication. The threshold for renal insufficiency was serum creatinine >150 μmol/L or glomerular filtration rate (GFR) < 50 mL/min. The latter was calculated according to the Cockcroft–Gault equation.[16] The assessment of the effect of the renal artery reconstruction on the blood pressure was based on the Guidelines for the Reporting of Renal Artery Revascularisation in Clinical Trials.[17]

Of the 40 patients, eight were from the primary catchment area of Uppsala and 32 (80%) were referred from 13 other hospitals, mostly from central Sweden. Prior to discharge, all patients underwent renal duplex scanning, including measurement of renal artery and/or graft blood flow velocity and assessment of parenchymal resistance. The patients were further examined by duplex at one month, at one year, and thereafter annually. In cases of relapsing resistant hypertension and/or clear signs of restenosis on duplex, angiography was undertaken. Most patients were followed at their referring local hospitals in collaboration with the vascular surgeons at the Uppsala University Hospital. The head of vascular surgery and/or nephrology at each referring hospital was contacted by phone and/or mail to obtain data on those patients. To the authors' knowledge, no endovascular re-interventions took place in any of the patients at any other hospital.

As a unique 10 digit personal identity number is allocated to all Swedish citizens and permanent residents, long-term survival and cause of death can be followed accurately in all patients. In September 2013 all the patients were followed up with respect to survival by computerised cross linkage to two national registers, the Swedish Cause of Death Register and the Population Register. The latter is updated every week, and there is a maximum delay of three weeks from death to registration. By use of these combined registers, all patients could be assigned a date of death or identified as being alive on 1 August 2013, thereby providing a 5–20 year follow up for each patient.

The study was approved by the ethical committee of the Uppsala region.

Continuous variables were summarised with medians and ranges, and categorical variables with frequencies. The Kruskal–Wallis H test was used to determine any differences between the groups. The Wilcoxon signed ranks test was employed for within group comparisons. The Kaplan–Meier method was applied for survival analysis. IBM SPSS Statistics for Windows 22.0 was used for data processing and statistical analyses.

RESULTS

Of the 40 patients, 25 were women (63%). Of patients with RAS, 22/31 (71%) were women, whereas there was a male predominance among patients with RAA (Table 1). The median age of the entire cohort was 60 years (range 23–78 years). Patients with ARAS were older than those of the two other groups ($p = .008$). In 22 of the 23 patients with ARAS the predominant indication for renal artery reconstruction was hypertension. In the remaining case, renal failure secondary to renal ischaemia was the primary indication. Nine of the patients with ARAS suffered from a combination of hypertension and renal failure. None of the FMD patients underwent surgery for renal failure; all eight patients had difficulty controlling their hypertension, despite the use of multiple antihypertensive drugs. Mean aneurysm diameter in patients with RAA was 27 mm (range 15–42 mm). The diameter distribution of the repaired aneurysms is presented in Fig. 1. All RAAs had some degree of calcification on pre-operative imaging.

Table 1. Baseline characteristics of 40 patients undergoing open surgical renal artery reconstruction between 1993 and 2007

	ARAS ($n = 23$)	FMD ($n = 8$)	RAA ($n = 9$)	p-value
Women	16 (70)	6 (75)	3 (33)	.12
Age, years	70 (29–78)	51 (24–55)	58 (23–66)	.008
Diabetes	2 (9)	0	0	.47
COPD	1 (4)	0	0	.69
Ischaemic heart disease	4 (17)	0	1 (11)	.47
Heart failure	2 (9)	1 (13)	0	.60
Cerebrovascular insult	3 (13)	2 (25)	0	.31
Peripheral vascular disease[a]	11 (48)	0	0	.004
Renal function and blood pressure				
Serum creatinine, μmol/L	148 (84–331)	103 (74–138)	84 (72–140)	.001
GFR, mL/min	37 (14–122)	75 (52–82)	88 (54–149)	.003
SBP, mmHg	180 (130–240)	160 (105–190)	140 (115–170)	.002
DBP, mmHg	95 (70–135)	80 (60–100)	90 (80–100)	.22
No. of antihypertensive drugs				.002
0	1 (4)	0	3 (33)	
1	2 (9)	0	3 (33)	
2	4 (17)	2 (25)	2 (22)	
≥3	15 (65)	6 (75)	1 (11)	

Data are *n* (%) or median (range). ARAS = atherosclerotic renal artery stenosis; FMD = fibromuscular dysplasia; RAA = renal artery aneurysm; COPD = chronic obstructive pulmonary disease; GFR = glomerular filtration rate; SBP = systolic blood pressure; DBP = diastolic blood pressure.
[a] Vascular disease other than renal and cardiac.

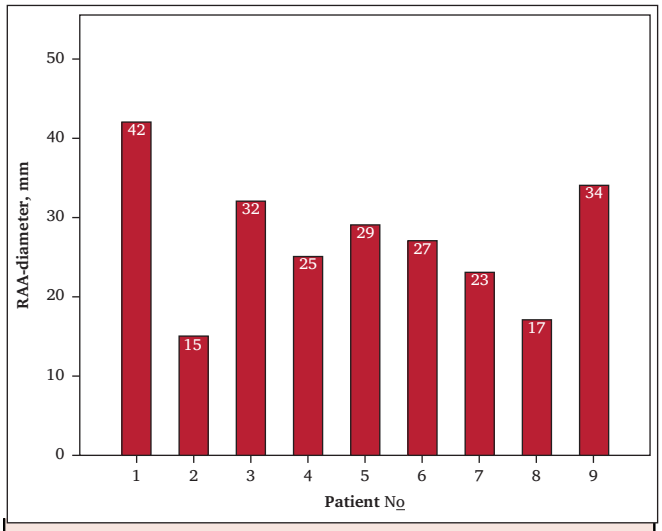

Figure 1. Size distribution of the renal artery aneurysm (RAA) in 9 patients undergoing surgical repair.

As PTRA was available during the entire study period, each patient was assessed with respect to anatomical and pathophysiological conditions to select the most suitable technique. In fact, six patients with ARAS (26%) had undergone PTRA of the affected renal artery with unsatisfactory result prior to the surgical reconstruction. Two patients with FMD (25%) had primarily been treated endovascularly by balloon angioplasty, whereas no patient with RAA had been considered suitable for endovascular repair.

In addition to being older, patients with ARAS also had inferior renal function, with a higher pre-operative serum creatinine level and lower GFR than patients with FMD or RAA, respectively (Table 1). A GFR <50 mL/min was present in 67% of the patients with ARAS, and 11 of 23 (48%) of the patients with ARAS also had extra-renal peripheral arterial disease, whereas none of the patients with FMD or RAA did ($p = .004$). Patients with ARAS, as well as patients with FMD, were taking a median of three antihypertensive drugs. All of the eight patients with FMD had normal renal function. The patients with RAA had a median use of one antihypertensive drug. All of them had normal renal function. The risk of rupture was the principal indication for surgical repair in patients with RAA; one woman was of childbearing age. One patient had suffered embolisation from the aneurysm thrombus, threatening renal function.

Renal artery disease was evenly distributed between the right and left side in patients with atherosclerotic disease; two patients with ARAS underwent bilateral procedures, in 11 cases the right renal artery was reconstructed, and in 10 patients the left renal artery. Thus, in the 23 patients with ARAS, 25 renal arteries were repaired. In FMD, the disease was located in the right renal artery in seven of eight patients (88%). Of the patients with RAA, six of nine (67%) aneurysms were located on the right side. Three had an aneurysm of the main renal artery, in two patients the aneurysm was situated in conjunction with the first bifurcation, and in four it was even more peripheral.

All but two renal artery reconstructions were carried out *in situ*. In one FMD and one patient with RAA, the repair was done back table with the kidney explanted and perfused, followed by auto-transplantation. One patient with ARAS underwent simultaneous contralateral nephrectomy. The most frequent reconstructive method in patients with ARAS was aorto-renal bypass, in most cases using synthetic grafts (Table 2). In one third of the patients with ARAS the lesion was managed by endarterectomy (Fig. 2). Aorto-renal bypass with a synthetic graft was carried out in six of eight (75%) of the patients with FMD. In five (56%) of the patients with RAA, the aneurysm was resected. The renal artery was reconstructed with an autologous vein graft in two of the cases and with synthetic graft in three. In four patients with RAA (44%), aneurysmorrhaphy was performed, as first described by Matas.[18]

The effect of the operation on blood pressure and serum creatinine is demonstrated in Table 3. In patients with ARAS, systolic blood pressure decreased at one month ($p = .003$) and at one year ($p = .03$) post-operatively. There was also a beneficial effect on the number of antihypertensive drugs at one month ($p = .01$). Similar trends were observed in patients with FMD but did not reach statistical significance.

There was one early death ($n = 1/40$ [2.5%]): a 61 year old woman with ARAS and extensive peripheral arterial disease. She underwent bilateral procedures and developed bowel ischaemia post-operatively. Bowel resection was performed, but the patient died on the second post-operative day. Another three patients underwent re-operation for bleeding within the first 2 days, and yet another one after three weeks, to evacuate a haematoma. One patient with FMD developed graft stenosis, which was

Table 2. Technique used for renal artery reconstruction

Surgical method	ARAS ($n = 25$)[a]	FMD ($n = 8$)	RAA ($n = 9$)
Bypass	17 (68%)	8 (100%)	0
Aorto-renal	15 (60%)	7 (88%)	–
Autologous vein	1	1	–
Dacron	4	3	–
PTFE	8	3	–
Dacron + PTFE	2	0	–
Ilio-renal	2 (8%)	1 (12%)	–
Autologous vein	0	1	–
Dacron	1	0	–
PTFE	1	0	–
Endarterectomy	8 (32%)	0	0
Aneurysmorrhaphy	0	0	4 (44%)
Aneurysm resection[b]	0	0	5 (56%)
Autologous vein			2
Dacron			3

ARAS = atherosclerotic renal artery stenosis; FMD = fibromuscular dysplasia; RAA = renal artery aneurysm. PTFE = polytetrafluoroethylene.

[a] Two patients with ARAS underwent bilateral procedures, hence 25 renal artery reconstructions in 23 patients.

[b] Material used for renal arterial reconstruction in association with aneurysm resection.

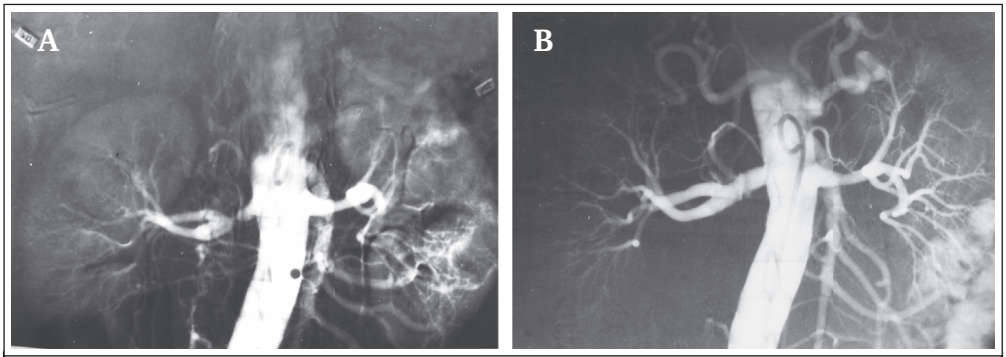

Figure 2. (A) Pre-operative and (B) post-operative renal angiogram in a patient undergoing patch angioplasty for right renal artery stenosis.

Table 3. Outcomes up to one year after open surgical renal artery reconstruction

	ARAS (n = 23)	*p*-value *vs* baseline	FMD (n = 8)	*p*-value *vs* baseline	RAA (n = 9)	*p*-value *vs* baseline
Pre-operative SBP	180 (130–240)		160 (105–190)		140 (115–170)	
SBP (mmHg) one month post-op	155 (120–205)	.003	137 (112–170)	.13	140 (120–155)	.44
SBP (mmHg) one year post-op	160 (120–220)	.03	142 (130–180)	.35	150 (140–170)	.22
Pre-operative serum creatinine (μmol/L)	148 (84–331)		103 (74–138)		84 (72–140)	
Serum creatinine one month post-op (μmol/L)	142 (76–696)	.31	104 (81–142)	.89	125 (72–136)	.22
Serum creatinine one year post-op (μmol/L)	138 (75–713)	.70	105 (86–121)	.46	85 (75–171)	.07
Number of antihypertensive drugs at one month	2.0 (1–4)	.01	2.5 (1–4)	.11	1.0 (0–4)	.32

Data are median (range). *P* values refer to within group comparisons; all comparisons relate to the pre-operative value. ARAS = atherosclerotic renal artery stenosis; FMD = fibromuscular dysplasia; RAA = renal artery aneurysm; SBP = systolic blood pressure.

managed with surgical patch angioplasty six months post-operatively, another patient had an incisional hernia repair after 14 months, and finally there was a patient with RAA with multiple aneurysms who was readmitted for recurring aneurysms. In total, eight of 40 (20%) patients underwent open re-intervention for various reasons. Two other patients were treated for renal artery restenosis endovascularly, after 2 months (patient with ARAS) and 34 months (patient with FMD), respectively.

All but the one patient who died were examined by duplex prior to discharge, in total 39 patients (40 reconstructions), with open reconstructions in every case. One patient, a 75 year old woman, required renal replacement therapy (RRT) post-operatively. In a 74 year old woman, RRT was initiated three years post-operatively. Both had ARAS. For the whole cohort, two occlusions were identified on routine duplex surveillance, after three and five years, respectively. The occlusions were left untreated as the kidneys were hypotrophic.

Median follow up was 10.6 years (interquartile range 6.4—13.8 years), and, at the end of follow up, 24 patients were still alive. Fifteen of the 16 deaths occurred in patients with ARAS, whose five year survival was 78 ± 9% and 10 year survival 47 ± 11%. Five year survival of the entire cohort was 88 ± 5% and 10 year survival 69% ± 8% (Fig. 3).

DISCUSSION

The present study has demonstrated excellent primary patency with very few target artery re-interventions, and low mortality associated with open surgical renal artery reconstruction. Three of four patients had an uneventful long-term course without any major complication or need for open or endovascular re-intervention. The findings of this report highlight the importance of resolving the indications for renal arterial revascularisation in RAS, and to establish what patient categories might benefit from being offered open surgery.

The undecided findings of the two fairly recent randomised trials, assigning a total of more than 1700 patients with ARAS either to undergo PTRA combined with BMT or to receive BMT alone, have caused renewed debate on the need for improved identification of patients who would benefit from renal artery revascularisation.[2,3,19] The ASTRAL trial was a multicentre study, principally from the UK, enrolling patients during the years 2000—2007, that demonstrated no clinical benefit from revascularisation on the rates of renal events, major cardiovascular events, or death.[2] The exclusion criteria included previous renal artery revascularisation, patients considered to require surgical revascularisation, or those who were thought to need revascularisation within the next six months; all of the above rendered the findings less generalizable. The CORAL study was a multicentre trial from the USA, randomly assigning patients to either regimen during the period 2005—2010, showing that PTRA did not confer a significant advantage in prevention of clinical events or all cause mortality.[3] In neither one of the trials, however, was intra-arterial pressure measurement performed routinely,

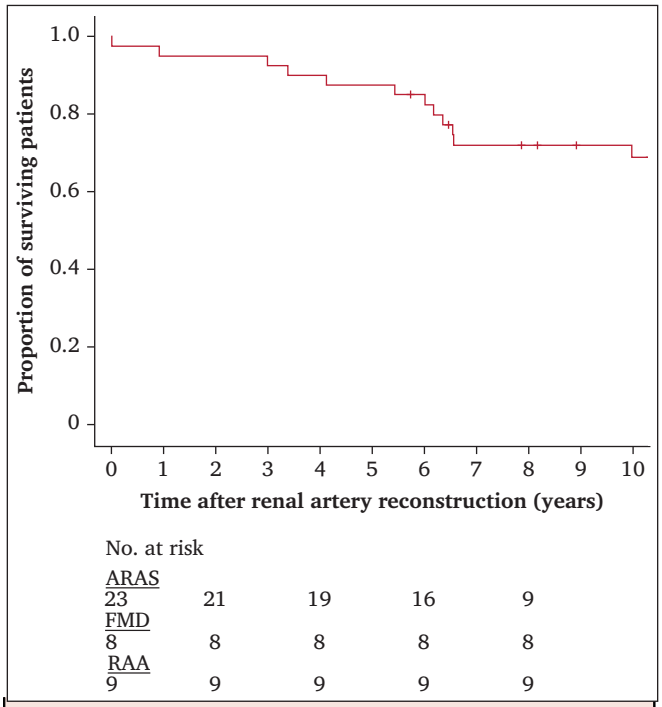

Figure 3. Kaplan Meier estimates of survival after renal arterial reconstructive surgery, with respect to the underlying pathology. As there were no deaths in the FMD or RAA groups, the numbers at risk remain unchanged throughout the period. The curve also illustrates that all the deaths occurred in the ARAS group. ARAS = atherosclerotic renal artery stenosis; FMD = fibromuscular dysplasia; RAA = renal artery aneurysm.

whereas in the present study it was part of the routine prior to renal revascularisation, both open and endovascular.

The results of these two major trials are in accordance with the outcome of a prospective, population based study, which found a very low rate of progression of ARAS in prevalent cases, albeit that only 55% of the participants were on antihypertensive medication. Progression to significant stenosis was even more infrequent, and no case progressed to occlusion.[20] The result of a previous study of patients with a single functioning kidney and contralateral atherosclerotic renal artery occlusion indicated that low GFR was the most important predictor of death or dependence on RRT, whereas renal vascular anatomy had no impact on the outcome.[21] It is likely that in patients with ARAS, variables other than excretory function should also be estimated, such as renal blood flow, renal size, and intrarenal parenchymal and vascular disease.[19,21] Obviously, medical management of atherosclerotic peripheral vascular, renal, and coronary artery disease has improved dramatically over the last two decades, which most probably has contributed to the slower disease progression in ARAS. Thus, the indication for revascularisation in ARAS is still controversial. The results of this report have shown that, when indicated, open surgery can be performed with acceptable risk and excellent durability.

Patients with FMD are often considerably younger, have fewer risk factors for atherosclerosis, and fewer comorbidities than patients with ARAS. Renal failure secondary to FMD is much less common than in ARAS. Unsatisfactory control of hypertension is generally considered a reason to intervene, and endovascular treatment has gradually become the first choice, whereas surgery is often reserved for patients with complications of PTRA or recurrent stenosis after PTRA.[22] In the present series of patients with FMD, the right renal artery was more commonly affected than the left. That was also the case for RAA. Previous studies have made the same observation,[9,23] suggesting that the right artery may be more prone to traction and intramural ischaemia as it is longer than the left renal artery. FMD, in turn, may be a cause in the development of RAA. Early outcome of both PTRA and surgery is generally favourable in FMD. Long-term follow up of patients by the Düsseldorf group, showed a primary patency rate of 74% at five years, and secondary patency rate of 85%, but a fairly low number of patients were cured of their hypertension.[24] In the present study, there were no occlusions in patients with FMD, but two patients developed restenoses.

Available graft materials for open repair include saphenous vein, hypogastric artery, and synthetic conduit. In addition to trans-aortic endarterectomy for ARAS, a saphenous vein graft has traditionally been used for reconstruction or bypass, both in ARAS and FMD. A favourable outcome has also been demonstrated with synthetic grafts, which were used predominantly in the present report.[25] As surgical therapy nowadays is mostly the second choice treatment, after failed PTRA or in restenosis after one or more previous endovascular attempts, the reported results of surgery may not be as good as after primary surgery. Surgical repair may be particularly beneficial in anatomically complicated lesions involving the renal artery bifurcation or in coexisting RAA.[26] Similar considerations should be made in the management of patients with RAA, who in most cases are treated by stent graft relining or coil embolisation. In young patients with renal artery branch aneurysm, *ex vivo* repair with kidney auto-transplantation has been shown to have durable results, using the hypogastric artery as the graft in the majority of cases.[27] Patients with FMD or RAA are likely to benefit from centralised care. The recent guidelines of the European Society of Cardiology and the European Society for Vascular Surgery do not advocate routine revascularisation in RAS secondary to atherosclerosis, whereas in FMD with hypertension and/or renal impairment PTRA should be considered. The guidelines also underline the remaining role of open surgical repair under certain circumstances.[28]

In summary, this report has demonstrated favourable durability, as well as low mortality and fairly low morbidity, in association with open surgical renal arterial reconstruction. Patients with ARAS differ greatly from those with FMD or RAA, as ARAS is commonly part of a generalised disease. The present analysis is limited by the low number of patients, particularly with FMD or RAA, and single blood pressure measurement registrations with no ambulatory continuous home measurement data. Nevertheless, this long-term study, with a median follow up of >10 years, provides an important reminder of the potential benefits of

surgical repair in selected patients. Further studies to define the role of open surgery in FMD and in RAA are mandatory. In addition to the indications of failed PTRA or recurring stenoses, surgical repair should be considered in complex anatomy, such as when the lesion is situated close to the renal artery bifurcation, in cases of multiple renal arteries and in young patients. Renal artery disease cannot be assessed solely based on vascular anatomy and renal excretory function, but in particular in atherosclerotic patients with RAS, improved criteria for invasive therapy should be defined.

CONFLICT OF INTEREST

None.

FUNDING

None.

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