follow up period. Finnmark, where the association was weakest, had the longest follow up time. This inverse relationship between the length of follow up and the strength of the effect of coffee on coronary death fits in with the finding of La Croix *et al.*,⁴ who measured coffee intake several times and found that the estimate of relative risk based on the most recent measurement or on a cumulative measure was greater than that based on the first measurement of consumption.⁴

Subjects who had a high risk were recommended to have a further examination and intervention, if appropriate. For men the percentage referred increased with increasing coffee consumption, whereas for women it by and large decreased. Accordingly, the intervention may have weakened the relation between coffee consumption and death from coronary heart disease in men and strengthened it in women.

The major uncertainty relating to previous studies has been whether the apparent relation between coffee and death from coronary heart disease is mediated through correlated lifestyle factors.²¹ We took physical activity and stress into consideration, but we have no information about socioeconomic status. As regards diet, a cross sectional study of the first Oppland survey carried out five years before the Oppland part of this study showed that dietary habits and lifestyle could not explain the association of coffee and serum cholesterol concentration,¹⁰ and a follow up relating dietary habits and lifestyle to death from coronary heart disease has not yet been done.

We conclude that coffee consumption is fairly strongly related to death from coronary heart disease, but a potential causal role is weakened by the varying strength of the relation in different groups. To verify the observed effect of coffee on deaths from coronary heart disease over and above the effect on cholesterol concentration, cholesterol concentration must be determined more accurately than by a single measurement.

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Blood pressure response to percutaneous transluminal angioplasty for renovascular hypertension: an overview of published series

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Abstract

Objective—To evaluate the efficacy and safety of transluminal angioplasty in the treatment of renovascular hypertension.

Design—Overview of 10 published case series.

Setting—Mostly tertiary referral centres.

Patients—691 Patients treated by angioplasty for renovascular hypertension, 464 for atherosclerotic stenosis, 193 for fibromuscular stenosis, and the remainder mainly for post-transplant stenosis. The inclusion criteria varied considerably between studies.

Interventions—Percutaneous transluminal renal artery angioplasty (successful or attempted); prophylaxis against restenosis in most cases. Policies on antihypertensive drug treatment and follow up varied.

Main outcome measures—Blood pressure response in the individual papers, with each patient classified as either cured, improved, or failed. Each study used a different definition of improvement in blood pressure. Complication rates.

Results—Follow up data were available for 670 patients. The procedure was technically successful in 611 patients (88%). The overall cure rate for

hypertension was 24% (163 patients) and a further 43% (286) were "improved." There were large and significant variations between studies in the rate of technical success and also the blood pressure outcome. In each series patients with fibromuscular lesions, had a higher cure rate than those with atherosclerotic lesions (overall cure 50% v 19% odds ratio 3.9, 95% confidence interval 2.6 to 6.0). Complications were reported in 63 (9%) patients and three patients died (0.4%).

Conclusions—The evidence for the value of angioplasty in treating renovascular hypertension has serious limitations. Angioplasty for fibromuscular disease seems to be worth while, but for atherosclerotic lesions the benefit appears to be small and its efficacy needs to be compared with medical therapy in randomised trials. These findings emphasise the importance of early formal evaluation of new therapeutic techniques.

Introduction

During the past 10 years percutaneous transluminal angioplasty has been used widely to treat renovascular hypertension, and several case series have been pub-

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lished. We present here an overview of the findings in these series and assess the evidence for the efficacy and safety of the procedure.

Methods

We searched published reports up to the end of 1987 to identify series of hypertensive patients who had renovascular disease treated by angioplasty. Small series, arbitrarily defined as those with fewer than 30 patients, were excluded because a low success rate in centres with limited experience of the procedure would bias the findings against angioplasty. Those which included only specialised cases—for example, children or patients who had undergone transplantation—were also excluded, as were series which were incomplete because they did not account for technical failures. When more than one series had been reported from a single centre only the largest series was included in the analysis. Ten series were identified which fulfilled these criteria.¹⁻¹⁰

We extracted information on the protocol and findings of each study. When available, we sought the following items of information: *protocols*—selection criteria, measurement of blood pressure, follow up schedule, policy for adjusting antihypertensive drugs, use of prophylaxis against restenosis or thrombosis, definitions of cure and improvement; *findings*—number of patients in whom angioplasty was attempted, number of technically successful dilatations, the blood pressure response as categorised by the authors, measurements of renal function, the number and nature of any complications.

Results

PROTOCOLS

Selection criteria

The criteria used for selecting patients for angioplasty varied widely between these series. There was no uniformity in the degree of stenosis or the need for renal vein renin measurements. For example, three studies included patients with greater than 50% stenosis,^{3,7,10} while another included only patients with greater than 75% stenosis plus abnormal renal vein renin values.⁴ One centre included patients with angiographic evidence of stenosis of any degree, provided that there was lateralisation of renal vein renin values.⁵ In another the decision was made after a multi-disciplinary discussion of the results of a number of investigations.⁸ Four reports gave no selection criteria at all.^{1,2,6,9} Furthermore, none of the papers described the population from which the patients were drawn.

Blood pressure methods and follow up

Most reports gave little information about the follow up of patients, particularly with regard to the measurement of blood pressure. In four series follow up

appeared to have been conducted according to a defined schedule at the centre which performed the procedure.^{1,3,4,8} In three series, however, follow up blood pressure measurements were obtained elsewhere—for example, by writing or telephoning the patient or referring physician.^{6,7,10} Three reports did not state how or where the follow up measurements were obtained.^{2,5,9}

Drug policies

The reports gave little information about policies for adjusting antihypertensive drug treatment before or after angioplasty. In one centre antihypertensive drugs were stopped immediately before the procedure to avoid precipitous falls in blood pressure.¹⁰ The criteria for reintroducing treatment were not stated. Another report stated that patients had their usual drugs continued, reduced in dosage, or discontinued depending on the blood pressure response and also stated that alternative drugs were not used.³ The other reports gave no information about changes in antihypertensive drug treatment.

Prophylaxis against restenosis or thrombosis after angioplasty was used in all but ones series,¹ but the regimens varied. These included aspirin and dipyridamole,^{2,5,8,10} aspirin alone,^{4,6,7} aspirin or warfarin,⁹ and coumarin.³

Definitions of cure and improvement of hypertension

In all studies the definition of cure of hypertension after angioplasty required that the patient had been able to stop taking all antihypertensive drugs. In five centres cure was defined as a diastolic blood pressure of 90 mm Hg or less.^{1-4,10} In two further centres the proviso was added that diastolic blood pressure had to have fallen by 10 mm Hg or more from values before angioplasty.^{5,7} Three reports used both systolic and diastolic criteria,^{6,8,9} as follows: <140/90 mm Hg; <150/95 mm Hg; <160/95 mm Hg.⁹ It is not clear whether either or both systolic and diastolic blood pressure had to have reached these levels.

The various definitions of "improvement" in blood pressure used in this series are shown in table I. No two studies used exactly the same definition. Most of the definitions were complex and based on percentage falls in diastolic blood pressure and a reduction in medication. Four studies used definitions that were imprecise and open to a variety of interpretations.^{1,2,5,8} The vaguest definition, that blood pressure became easier to control after angioplasty,⁵ seems to have been interpreted liberally since all patients in this series who were not cured or victims of technical failures were judged to have been improved (see table II).

FINDINGS

Blood pressure outcome

In total 691 patients had been treated by angioplasty, 464 for atheromatous stenosis, 193 for fibromuscular

TABLE I—Definitions of "improvement" in blood pressure after renal artery angioplasty in 10 series of hypertensive patients

Reference No	Definition
1	Diastolic blood pressure <90 mm Hg with medication markedly reduced or Diastolic blood pressure >90 mm Hg with decreased medication plus significant reduction (comparison of 4 baseline against 3 post-treatment measurements, $p < 0.01$ in a one tailed t test)
2	Blood pressure significantly reduced (diastolic blood pressure <100 mm Hg) with decreased medication
3	Diastolic blood pressure 91-109 mm Hg with a decrease of at least 15% or a decrease of at least 10% plus one drug stopped
4	Diastolic blood pressure decreased by at least 15%
5	Blood pressure became easier to control
6	Diastolic blood pressure decreased by at least 15 mm Hg with reduced medication
7	Diastolic blood pressure 90-110 mm Hg and decreased by at least 15%
8	Normotension on basic antihypertensive therapy or Diastolic blood pressure decreased by at least 10%
9	Diastolic blood pressure decreased by at least 15% to 95-110 mm Hg or Blood pressure 160-95 mm Hg or less with drug treatment
10	Diastolic blood pressure decreased at least 15% with drug treatment

TABLE II—Summary of outcome after angioplasty for renal artery stenosis in 10 published series of hypertensive patients. Results are numbers (percentages) of patients

Reference No	Angioplasty attempted	Excluded from analysis*	Technical failure	Blood pressure response†		
				Cured	Improved	Failed
1	31	3	5 (16)	7 (25)	6 (21)	15 (54)
2	68	0	10 (15)	12 (18)	38 (56)	18 (26)
3	70	0	2 (3)	14 (20)	29 (41)	27 (39)
4	89	0	21 (24)	26 (29)	22 (25)	41 (46)
5	98	0	7 (7)	25 (26)	66 (67)	7 (7)
6	63	8	8 (13)	16 (29)	17 (31)	22 (40)
7	94	2	12 (13)	14 (15)	42 (46)	36 (39)
8	80	0	11 (14)	21 (26)	29 (36)	30 (38)
9	65	7	5 (8)	20 (34)	22 (38)	16 (28)
10	33	1	3 (9)	8 (25)	15 (47)	9 (28)
Totals	691	21	84 (12)	163 (24)	286 (43)	221 (33)
Range (%)			3-24	15-34	21-67	7-54

*Excluded from analysis of blood pressure response because they were not followed up.

†Results cover total number of patients followed up, including those in whom angioplasty was a technical failure.

TABLE III—Summary of outcome after angioplasty in 10 published series of hypertensive patients according to indication for angioplasty (atheromatous or fibromuscular renal artery stenosis). Results are numbers (percentages) of patients

Reference No	Atheromatous renal artery stenosis				Fibromuscular renal artery stenosis			
	Technically successful angioplast	Blood pressure response			Technically successful angioplasty	Blood pressure response		
		Cured	Improved	Failed*		Cured	Improved	Failed*
1	13	2 (15)	4 (31)	7 (54)	8	5 (63)	1 (13)	2 (25)
2	44	8 (18)	29 (66)	7 (16)	9	4 (44)	5 (56)	0 (0)
3	44	4 (9)	19 (43)	21 (48)	21	10 (48)	10 (48)	1 (5)
4	34	7 (21)	10 (29)	17 (50)	27	16 (59)	9 (33)	2 (7)
5	61	15 (25)	46 (75)	0 (0)	27	10 (37)	17 (62)	0 (0)
6	34	5 (15)	15 (44)	14 (41)	13	11 (85)	2 (15)	0 (0)
7	60	9 (15)	30 (50)	21 (35)	26	5 (25)	12 (60)	3 (15)
8	48	11 (23)	21 (44)	16 (33)	21	10 (48)	8 (38)	3 (14)
9	31	5 (29)	15 (48)	7 (23)	22	11 (50)	7 (32)	4 (18)
10	22	3 (14)	13 (59)	6 (27)	7	5 (71)	2 (29)	0 (0)
Totals	391	73 (19)	202 (52)	116 (30)	175	87 (50)	73 (42)	15 (9)
Range (%)		9-29	29-75	0-54		25-85	13-63	0-25

*Excludes technical failures.

stenosis, and the remainder for other lesions, notably stenosis following transplantation. In eight reports which gave the mean duration of follow up after angioplasty this varied from 11 to 26 months, with a total of 21 patients (3%) having been lost to follow up. Table II summarises the blood pressure outcome of angioplasty in the 10 series. The procedure was technically unsuccessful in 84 patients (12%). The rate of technical failure between series varied from 3% to 24% and this difference was significant ($\chi^2=21.5$; $df=9$; $p<0.02$). In the analysis of blood pressure response presented in table II technical failures have been regarded as treatment failures, using the "intention to treat" principle. The numbers of patients cured and improved are those quoted in the original papers and are therefore subject to the varying definitions used.

Hypertension was cured by angioplasty in 163 patients (24%), and it was said to be improved in a further 286 (43%). One third of all patients were judged to have received no benefit. There was large variation between studies in blood pressure response, and these differences would not be expected by chance ($\chi^2=71.3$; $df=18$; $p<0.001$). In examining the reason for this, we found that the proportions of patients categorised as improved (21-67%) and failed (7-54%) varied greatly, although the cure rate was fairly uniform (range 15-34%).

To see whether or not these variations might be explained by differences in the type of lesion treated, we examined separately patients with atheromatous and fibromuscular stenoses. For most patients whose angioplasty was a technical failure the type of stenosis was not given. These patients and those who were not followed up (91 in total) were excluded from this analysis. The results in these two main diagnostic groups are shown in table III. In all 10 series the cure rate was higher for patients with fibromuscular stenosis

than for those with atheromatous stenosis (combined odds ratio 3.9, 95% confidence interval 2.6 to 6.0; figure). The overall cure rates were 50% in fibromuscular disease and 19% in atherosclerotic disease. Considerable variation in the blood pressure response was present within both major diagnostic categories. In particular, the failure rate in atherosclerotic lesions varied from 0 to 54% (table III).

Renal function

None of the reports included measurements of renal function before and after angioplasty for all patients studied, although two quoted data for 42/65⁹ and 27/33¹⁰ patients. Both studies apparently showed a significant improvement in renal function, although when this was analysed separately according to the type of lesion a mean reduction of 12 $\mu\text{mol/l}$ in serum creatinine concentration for atherosclerotic patients was not significant.⁹ Two other papers each reported considerable improvement in renal function in two patients with a single functioning kidney.¹⁴ One paper reported that in a subgroup of 29 patients with renal insufficiency before angioplasty renal function improved in 13 patients.⁵

Complications

Sixty three complications were reported in 691 patients (9.1%). Three were fatal (cholesterol embolism, cerebral haemorrhage, bowel infarction), a rate of 4.3 deaths per 1000 patients. According to the classification of Mahler *et al.*,¹¹ 56 complications (89%) were direct and seven (11%) indirect. It was not possible to determine from the reports the proportions of complications which were major and minor. Those most frequently reported were renal artery dissection (14), renal artery thrombosis or occlusion (10), segmental renal infarction (7), and haematoma formation or puncture trauma (7). The indirect complications were cerebrovascular accidents (3), myocardial infarction (1), anterior spinal artery thrombosis (1), brachial artery thrombosis (1), and bowel infarction (1).

Discussion

There have been no randomised trials comparing transluminal angioplasty for renovascular hypertension with surgical or medical treatment. Nevertheless, angioplasty is generally accepted to be as effective as surgery but simpler and safer, and it is increasingly

Log odds ratios (●) and 95% confidence intervals (—) for cure rates for fibromuscular versus atherosclerotic disease in 10 series of hypertensive patients treated by renal artery angioplasty. An odds ratio greater than 1 indicates a higher success rate in fibromuscular disease

regarded as the treatment of choice. The pooled results of published case series purport to show that hypertension was cured in a quarter of patients while one third obtained no benefit. To what extent the remaining patients did benefit from angioplasty is uncertain, mainly because these studies were uncontrolled, and "improvement" in blood pressure could have occurred spontaneously in a substantial proportion of patients.¹² Patients whose hypertension was cured by angioplasty still needed regular follow up plus prophylactic medication against restenosis.

Because of the possibility of publication bias, these findings may overestimate the true benefit from angioplasty—that is, series with findings unfavourable to the procedure may have been less likely to have been published. The studies reviewed also had several important weaknesses. The selection criteria were generally ill defined, and the patients studied were probably highly selected, which could have biased the findings in favour of angioplasty. Most studies were conducted in tertiary referral centres and their results may not be widely generalisable to unselected populations. There was significant variation in the technical failure rate between centres. This difference was probably due to selection factors rather than variation in technical skill.

There were also large differences between studies in the proportions of patients classified as improved or failed. Given the multiplicity of definitions of improvement in blood pressure (table I), this was hardly surprising. Definitions of cure were more uniform and cure rates varied much less. Other factors which may have accounted for differences in blood pressure outcome include manipulation of antihypertensive drugs and methods for evaluating the blood pressure response. Most of the follow up blood pressure data were inadequate because no attempt was made to prevent measurement bias, formal follow up schedules were not used, and policies on drug treatment were non-existent. An important part of the benefit from angioplasty is likely to be a treatment sparing effect,¹² but these studies did not document it.

The papers included in our overview also did not include enough data to permit an adequate assessment of the effect of angioplasty on renal function. Two studies apparently showed significant improvement in renal function, but the absence of data for some patients may have been a source of bias.^{9,10} Two papers published very recently provide relevant data on this point. In a study of atherosclerotic patients renal function after angioplasty was unchanged in the long term.¹³ Because there was no comparator group, it is uncertain to what extent this finding represents a benefit. Of 79 patients with renovascular disease of various causes accompanied by pre-existing renal insufficiency or deteriorating renal function, 34 (43%) had a reduction in serum creatinine concentration of 20% or more during a mean follow up period of 16 months after angioplasty.¹⁴ Overall, a beneficial effect of angioplasty on renal function has not been convincingly established.

The pooled analysis of 10 studies supports the view that the outcome of renal artery angioplasty depends on the type of stenosis treated. In all studies cure rates were higher for fibromuscular disease than for atherosclerotic disease. In patients whose angioplasty was technically successful the overall cure rate in fibromuscular disease was 50%. Despite our reservations about the methods of these studies, we do not doubt

that angioplasty for fibromuscular disease is worth while.

In atheromatous disease the cure rate after technically successful angioplasty was only 19%. In completely unselected patients atherosclerotic lesions are associated with a very high rate of technical failure, perhaps as much as 60%.¹² The true cure rate might therefore be as low as 8%. It is not certain whether such a small benefit is worth while, especially as atherosclerotic patients seem to be particularly susceptible to important complications.¹⁹ In atherosclerotic stenosis there is a need for randomised comparisons of angioplasty against standard medical treatment. Until such studies have been performed, angioplasty for atherosclerotic lesions is difficult to justify since the small benefit might well be outweighed by the risks.

We are critical of the haphazard and unscientific way in which angioplasty has been evaluated. There is a sharp contrast in the quality of data that is acceptable for evaluation between a theoretically attractive practical procedure such as angioplasty and a new drug. If these data had been used to support the efficacy of an antihypertensive drug, no regulatory body would have found them acceptable.

Technological advances in many different aspects of medical practice will continue to emerge, and if we are to avoid practising on the basis of fashion a more organised and critical approach to evaluation must be adopted. Choosing the right moment to perform controlled experiments is difficult because the technology and skill usually improve rapidly in the early years. This does not mean, however, that proper trials can be dispensed with. Such trials need to be scientifically rigorous and pragmatic both in design and assessment of outcome. Carefully chosen selection criteria are essential so that the findings will be broadly applicable to general populations.

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