Ann R Coll Surg Engl 1994; **76**: 132–135

GORA: a scoring system for the quantification of risk of graft occlusion

G P Copeland ChM FRCS[1]
Consultant Surgeon

P N Wake FRCS[1]
Consultant Surgeon

P Edwards MCh FRCS[2]
Consultant Surgeon

P L Harris FRCS[3,4]
Consultant Surgeon

A Wilcox[3]
Research Assistant

[1] Warrington Hospital NHS Trust
[2] Southport and Formby District General Hospital
[3] Broadgreen Hospital, Liverpool
[4] Royal Liverpool Hospital

Key words: Surgical audit; Vascular surgery; Vascular graft

Auditing the outcome from vascular surgery with regard to graft occlusion is made difficult by variations in the type of surgery performed and the case mix. These difficulties are compounded when attempting to compare units. In the present study we have attempted to develop a scoring system to predict the risk of graft occlusion, and thus compensate for these variables. Prospectively collected data from 214 consecutive patients undergoing vascular reconstructive surgery (233 arterial grafts) were analysed. Graft occlusion occurred in 82 patients (35.2%). Using a multivariate linear regression analysis of these data a five-factor, five-grade scoring system has been devised (GORA: Graft Occlusive Risk Assessment). Logistic regression analysis of the observed risk of occlusion with this derived score produced the following relationship between the odds ratio of occlusive risk and GORA score

$$(\log_e R/1-R=(0.229\times \text{score})-4.165)$$

The score was then validated in a different group of 186 patients (196 arterial grafts). In both groups the score was found to predict accurately the risk of graft occlusion ($P<0.001$). There was no significant difference in the receiver operating characteristic curves between the estimation and validation groups.

The use of autologous and prosthetic vascular grafts has increased over the past 20 years, both for limb salvage and in the management of occlusive and aneurysmal vascular disease. One major complication attendant upon such surgery is, of course, that of graft occlusion. Auditing the results of vascular surgery, with regard to graft occlusion, can be difficult if one wishes to compare units or changes within a unit over time. Variations in case mix, indications for surgery and type of operation undertaken make crude overall occlusion rates of little use. Even comparisons of the occlusive risk of similar grafts can be difficult unless allowances are made for known risk factors *(1)*. A scoring system which predicts the risk of graft occlusion in all clinical settings would allow the risk of graft occlusion to be quantified, and allow vascular audit to be conducted in a scientific way.

In the general surgical setting, the combination of multivariate linear regression and logistic regression analysis has been shown to produce a scoring system, POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity) *(2)* which can predict mortality and morbidity accurately, and allow comparative audit *(3,4)*. The aim of the present study was to use similar techniques to develop and validate a scoring system which would quantify the risk of graft occlusion.

Correspondence to: Mr G P Copeland, Department of Surgery, Warrington Hospital NHS Trust, Lovely Lane, Warrington, WA5 1QG

Methods

From 1 January 1985 data were collected prospectively from 250 consecutive patients undergoing vascular graft insertion at Broadgreen Hospital; 50 aortic or aortoiliac grafts, 50 aortofemoral or axillofemoral grafts, 50 suprageniculate femoropopliteal grafts, 50 infrageniculate femoropopliteal grafts and 50 femorodistal grafts.

Table I. GORA (graft occlusive risk assessment) score

Score	*0*	*1*	*2*	*4*	*8*
Reason	Aneurysm	Claudication	Critical limb Emergency op	—	—
Type of graft	—	Autologous	—	Artificial	—
Site of distal anastomosis	Aortic	Femoral	—	Popliteal (above knee)	Popliteal (below knee)
Ankle brachial pressure index	>1	0.8–0.99	0.6–0.79	0.4–0.59	<0.4
Runoff	3 vessel	—	2 vessel	1 vessel	No visible runoff

In all, 35 variables were assessed including:

Physiological and biochemical determinants—age, signs of cardiac failure, respiratory problems, blood pressure, pulse and rhythm, neurological status (confusional state, stroke), urea, electrolytes (sodium, potassium), haemoglobin, white cell count, electrocardiogram, chest radiograph changes.

Pre- and postoperative medication (anticoagulant drugs, cardiac drugs, other medication), smoking pre- and postoperatively and amount.

Presence of accompanying malignancy.

Aetiology of vascular disease.

Reason for graft insertion (aneurysm, occlusive disease).

Previous graft insertion, either early or late, at the same site or at an alternative site.

Posterior tibial artery pressure, ankle brachial pressure index.

Runoff on angiography.

Graft material and form of graft.

Site of proximal and distal anastomosis.

Timing of surgery (elective, urgent, immediate).

Formation of arteriovenous fistula.

Physiological and biochemical variables were those present at the time of graft insertion.

In all, 24 patients died in the perioperative or immediate postoperative period, and in 12 patients follow-up was incomplete. Patency was assessed clinically at 2 years, or before death if this occurred earlier (6.1% died before 2 years; median survival in these patients was 9 months). Thus, details from 214 patients were available for analysis, in whom 233 grafts were inserted (some patients underwent synchronous femoropopliteal or femorodistal bypass grafts).

Graft occlusion occurred in 82 grafts (35.2%).

All variables from these 214 patients were subjected to multivariate discriminant analysis and, using this linear discriminant technique, multivariate discriminant function coefficients were obtained for each variable. Only significant independent factors were included in the final score design. The multivariate discriminant function coefficient of these factors was divided by a constant and rounded to the nearest whole number to derive a point value on an exponential score (1, 2, 4, 8) for the variable.

This analysis produced a five-factor, five-grade (scores 0, 1, 2, 4, 8) scoring system, which we have entitled GORA (Graft Occlusive Risk Assessment) (Table I). Any increase or decrease in score variables from this number, or alteration in weighting value resulted in loss of predictive ability with regard to graft occlusion.

All patients were scored using the GORA score, and logistic regression analysis of the observed rate of graft occlusion with this derived score produced the following relationship between the odds ratio of occlusive risk and GORA score ($\log_e R/1-R=(0.229\times \text{score})-4.165$).

In order to validate this derived score, all patients admitted to Warrington District General Hospital from 1 January 1987 to 1 June 1990, and undergoing vascular graft insertion, were scored using the GORA system. A total of 226 patients underwent graft insertion; 65 aortic or aortoiliac grafts, 56 aortofemoral or axillofemoral grafts and 115 femoropopliteal or femorodistal grafts. In all, 40 patients died during the immediate perioperative or postoperative period. Thus, details on 186 patients were available for analysis in whom 196 grafts were inserted. Patency was assessed clinically at 2 years or at death if this occurred earlier (7.0% died before 2 years; median survival in this group was 13 months). Graft occlusion in this validation group occurred in 49 grafts (25.0%). The range of scores in the estimation and validation groups are shown in Fig. 1. Few high-risk

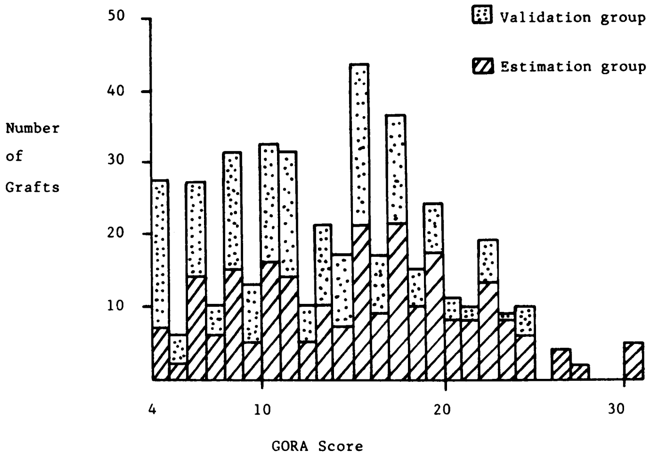

Figure 1. Distribution of GORA scores in the estimation and validation groups.

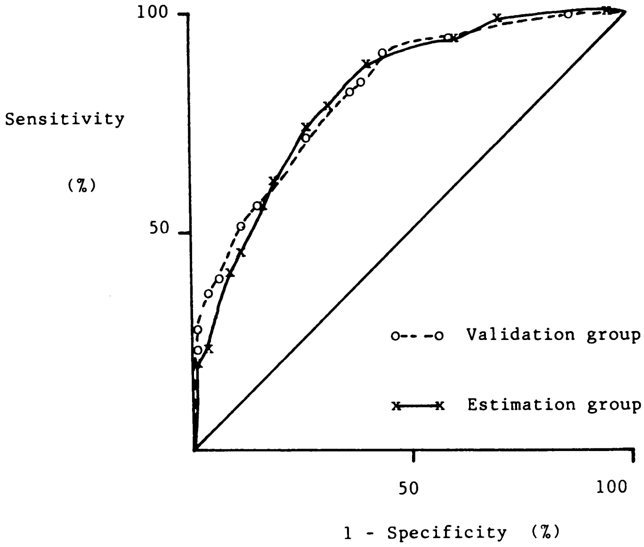

Figure 2. Receiver operating characteristic curves comparing the estimation and validation groups. There was no significant difference between the two groups.

femorodistal grafts were performed in the validation unit.

In the estimation groups, 21 grafts occluded early (within 30 days of operation) and 61 late (between 30 days and 2 years). The mean GORA score of those grafts which occluded early was significantly higher than those which occluded late (22.7 ± 1.0 *vs* 18.0 ± 0.6; $P < 0.001$). A similar relationship was seen in the validation group, where eight grafts occluded early (GORA score 21.4 ± 0.8) and 41 occluded late (GORA score 15.6 ± 0.7) ($P < 0.001$).

The GORA score accurately predicted the risk of graft occlusion in both the estimation and validation groups (Table II and Table III) (χ^2, $P < 0.001$). The predictive accuracy of this equation was assessed by the determination of a receiver operating characteristic curve (ROC curve), by determining classification matrices for different levels of predicted risk. The resultant ROC curves are illustrated in Fig. 2. There was no significant difference between the two curves.

Table II. Observed and predicted rates of graft occlusion in the estimation group for patients with GORA scores within the ranges indicated

Score range	*Number of grafts*	*Number of graft occlusions*	
		Observed no.	*Predicted no.*
4–7	29	0	1
8–11	50	5	6
12–15	43	13	11
16–19	57	28	26
20–23	37	20	25
24–27	12	11	10
>28	5	5	5
Total	233	82	84

Table III. Observed and predicted rates of graft occlusion in the validation group for patients with GORA scores within the ranges indicated

Score range	*Number of grafts*	*Number of graft occlusions*	
		Observed no.	*Predicted no.*
4–7	41	0	2
8–11	57	8	7
12–15	48	14	13
16–19	34	14	15
20–23	12	9	8
24–27	4	4	3
>28	0	0	0
Total	196	49	48

Discussion

Audit is a vital part of surgical practice, both as an educational process and as a means of assessing the quality of surgical care. However, quantification of the 'quality of care' can be particularly difficult. In the present regard, expression of the overall rate of graft occlusion would be meaningless unless consideration was given to the type of graft and the individual patient's vascular status. To realistically quantitate 'quality of care' it is necessary to set norms, and to do this it must be possible to predict the outcome from a particular action (in this case a vascular graft procedure). Scoring systems would appear to offer a means of predicting outcome and thus allow the production of norms.

Scoring systems which assess the chances of survival in an intensive therapy unit are already widely used *(5)*, as are systems to assess operative mortality and morbidity *(2,6–8)*. Whereas numerous factors are recognised to influence the risk of graft occlusion, graft material, site of graft, runoff, pre- and postoperative smoking habits, disorders of lipid metabolism, diabetes and previous vascular reconstruction *(1,9,10)*, their relative importance in relation to each other has not been explored. The aim of the present study was to devise a scoring system which assessed these relative risks, and thus enabled a prediction to be made of the risk of graft occlusion in all clinical settings.

The resultant score variables and individual factor weightings were devised by a linear multivariate discriminant technique which has been recommended as the statistical method that best simulates the formation of clinical judgement *(11,12)*. The factors selected by this analysis are not unrecognised, but the interrelationship between the variables has not previously been described. At first sight, it is surprising that the present multivariate analysis excludes certain factors, such as diabetes and postoperative smoking habits. However, it should be remembered that the present analysis aims to produce a method for comparing all types of vascular graft in all settings. In some circumstances, in particular femoropopliteal and femorodistal bypass grafts, certain factors may be of importance, but across the spectrum of vascular grafts they lose their significance. While it would be tempting to analyse the data from different types of graft, this would result in many different scores. This would defeat the object of devising a score which could be used for audit purposes across the range of potential arterial reconstruction. Indeed, our intention was to devise a score which could allow a quantitative quality measure to be determined for audit purposes. The present score may appear to oversimplify the aetiology of graft occlusion, which is almost certainly multifactorial and in the case of late intimal hyperplasia somewhat idiosyncratic; the present score accepts that occlusion, whatever its cause, may occur, but allows assessment as to whether its occurrence was 'reasonable'. The factors must be easy to obtain and be readily available in all clinical settings. Using such a technique it is possible to compare observed with expected occlusion rates, and hence produce a quality measure. In the general surgical settings we have developed the concept of an O:E (observed:expected) ratio for mortality and morbidity *(3)*, which could be used for comparative purposes.

Graft occlusion has been arbitrarily assessed up to 2 years. While graft occlusion can, of course, occur after that time, the incidence should be low in comparison with the preceding period. Indeed, in the present study, in the estimation group, only three grafts (1.3%) occluded during the period 2–5 years. We would suggest, therefore, that a 2-year assessment would be a suitable duration to allow comparable audit to be practical. It is not surprising that there is a significant difference between the GORA scores for patients experiencing early and late graft occlusion. Indeed there would appear to be a significant difference in the mean GORA score for grafts occluding late between the two centres (18.0 ± 0.6 *vs* 15.6 ± 0.7; $P < 0.01$). This demonstrates only too well the dangers of using inappropriate audit data for comparative purposes. The difference in mean score merely represents the case mix, not the quality of surgical outcome.

That GORA accurately predicts the risk of graft occlusion is shown by Table II and Table III. Indeed, this accuracy is shown across the score range, there being no significant difference at any point of the ROC curves. It is interesting to note that there are differences in case mix between the two units as shown by the score ranges and the overall occlusion rate. GORA appears to compensate adequately for these differences in case mix.

It is our hope that GORA may allow comparative vascular audit to be approached in a quantitative fashion. Estimation of the expected number of graft occlusions in any particular unit and comparing this with the observed number would allow production of O:E ratios (the ratio of observed to predicted). A ratio of less than 1.0 would indicate a unit performing better than average, and a ratio of greater than 1.0 worse than average. Determination of such ratios would allow comparative audit to be contemplated, both between units and within a unit over a period of time. Such a system could also be of potential benefit in the clinical trial setting.

References

1 Budd JS, Brennan J, Beard JD, Warren H, Burton PR, Bell PRF. Infrainguinal bypass surgery: factors determining late graft patency. *Br J Surg* 1990; **77**: 1382–7.

2 Copeland GP, Jones D, Walters M. POSSUM: a scoring system for surgical audit. *Br J Surg* 1991; **78**: 356–60.

3 Copeland GP. The POSSUM scoring system. *Med Audit News* 1992; **2**: 123–5.

4 Copeland GP, Jones D, Wilcox A, Harris PL. Comparative vascular audit using the POSSUM scoring system. *Ann R Coll Surg Engl* 1993; **75**: 175–7.

5 Knaus WA, Draper EA, Wagner DP, Zimmerman JE. Apache II: a severity of disease classification system. *Crit Care Med* 1985; **13**: 818–29.

6 Cooperman M, Pflug B, Martin EW, Evans WE. Cardiovascular risk factors in patients with peripheral vascular disease. *Surgery* 1978; **84**: 505–9.

7 Domaingue CM, Davies MJ, Cronin KD. Cardiovascular risk factors in patients for vascular surgery. *Anaesth Intensive Care* 1982; **10**: 324–7.

8 Goldman L, Caldera DL, Nussbaum SR *et al.* Multifactorial index of cardiac risk in non-cardiac surgical procedures. *N Engl J Med* 1977; **297**: 845–50.

9 Stein M, Ameli M, Gray R, Grosman H, Aro L. Angiographic assessment of arterial outflow in patients undergoing aortobifemoral bypass reconstructions: the predictive value of a new classification system. *Br J Surg* 1991; **78**: 364.

10 Rutherford RB, Jones DN, Bergentz SE *et al.* Factors affecting the patency of infrainguinal bypass. *J Vasc Surg* 1988; **8**: 236–46.

11 Nie NH, Hull CH, Jenkins JG *et al.* eds. *Statistical Package for the Social Sciences.* New York: McGraw-Hill, 1975: 434–67.

12 Overall JE, Williams CM. Models for medical diagnosis. *Behav Sci* 1961; **6**: 134–41.

Received 28 July 1993