

## Assessment of reconstructive procedures for femoropopliteal artery occlusive disease

*Summary: A total of 117 consecutive reconstructive procedures for femoropopliteal arterial occlusive disease in 105 extremities of 101 patients have been reviewed. The types of procedures included 10 homografts, 28 Dacron and Teflon prosthetic grafts, 16 thromboendarterectomies and 63 vein bypass grafts. There were three postoperative deaths.*

*The results of autogenous vein bypass grafts, as indicated by an early success rate of 90% and late patency rate of 76%, are superior to those obtained by other methods of reconstruction in the institution where this study was made.*

*Early failure of these grafts in most instances relates to technical errors which can be reduced by meticulous surgical technique, operative angiography and close postoperative follow-up with early correction.*

*Some of the late failures can be attributed to stenosis of the graft rather than to the progressive nature of the arteriosclerotic disease. Repeated follow-up examinations of the extremity at regular intervals and early angiography in the patients with return of symptoms may allow correction of the graft defect and salvage of the extremity.*

ALLAN R. DOWNS, M.D., F.R.C.S.[C]

B. K. SINHA, M.D., F.R.C.S.[C]

Winnipeg, Man.

The concept of arterial reconstruction for occlusive disease of the femoropopliteal artery is generally accepted. There is not, however, a universally accepted and proved single method of reconstruction applicable to every patient. In this stage of development it seems appropriate to reappraise critically one's results from time to time and to compare them with those of others. The purpose of this study is to review our experience with the femoropopliteal reconstructive procedures at The Winnipeg General Hospital in order to ascertain the procedure of choice for patients with symptomatic femoropopliteal occlusive disease.

### Materials and methods

#### *Clinical material*

A clinical study has been carried out in 101 patients who have undergone 117 femoropopliteal arterial reconstructions in 105 extremities for occlusive disease from June 1957 to June 1967. There were 91 males and 10 females. The ages ranged from 24 to 79 years, 84% of the patients being over 50 years (Fig. 1). All had arteriosclerotic occlusive disease with the exception of the youngest patient, a 24-year-old man with Buerger's disease. In 45 patients, the occlusive process was predominantly unilateral, in 42 it was bilateral affecting both femoropopliteal arteries and in 14 it was diffuse, involving aortoiliac and iliofemoral arteries in addition to the femoropopliteal arteries. This report includes two patients with occluded popliteal aneu-

rysms who presented with ischemic symptoms, but no cases of popliteal or femoral aneurysms without occlusion. Demonstrable co-existing disease processes were present in all but 15 patients. Additional manifestations of arterial disease were present in over 80%, including evidence of cardiovascular, renovascular and cerebrovascular disease. Other associated diseases included diabetes mellitus in 18% and pulmonary disease in 19% of the patients (Table I).

#### *Indications for operation*

The indications for operation were incapacitating claudication, rest pain, gangrene or a combination of these. All patients were classified clinically into one of three stages, as determined by symptoms and signs in the operated extremity (Table II). There was claudication only in 46 extremities (Stage I), rest pain in 41 (Stage II), and ulceration or gangrene in 18 (Stage III).

#### *Preoperative angiography*

Preoperative angiography was performed in all patients. Thirty-three patients had aortograms and the remainder had unilateral or bilateral femoral arteriograms. When the aortogram failed to demonstrate the popliteal outflow ade-

---

Presented at the Annual Meeting of the Royal College of Physicians and Surgeons of Canada, Toronto, January 1968.

From the Departments of Surgery, University of Manitoba and Winnipeg General Hospital, Winnipeg, Manitoba.

ALLAN R. DOWNS, M.D., F.R.C.S.[C], Associate Professor of Surgery.

B. K. SINHA, M.D., F.R.C.S.[C], Assistant Professor of Surgery.

Reprint requests to: Dr. A. R. Downs, Department of Surgery, Winnipeg General Hospital, 700 William Avenue, Winnipeg, Manitoba.

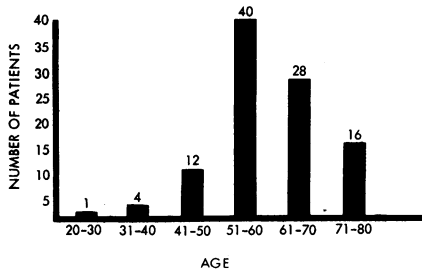


FIG. 1—Age of patients (by decades) operated on for femoropopliteal arterial occlusive disease.

quately, a femoral arteriogram was usually performed if the femoral pulses were palpable. When preoperative angiography failed to visualize adequately the popliteal artery and its branches, an operative popliteal arteriogram was performed as the initial step in the operation. The outflow classification is a modification of that described by Linton and Darling.<sup>1</sup> The outflow was assessed and recorded for 112 operations (Table III). Angiography was inadequate for interpretation in five instances. The popliteal outflow was good to excellent at the time of operation in

76 angiographic studies and fair to poor in 36.

#### Type of reconstructions and technique

The operative procedures used for femoropopliteal artery reconstruction during the past ten years have changed from homografts to the use of Dacron and Teflon synthetics to thromboendarterectomies and autogenous vein bypass grafts (Table IV). The homografts were used in the course of early experience and have not been used since 1958. Synthetic grafts were used almost entirely from 1958 to 1961. Since 1961, thromboendarterectomies with or without patch angioplasty and vein bypass grafts have been used almost exclusively. However, in occasional instances where reconstruction by these methods was not feasible, owing either to technical problems or unavailability of veins, a Dacron prosthesis has been used. The homografts were inserted as replacement grafts in some instances but usually as bypass grafts. The synthetic grafts have all been inserted following the bypass principle as described by Kunlin.<sup>2</sup> The thromboendarterectomies have been used primarily for short segment occlusions. The usual method has been the semi-closed technique with exposure of the artery and intraluminal stripping with Cannon strippers. The arteriotomies have been closed with vein or prosthetic patch grafts. The reversed autogenous saphenous vein grafts have been inserted using the bypass techniques described by Kunlin<sup>2</sup> and by Darling, Linton and Razzuk.<sup>3</sup> The vein bypass grafts vary in length, but usually extend from the common femoral artery to the popliteal artery. The majority have extended distal to the knee joint. When the vein was

not adequate in diameter throughout its entire length, an endarterectomy of the common femoral artery and proximal superficial femoral artery was performed, using the narrow segment of vein for closure of the arteriotomy as a long proximal anastomosis. Five patients have had associated proximal aortoiliac disease treated at the same time as the femoropopliteal reconstruction. Three patients had iliac thromboendarterectomies with insertion of a vein graft distally. In one patient a bifurcation aorto-femoral Dacron prosthetic bypass graft was done along with a unilateral femoropopliteal vein bypass graft. In another instance an ilio-femoral Dacron bypass graft was combined with a femoral endarterectomy. Thirty-one patients have had concomitant lumbar sympathectomy, 21 of whom had a vein bypass graft. Most of the sympathectomies were done in patients who had rest pain or gangrene or poor outflow tract.

#### Mortality

There were three postoperative deaths, so that the mortality rate was 3%. Two patients died of gram-negative septicemia, one as a result of peritonitis from a perforated rectum and the other from urinary tract infection. One patient died of hepatic failure as a result of pre-existing acute yellow atrophy of the liver.

#### Postoperative complications

The postoperative complications exclusive of the deaths are set forth in Table V. Fifteen patients developed pulmonary complications, including four with emboli; two had coronary insufficiency without proved infarction and two developed urinary tract infection. Leg edema occurred in 29 patients and

**TABLE I**  
Coexisting disease in 101 patients with femoropopliteal occlusive disease

|                        | %  |
|------------------------|----|
| Hypertension.....      | 56 |
| Cardiac disease.....   | 41 |
| Cerebral disease.....  | 14 |
| Renal disease.....     | 5  |
| Diabetes mellitus..... | 18 |
| Pulmonary disease..... | 19 |

**TABLE II**  
Clinical stage of disease in 105 extremities of 101 patients with femoropopliteal occlusive disease

|                                 |     |
|---------------------------------|-----|
| I Claudication only.....        | 46  |
| II Rest pain.....               | 41  |
| III Ulceration or gangrene..... | 18  |
| TOTAL.....                      | 105 |

**TABLE III**  
Angiographic assessment of the outflow tract in 117 extremities of 101 patients with femoropopliteal occlusive disease

|  | Extremities |
|--|-------------|
| Excellent—Popliteal artery and three branches patent.....                      | 28          |
| Good — Popliteal artery and two branches patent.....                           | 48          |
| Fair — Popliteal artery and one branch patent.....                             | 20          |
| Poor — (a) Popliteal patent and all branches occluded.....                     | 16          |
| (b) Popliteal occluded and one or more branches patent.....                    | 16          |
| (c) Popliteal occluded and all branches occluded in proximal third of leg..... | 5           |
| Inadequate visualization or not available.....                                 | 5           |
| TOTAL.....   | 117         |

**TABLE IV**  
Methods of femoropopliteal reconstruction

|  |     |           |
|--|-----|-----------|
| Homograft.....   | 10  | 1957-1958 |
| Dacron bypass graft.....                                 | 10  | 1958-1961 |
| Teflon bypass graft.....                                 | 18  |           |
| Thromboendarterectomy with or without patch closure..... | 16  |           |
| Autogenous reversed saphenous vein bypass graft.....     | 63  | 1961-1967 |
| TOTAL.....   | 117 |           |

was controlled with supporting bandaging. Wound complications occurred in 23 patients. Nine patients had a hematoma or seroma without infection or serious consequences, and 13 patients developed skin necrosis with a minor degree of superficial infection. This complication was most commonly associated with a long thigh incision for removal of the saphenous vein and can usually be prevented by the use of interrupted thigh incisions. A deep staphylococcal wound infection with a false aneurysm occurred at the distal anastomosis in one patient who had a vein graft. The graft was removed, with restoration of the limb to its preoperative state. This was the only graft occlusion which could be directly attributed to wound infection (Table VI).

### Follow-up

Follow-up examination has been completed in 100 of the 101 patients. Examination has been conducted by the attending surgeon in 85 patients and by the referring physician in 15 patients. Postoperative arteriograms have been performed in 49 patients at varying intervals

in the follow-up period. Nineteen patients with patent vein bypass grafts have had cineangiograms in addition to the standard films. Patients' answers to questionnaires or subjective assessment were not accepted as adequate follow-up. The criteria of patency were either the presence of distal pulses not palpable before operation or arteriographic evidence of patency. All patients have been followed up at least 12 months postoperatively or until death. A total of 21 patients have died in the follow-up period, usually of causes related to the primary disease; 15 of these deaths were due to arteriosclerotic cardiovascular disease.

### Results

The early and late results are outlined in Table VII. The early graft patency rate refers to the first 30 days following operation, and the late patency rate refers to the follow-up period after 30 days. This arbitrary division is an attempt to separate the technical failures from other causes of occlusion. Of the 10 homografts, one occluded immediately following operation and the remaining nine have occluded subsequently. The overall results of the synthetic grafts have also been poor, as indicated by a late patency rate of 40% for Dacron grafts and 33%

for Teflon grafts. Some of the synthetic grafts, however, have remained patent for prolonged periods, one for as long as 7 years. Thromboendarterectomies gave fairly good early results, but the late patency rate of 50% has been disappointingly low. Our best overall results have been achieved by the autogenous vein bypass grafts, with an early success rate of 90% and a late success rate of 76%.

The early and late results of 63 vein grafts are shown in Fig. 2. The grafts at risk at any given time are compared with the number which are patent. There were six early and nine late occlusions. Three grafts occluded in the one- to six-month period, two occluded in the 7- to 12-month interval and three occluded in the 13- to 24-month period. Out of 24 patients at risk in the 25- to 36-month period and 10 patients at risk in the 3- to 4-year period, none have occluded. Of the seven patients at risk over four years, the vessels have remained patent in all. The longest period over which a vein graft continues to function is 80 months.

It appears that there is a positive correlation between patency rate of vein grafts, both early and late, and excellent or good outflow tract as assessed by preoperative angiography (Table VIII).

**TABLE V**  
Postoperative complications

|  |    |
|--|----|
| Pulmonary complications.....                   | 15 |
| Pulmonary embolus.....                         | 4  |
| Pneumonia.....                                 | 1  |
| Atelectasis and bronchitis.....                | 10 |
| Iliofemoral thrombophlebitis.....              | 11 |
| Coronary insufficiency.....                    | 2  |
| Urinary tract infection.....                   | 2  |
| Leg edema.....                                 | 29 |
| Wound complications.....                       | 23 |
| Hematoma or seroma.....                        | 9  |
| Skin necrosis.....                             | 13 |
| Deep infection with septic false aneurysm..... | 1  |
| False aneurysm*.....                           | 2  |

\*One patient had false aneurysm develop twice at anastomoses which were successfully repaired.

**TABLE VI**  
Fate of grafts complicated by wound infection and/or skin necrosis

|   |   |
|---|---|
| Teflon.....                               | 2—2 acute occlusions  |
| Homograft.....                            | 1—patent  |
| Thromboendarterectomy and vein patch..... | 1—occluded at 18 months   |
| Vein grafts.....                          | 10—7 remained patent<br>1 acute occlusion<br>1 false aneurysm occluded by re-operation<br>1 occluded at 10 months |

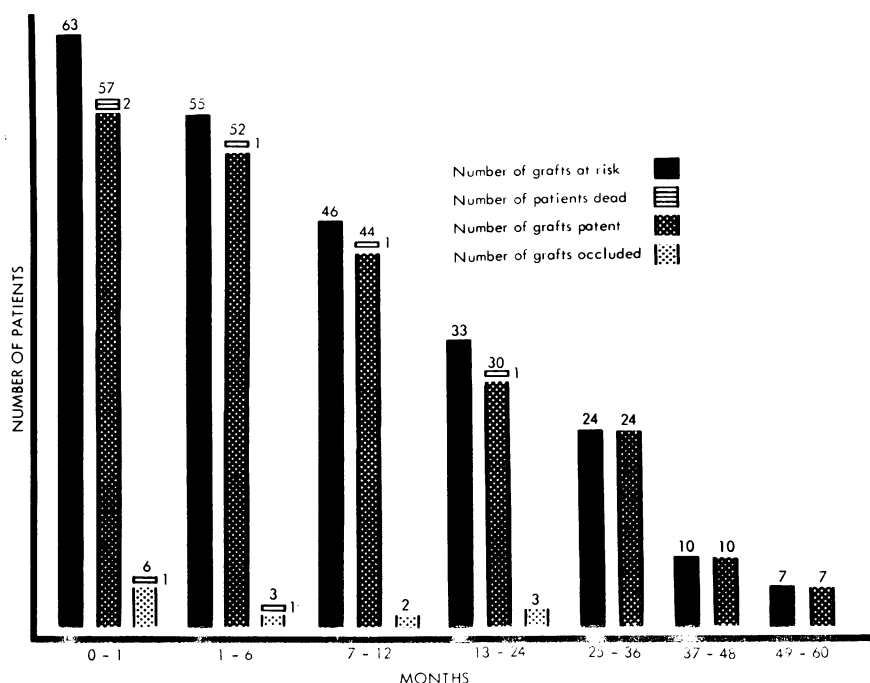


FIG. 2 — Early and late results of the 63 vein grafts.

**TABLE VII**  
Early and late results of 117 reconstructive procedures for femoropopliteal occlusive disease

| Procedure                  | No. of operations | Patent          |    |                  |    |
|----------------------------|-------------------|-----------------|----|------------------|----|
|                            |                   | Early 0-30 days |    | Late 1-84 months |    |
|                            |                   | No.             | %  | No.              | %  |
| Homograft.....             | 10                | 9               | 90 | 0                | 0  |
| Dacron.....                | 10                | 6               | 60 | 4                | 40 |
| Teflon.....                | 18                | 12              | 66 | 6                | 33 |
| Thromboendarterectomy..... | 16                | 12              | 75 | 8                | 50 |
| Vein.....                  | 63                | 57              | 90 | 48*              | 76 |

\*One vein graft lost to follow-up, assumed to be occluded.

**Analysis of early and late occlusions**

Analysis of early and late occlusions following various femoropopliteal reconstructive procedures is presented in Table IX. Repeat operations were done in 13 instances, four for early occlusion and nine for late occlusion, with successful reconstruction in seven patients. These patients had Stage I or II disease and had good to excellent outflow on angiographic assessment. In contrast, failures occurred in patients who had poor or fair outflow; two of these patients were diabetic.

**Amputation rate**

Fourteen of the 105 extremities operated on eventually came to either a below-knee or an above-knee amputation, an amputation rate of 13.3% for the entire series and 27.4% in the occluded group.

Six amputations were done early and eight during the late follow-up period (Table X). Five of the amputations were necessitated by occlusion of vein grafts. The remaining nine amputations were carried out because of failures occurring after other types of reconstructive procedures. Nine patients had poor or fair outflow and six had diabetes mellitus of varying severity. Twelve of the 14 amputations were done in patients with Stage II and III disease, and only two in patients with Stage I disease. However, 14 of the 18 extremities in Stage III disease threatened by impending gangrene were eventually salvaged.

**Discussion**

In keeping with the findings of other authors,<sup>3-7</sup> our own results indicate that saphenous vein bypass

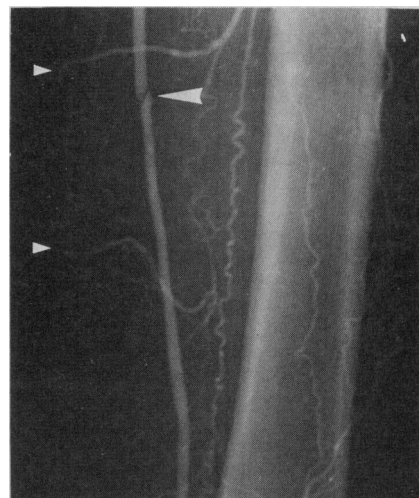


FIG. 3 — Arteriogram of a patient showing stenosis of the femoropopliteal saphenous vein bypass graft inserted approximately one year previously, with return of symptoms. Large arrow points to the site of stenosis and small arrows point to collaterals.

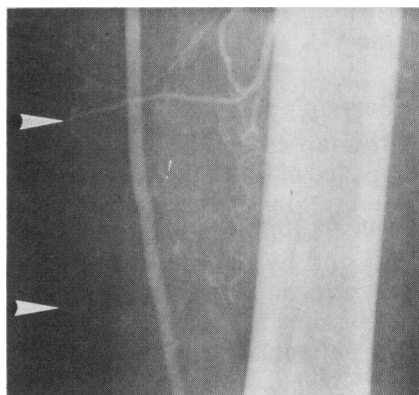


FIG. 4 — Postoperative arteriogram of the same patient following endophlebectomy and vein patch angioplasty of the vein graft. Arrows point to the same collaterals shown in Fig. 3 as landmark for the site of endophlebectomy.

**TABLE VIII**  
Early and late patency of vein grafts correlated with angiographic assessment of popliteal outflow

| Outflow                | No. of grafts* | Early patency |    | No. of grafts at risk | Late patency† |    |
|------------------------|----------------|---------------|----|-----------------------|---------------|----|
|                        |                | No.           | %  |                       | No.           | %  |
| Excellent or good..... | 40             | 38            | 95 | 37**                  | 33            | 90 |
| Fair or poor.....      | 22             | 18            | 81 | 18                    | 13            | 73 |

\*Excludes two patients with inadequate visualization of outflow.  
†Excludes one patient who died postoperatively with a patent graft.  
\*\*Assumes that one patient lost to follow-up is occluded.

**TABLE IX**  
Analysis of early and late occlusions following various types of femoropopliteal reconstructive procedures

| Type of reconstruction     | Early             |                              |                              | Late              |                              |                              |
|----------------------------|-------------------|------------------------------|------------------------------|-------------------|------------------------------|------------------------------|
|                            | No. of occlusions | No. of re-operations Success | No. of re-operations Failure | No. of occlusions | No. of re-operations Success | No. of re-operations Failure |
| Homograft.....             | 1                 |                              | 1                            | 9                 | 3                            | 1                            |
| Dacron.....                | 4                 |                              |                              | 2                 |                              |                              |
| Teflon.....                | 6                 |                              | 1                            | 7                 |                              | 1                            |
| Thromboendarterectomy..... | 3                 | 1                            |                              | 5                 | 2                            |                              |
| Vein.....                  | 6                 |                              | 1                            | 9                 | 1                            | 1                            |
| TOTAL.....                 | 20                | 1                            | 3                            | 32                | 6                            | 3                            |

**TABLE X**  
Analysis of major amputations following various types of femoropopliteal reconstructive procedures

|                            | No. of amputations |      |
|----------------------------|--------------------|------|
|                            | Early              | Late |
| Homograft.....             | 1                  | —    |
| Dacron.....                | 1                  | 1    |
| Teflon.....                | 1                  | 3    |
| Thromboendarterectomy..... | —                  | 2    |
| Vein.....                  | 3                  | 2    |
| TOTAL.....                 | 6                  | 8    |

graft is the procedure of choice for femoropopliteal arterial occlusive disease provided the vein is of adequate size. Most early postoperative failures appear to be secondary to technical factors such as faulty suture technique, kinking of the transplant and other tech-

nical errors. Some may be due to a combination of inadequate inflow and outflow tracts. Immediate operative correction, however, is indicated in instances with good or excellent outflow tract and where the failure is due primarily to a faulty technique. There was only one instance where the failure of the graft could be attributed to infection at the graft site. Although the late occlusions of the vein grafts have been generally attributed to the progression of the underlying arteriosclerotic disease, it is becoming apparent from our own studies that at least some of these failures are due to graft stenosis.<sup>8</sup> In 23 postoperative angiograms of patent vein bypass grafts, three patients have had stenosis in the graft. Two of these were associated with the return of symptoms and the third was asymptomatic. Fig. 3 shows an angiogram of a patient with stenosis of the femoropopliteal vein bypass graft approximately a year after the initial reconstruction. An angiogram done following endophlebectomy and vein patch angioplasty shows no evidence of persistent stenosis and a good outflow (Fig. 4). The two grafts which have been operated upon appear to have had fibrosis of the valve cusps as the cause of the stenosis. Both have remained patent since revision. Similar stenoses have been described by Breslau and De Weese<sup>9</sup> and by McNamara, Darling and Linton.<sup>10</sup>

We wish to thank Dr. John Farr and other members of the surgical staff and Dr. Ian Morrow of The Winnipeg General Hospital for their participation in this study.

## Résumé

*Evaluation des procédés chirurgicaux employés dans la maladie occlusive de l'artère fémoro-poplitée*

Nous avons passé en revue 117 cas consécutifs de reconstitution chi-

urgicale pratiquée dans l'occlusion de l'artère fémoro-poplitée. Ces opérations ont été faites sur 105 extrémités chez 101 patients. Parmi les opérations pratiquées figuraient 10 homœogreffes, 28 poses de prothèse au Dacron et au Teflon, 16 thrombo-endarterectomies et 63 greffes de dérivation veineuse. On a enregistré trois décès post-opératoires.

Les résultats de la greffe veineuse autogène par dérivation, comme le montrent la proportion de 90% de succès et le taux de 76% du rétablissement de la perméabilité, sont nettement supérieurs à ceux qu'ont donnés d'autres modes de reconstitution dans l'hôpital où cette étude a été entreprise.

Dans la majorité des cas, l'échec précoce de ces greffes est attribuable à des erreurs de technique qui peuvent être minimisées par une technique chirurgicale méticuleuse, une angiographie opératoire et une observation post-opératoire étroite avec correction précoce.

Quant aux échecs tardifs, ils peuvent être attribués plus à la sténose de la greffe qu'à la nature évolutive de la maladie artérioscléreuse. Des examens répétés de l'extrémité à intervalles réguliers et une angiographie précoce pratiquée chez des malades dont les symptômes récidivent, permettront de corriger le défaut de la greffe et de sauver l'extrémité.

## References

1. LINTON, R.R. and DARLING, R. C.: *Surgery*, 51: 62, 1962.
2. KUNLIN, J.: *Rev. Chir. (Paris)*, 70: 206, 1951.
3. DARLING, R. C., LINTON, R. R. and RAZZUK, M. A.: *Surgery*, 61: 31, 1967.
4. GUTELIUS, J. R., KREINDLER, S. and LUKE, J. C.: *Ibid.*, 57: 28, 1965.
5. DEWEESE, J. A. et al.: *Ibid.*, 59: 28, 1966.
6. VOLLMAR, J. et al.: *Ann. Surg.*, 168: 215, 1968.
7. LITHELAND, H. K. and ELLIOTT, J. A.: *Canad. J. Surg.*, 10: 186, 1967.
8. DOWNS, A. R. and MORROW, I. M.: *Current Topics of Surgical Research*, 1: 499, 1969.
9. BRESLAU, R. C. and DEWEESE, J. A.: *Ann. Surg.*, 162: 251, 1965.
10. McNAMARA, J. J., DARLING, R. C. and LINTON, R. R.: *New Eng. J. Med.*, 277: 290, 1967.

## GUIDANCE TO CONTRIBUTORS

### Manuscripts

...All material intended for publication should be submitted to the Editor at the editorial office of the Journal, 129 Adelaide Street West, Toronto 110, Ontario, with a covering letter requesting consideration for publication in the Journal. Acceptance is subject to the understanding that such material is submitted solely to this Journal, and will not be reprinted without the consent of both the Editor and the author. The Editor reserves the right to make such editorial changes as are considered necessary to ensure correctness of grammar, clarification of obscurities or conformity to Journal style. Articles should be typed, double-spaced, on paper 8½" x 11".

### References

...References should be limited to the minimum necessary and must be referred to by number in the text. These should include in order: the author's name and initials, in capital letters; abbreviated journal name; volume number, page number and year. The abbreviations of journal names should be those defined in the *Index Medicus* of The National Library of Medicine, Washington, D.C.: e.g. 8. Willis, W. H.: *Canad. Med. Ass. J.*, 88:411, 1963. References to books should include in order: author's name and initials; title of book, number of edition (if 2nd or 3rd, etc.); name of publishing house; city of publication, year of publication; page number (if a specific reference): e.g. 9. Underhill, F.: *A textbook of medicine*, 2nd ed., Jones & Jones Ltd., London, 1962, p. 1376.

### Illustrations

...Illustrations and tables should be sent detached from the manuscript. Illustrations, both half-tone and line, should be referred to as "Figures" and numbered in Arabic numerals. Tables should be numbered in Roman numerals. Each figure and each table must be accompanied by an explanatory legend, and the name(s) of the author(s) should be written on the reverse side. Separate sheets should be used for each table and illustration and for legends. Photographs should be glossy prints, unmounted and untrimmed, preferably not larger than 8" wide and 10" deep. The "top" of photographs, radiographs and photomicrographs should be indicated on the reverse side. Colour work can be published only at the author's expense. Magnification of photomicrographs must always be given. Patients must not be recognizable in illustrations, unless written consent has been obtained and supplied with the manuscript. Graphs and diagrams should be drawn in India ink.