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# Volume 17, issue 2

Canadian Medical Association

# The Canadian Journal of Surgery
# Le journal canadien de chirurgie

VOLUME 17 MARCH 1974 NO. 2

ISSN 0008-428X

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### QUILL ON SCALPEL



### THE CANADIAN CARDIOVASCULAR SOCIETY

Papers Presented at the Annual Meeting, Halifax, Nova Scotia, October 19, 20, 1973

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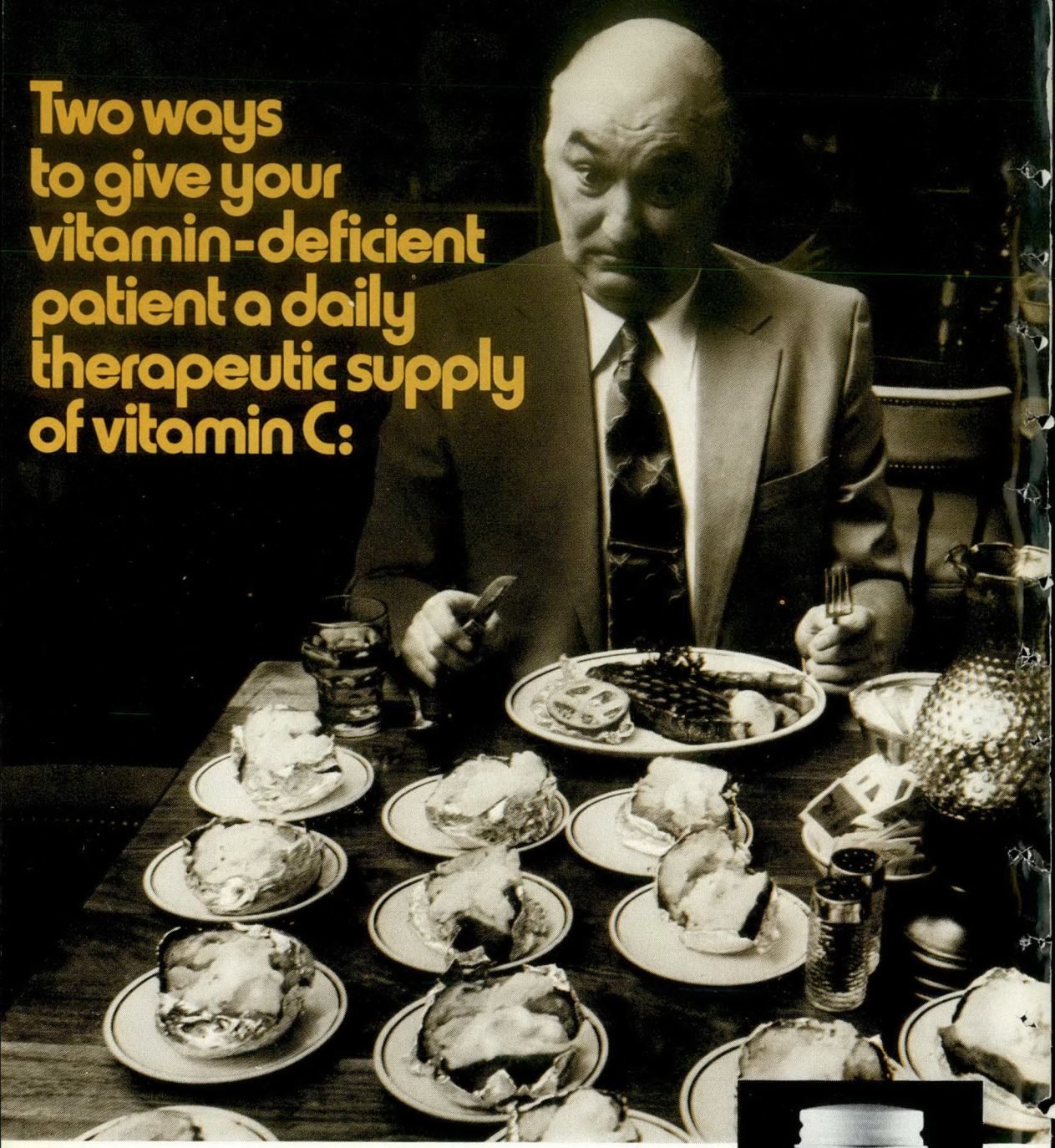

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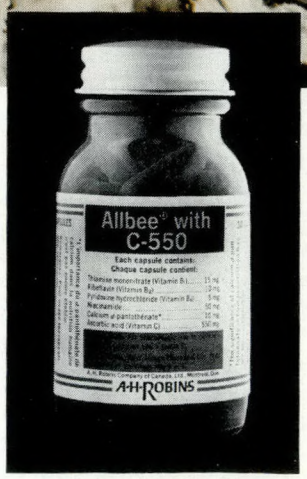


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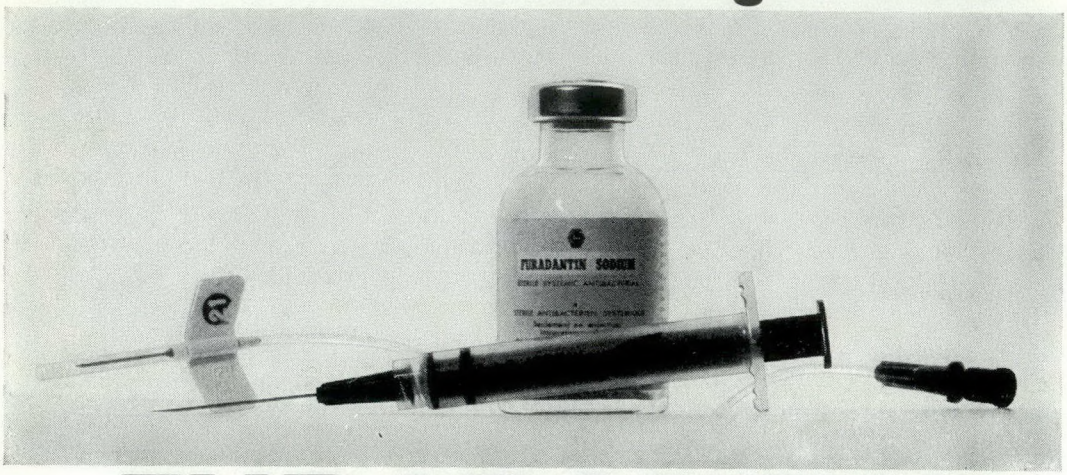


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| Proteus | 54.4 | 56.9 | 41.4 | 46.9 |
| Staphylococcus aureus | 93.1 | 92.0 | 100.0 | 97.0 |
| Pseudomonas | 11.3 | 8.1 | 12.1 | 8.3 |

*Source: R. A. Gosselin and Company, Incorporated, Dedham, Mass. Audit of Bacteriology Cultures, Vol. II Part II for the periods shown (1965, 1966, 1968, 1969). National Audit of Pathology (Urine) Cultures in hospitals (108) located throughout nine census regions.

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QUILL ON SCALPEL **This section provides a medium through which Canadian surgeons can declare themselves, briefly and informally, on the day-to-day affairs of surgery.**

## THE CANADIAN CARDIOVASCULAR SOCIETY

This issue of the *Canadian Journal of Surgery* contains nine papers presented by surgeons at the 26th Annual Meeting of the Canadian Cardiovascular Society in Halifax, N.S. in October 1973.

The Canadian Cardiovascular Society/ Société Canadienne de Cardiologie was incorporated in 1947 under the name of the Canadian Heart Association. In order to avoid confusion with the Canadian Heart Foundation, the name was changed to its present form in 1962. The initial members were physicians with an interest in the new developments in cardiology. The specialty of cardiovascular surgery began in the mid-fifties and was officially recognized in 1964 by the action of the Royal College of Physicians and Surgeons of Canada in inaugurating a Fellowship in Cardiovascular and Thoracic Surgery. The surgeons across Canada who were devoting their practice to cardiac and vascular surgery joined the Canadian Cardiovascular Society and became welcome and active members. The Society now consists of 500 active members of whom approximately 50 are surgeons. Two eminent Canadian surgeons have served as President of the Society—Dr. David Murphy and Dr. Wilfred Bigelow. Prominent surgeons have frequently been asked to deliver the annual special lectures: Dr. Gordon Murray, Dr. Arthur Vineberg, Dr. Wilfred Bigelow, Dr. Dwight Harkins, Dr. William Mustard, Dr. Norman Shumway, Dr. Gerald Austen, and Dr. Pierre Grondin.

Although the Society publishes the abstracts of its meetings in its "Proceedings" and occasionally in the *Canadian Medical Association Journal,* there has not been an official journal in which the complete scientific manuscripts have been published. Therefore the Council of the Society welcomed the invitation from the editors of the *Canadian Journal of Surgery* in 1972 to publish a limited number of papers of interest to surgeons in a special issue of the Journal. The first issue devoted to cardiovascular surgery was published in July 1973; the current issue is the second.

The international stature of Canadian surgical endeavour has not received the acknowledgement it deserves because of the past practice of the Royal College of Physicians and Surgeons of Canada and most of the various specialty societies, of publishing the papers presented at their meetings in abstract form only. The formal publication of the material is then frequently neglected by the author or else the manuscript is submitted to a specialty journal in the United States or elsewhere. Although the latter course offers certain advantages, it undoubtedly lessens the international impact of Canadian advances in surgery and reduces the potential value of the *Canadian Journal of Surgery.*

The writer expresses his thanks to Dr. Claude Labrosse and Dr. Whitmer Firor for collecting the manuscripts. He hopes that the co-operation between the Journal and the Canadian Cardiovascular Society will continue and that other surgical societies in Canada will follow the example.

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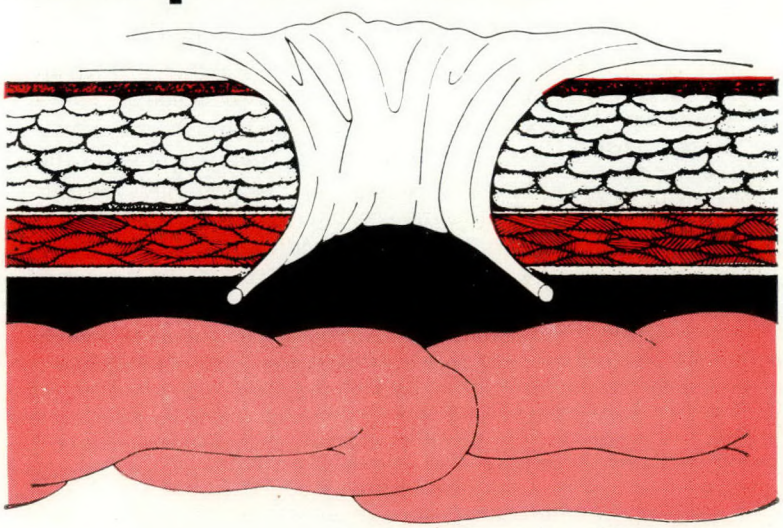

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# ROLE OF "MYOCARDIAL SINUSOIDS" IN THE EARLY RUN-OFF OF MYOCARDIAL ARTERIAL IMPLANTS: A CRITICAL REAPPRAISAL*

C. J. CHIU, M.D., Ph.D., M. L. MacRAE, B.Sc. and H. J. SCOTT, M.D., *Montreal, Que.*

**Summary: The concept that an extensive network of "endothelium-lined myocardial sinusoids" provides a unique early run-off for a surgically implanted artery has been widely accepted. The authors used India ink and nucleated chicken erythrocytes as markers to study the run-off from implants in canine myocardial tunnels. Light and electron microscopic studies, when correlated with the findings from corrosion casts, indicate that the blood introduced into the tunnel escapes into the interstitial space, which has no lining of endothelium. The initial minimal communications that may exist between the implant and the coronary vessels appear to be caused by traumatic disruption of the vascular bed in the process of creating the myocardial tunnel. Thus, neither the patency of the implanted vessel, nor the later development of implant-to-coronary vascular communications depends on the existence of the so-called "sinusoidal spaces" in the myocardium.**

**Résumé: On a maintenant largement accepté le concept qu'un vaste réseau de "sinusoïdes du myocarde, pourvus d'épithélium" puisse constituer une porte de sortie pour l'évasion précoce d'une artère implantée chirurgicalement. Les chercheurs ont voulu étudier comment se produisait chez le chien l'évasion des artères, implantées dans des tunnels myocardiques. Ils ont utilisé comme marqueurs de l'encre de Chine et des érythrocytes de poulet. Les examens au microscope classique et au microscope électronique, quand ils étaient mis en corrélation avec les renseignements fournis par les cylindres épithéliaux, indiquaient que le sang introduit dans le tunnel s'échappe dans l'espace interstituel, dépourvu d'endothélium. Quant aux minimes communications qui peuvent exister au début entre le greffon et les vaisseaux coronaires, elles sont causées par le traumatisme infligé au lit vasculaire au moment de la création du tunnel. De sorte que, ni la perméabilité du vaisseau greffé ni le développement ultérieur de communications vasculaires greffon-coronaires ne dépendent de l'existence dans le myocarde de ce qu'on appelle des "espaces sinusoïdaux".**

*From the Division of Cardiovascular and Thoracic Surgery, McGill University, and the Montreal General Hospital, Montreal 109, Que.

Supported by grants from the Medical Research Council of Canada and the Quebec Heart Foundation.

GRANT and Regnier,[1] Wearn *et al*[2] and a number of earlier anatomists,[3] using the techniques of serial histological sections and corrosion casts, described the so-called "myocardial sinusoids" in the heart. These structures were considered to be very thin-walled vascular spaces, the walls being composed of an endothelial layer with or without minimal supportive tissues, often of irregular shape and measuring in diameter approximately 100 to 250 $\mu$. On these structures Vineberg[4] based the rationale of the implantation of bleeding arteries into the myocardium. It was hypothesized that such a "sponge-like network of endothelium-lined myocardial sinusoidal system"[5] provided a unique run-off for the bleeding artery, thus maintaining its patency and preventing hematoma formation. This theory and the myocardial arterial implant procedure itself, met with considerable scepticism from surgeons for over two decades. However, in the early 1960s, with the advent of coronary angiography, the patency of the implanted artery was proved and the resultant surge of interest in the myocardial arterial implant procedure was accompanied by an uncritical acceptance of the rationale proposed for it.[6] In a recent article the continuity of myocardial sinusoidal spaces was purportedly demonstrated with a corrosion cast made by injecting polyvinyl acetate through a catheter inserted into the ventricular wall.[7]

Although this concept of myocardial arterial implant run-off is convenient and of historical value, it may be misleading in view of current knowledge of the anatomy and physiology of the myocardium. At present, the existence of so-called arterioluminal and arteriosinusoidal vessels is debatable,[8] and the evidence for their existence is considered inconclusive. Furthermore, in recent years infusion of fluid directly into the myocardium has been employed by physiologists to estimate the "intramyocardial pressure", which may be important in the distribution of coronary blood flow within the myocardium.[9] In these studies the infused fluid is thought to

enter the interstitial space. In the experiments described below we used two markers to trace the run-off from the myocardial implant in order to make a critical reappraisal of the role of myocardial sinusoids in the arterial implant procedure.

## Method

Five dogs weighing 15 to 22 kg were anesthetized with intravenous pentobarbital, 30 mg/kg body weight, intubated, and ventilated with a positive-pressure respirator. Left lateral thoracotomy was performed and the pericardium was opened longitudinally. The aortic pressure was monitored with a catheter inserted into the femoral artery and advanced to the aortic arch. A Statham strain gauge and a Grass recorder were used to monitor the blood pressure. A myocardial tunnel, 2 to 3 cm in length, was made to the left of and parallel to the left anterior descending coronary artery, and a 14-gauge venocath catheter with multiple side holes was introduced into the tunnel and sutured in place. The marker substance was then infused by means of the catheter at a hydrostatic pressure identical to the mean aortic pressure as recorded at the time. In two dogs an India ink suspension containing colloidal carbon particles (100 to 250 Å) was used as the marker, and the spread of the ink was followed macroscopically and with histological sections. In three other dogs, chicken (Gallus domesticus) blood was used as the marker substance. The chicken erythrocytes were chosen because their size (11 x 7 $\mu$) approximated that of the dogs' erythrocytes (7 $\mu$). Since all the chicken erythrocytes are nucleated, in contrast to the non-nucleated canine erythrocytes, histological identification and tracing of the path of the former is greatly facilitated. The chicken blood was obtained by direct cardiac puncture with a heparinized syringe. Up to 20 ml of chicken blood was infused and the rate of infusion into the myocardial tunnel was noted. All the animals were killed at the end of infusion and specimens were taken for both light and electron microscopic examinations. The myocardial specimens for histological study were fixed in 10% formalin-saline and stained with hematoxylin and eosin. For electron microscopic examination, the specimens were first fixed in 2.5% glutaraldehyde in 0.2% Sorensen's buffer and 1% osmium tetroxide. The specimens were dehydrated, embedded in epon, sectioned at 600 to 900 Å, and then stained with 4% uranyl acetate and Reynold's lead. An RCA Victor EMU-4 electron microscope was used to view and photograph the sections.

In five other animals, catheters were similarly introduced *in vivo* into the myocardium, and the hearts were then excised. In order to visualize any direct communication between the implant and the coronary vascular system, blue polyvinyl acetate plastic was injected into the intramyocardial catheter, and more of the same material coloured red was injected under pressure into the left coronary artery and myocardial implant run-off obtained. The findings from the corrosion-cast studies were correlated with those observed in the histological sections.

## Results

India ink injected into the myocardial tunnel was seen to spread peripherally with a somewhat irregular boundary, and was seen in the venules on the epicardium. Microscopically, the ink spread among the muscle bundles and was evenly distributed around each individual muscle fibre (Fig. 1). The bulk of the ink was found in the interstitial space between the muscle fibres and was not surrounded by any identifiable endothelial layer.

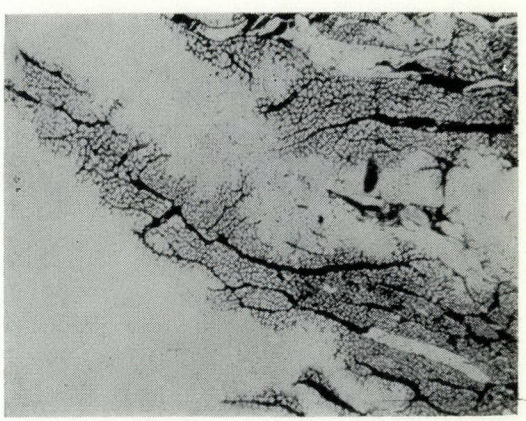

**Fig. 1.**—Intramyocardial spread of India ink injected via a catheter implanted in the myocardium.

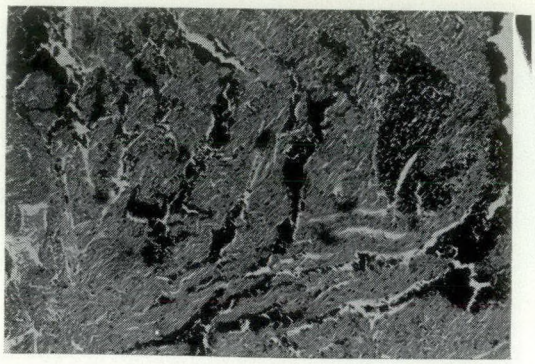

**Fig. 2.**—Pools of nucleated chicken red cells in the myocardium following infusion through the myocardial implant.

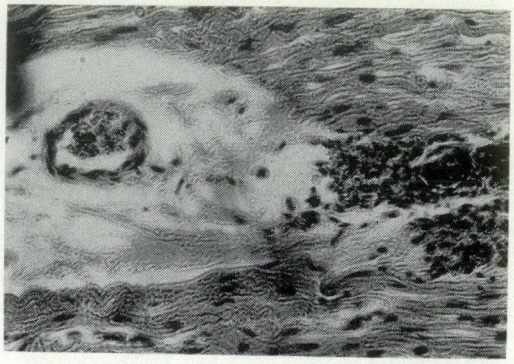

**Fig. 3.**—Non-nucleated canine erythrocytes are in the coronary vessel (left), while the nucleated chicken erythrocytes are in the interstitial space (right).

Fig. 2 demonstrates the intramyocardial distribution of the chicken erythrocytes, which spread in sheets in the interstitial space between the muscle bundles. However, in contrast to the India ink, the chicken red cells did not occupy the spaces surrounding individual muscle fibres, presumably owing to their larger size. Fig. 3 clearly indicates the interstitial distribution of the nucleated chicken erythrocytes, in contrast to the location of the non-nucleated canine blood cells in a clearly demarcated coronary microvessel. Thus the canine erythrocytes are confined in a space surrounded by endothelial cells, while the chicken red cells are outside such endothelium-lined spaces. This is more clearly demonstrated by the use of electron microscopy which shows the chicken erythrocytes to be in direct contact with the sarcolemma of the muscle fibres without intervening endothelial cells (Fig. 4). Multiple histological sections clearly indicate that the bulk of early run-off from myocardial arterial implants is into the interstitial space rather than into the so-called "myocardial sinusoidal spaces".

The corrosion-cast studies suggest the true nature of the early connections between the implant and the coronary vasculature. As shown in Fig. 5, the blue polyvinyl acetate injected into the implant escaped into the interstitial space around the myocardial tunnel. The red material injected into the left coronary artery under pressure can be seen also to escape into the interstitial space, but only in the immediate area of the myocardial tunnel (Fig. 5). Thus it would appear that the disruption of the coronary vessels produced by the creation

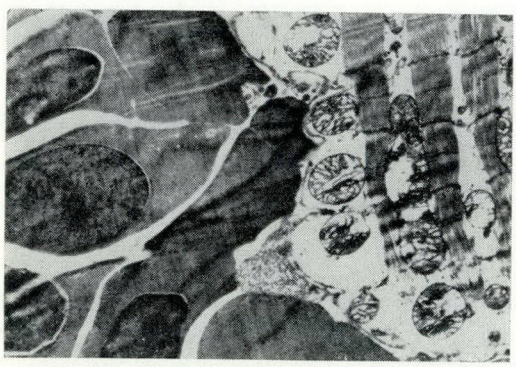

**Fig. 4.**—Electron microsopy demonstrates that the nucleated erythrocytes (left) are in direct contact with the myocardial sarcolemma without intervening endothelium.

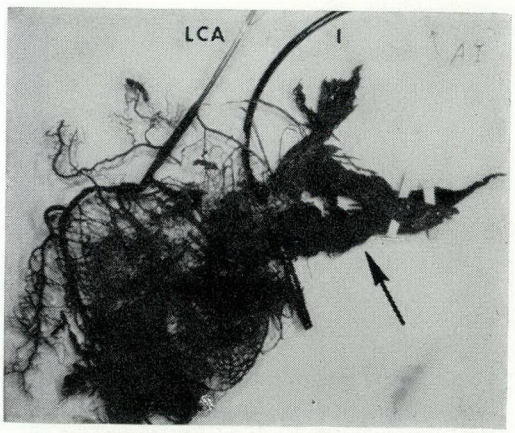


**Fig. 5.**—Corrosion cast demonstrates that the blue-coloured run-off (arrow) from the catheter implanted in the myocardium (I) communicates with the extravasated (red coloured) plastic injected into the left coronary artery (LCA).

of the myocardial tunnel brings about limited communication between the implant and the coronary vessels via the interstitial space surrounding the implant.

## Discussion

Many earlier studies indicated that the immediate run-off from the artery implanted into the myocardium was nil or very small,[10] and under our experimental conditions it was less than 2 ml/min. The experimental studies reported here, using both India ink and nucleated erythrocytes as markers, demonstrate that such minimal run-off is mostly into the interstitial space, which is a three-dimensional continuum, intermeshing with the syncytium-like myocardial fibres. These findings failed to support the concept of "sponge-like sinusoidal spaces" in the myocardium providing a unique run-off from an implant in this particular organ. Aside from the persisting controversy as to the existence of such sinusoidal spaces in the myocardium, other experimental studies indicate that adequate initial run-off may not be a *sine qua non* for the continued patency of such an implanted artery. The studies of Carlson *et al*[11] suggest that a segment of implanted vessel with no immediate run-off may stay open, presumably owing to the contractile compression of the myocardium against the implanted blood vessel, producing a to-and-fro movement of the blood column and resulting in its defibrination and non-coagulability. Yet such observations may not fully explain the implant patency, as illustrated in the work of O'Grady *et al*[12] in which a splenic artery was implanted into the parenchyma of the kidney. These renal implants were found to remain patent for a prolonged period. No "sinusoidal system" has been described in the kidney, and since the kidney is not a contractile organ one would not expect a to-and-fro movement of the blood contained in the implanted splenic artery.

It should be emphasized that the development of "delayed" communications between the myocardial arterial implant and the coronary artery has been demonstrated in numerous experimental and clinical cases by angiography. The results reported here should not imply any doubt as to the accuracy of such observations, nor should they be related to the clinical usefulness of the implant procedure. A critical reappraisal of the accepted "sinusoidal hypothesis", however, may provide new insight into the rationale for arterial implants in the heart and other organs.

The technical assistance of Frances Corbeil, B.Sc. and Connie Goodberry in the preparation of histological and electron microscopic sections is acknowledged.

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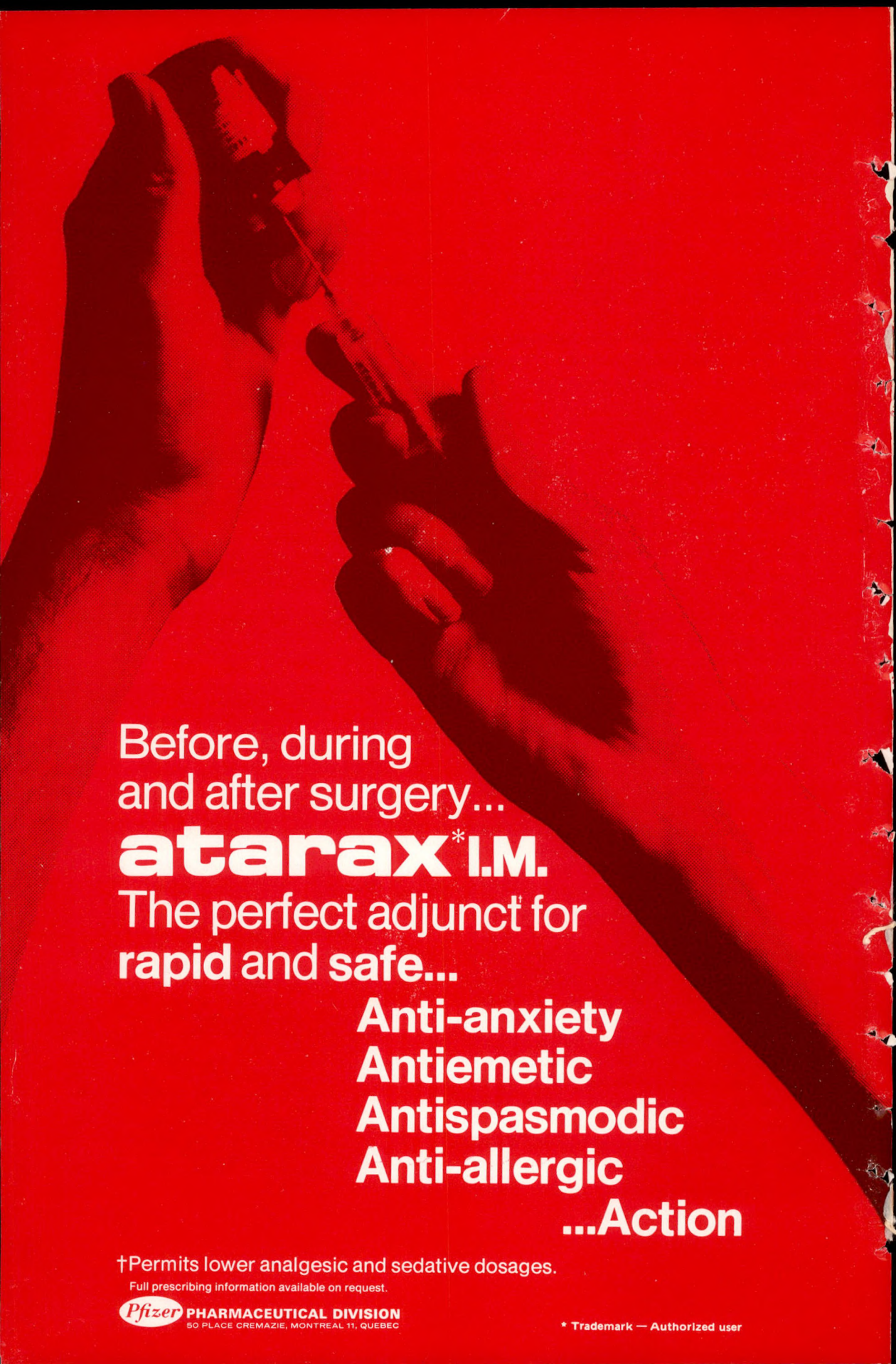

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# STRESS AT VASCULAR ANASTOMOSES IN RELATION TO HOST ARTERY:SYNTHETIC GRAFT DIAMETER*

C. E. KINLEY, M.D., F.R.C.S.[C], P. E. PAASCHE, B.Sc., A. S. MacDONALD, M.D., F.R.C.S.[C], A. E. MARBLE, M.Eng., P.Eng. and E. R. GOZNA, M.D.,
*Halifax, N.S.*

**Summary: Shear stress at host artery-synthetic graft anastomoses was calculated from measurements made on a Dacron prosthesis placed in the abdominal aorta of dogs. Results indicate that the minimum stress at the anastomosis occurs when the graft:host-artery radius ratio is approximately 1.4. A comparison of stress magnitudes indicates that for any ratio between 1.0 and 1.6, the stress at the anastomosis is less than one-thirtieth of the yield stress for 6-0 suture, suggesting that separation is not due to suture rupture but to suture tearing through the arterial wall.**

**Résumé: Nous avons calculé le stress par cisaillement auquel sont soumises les anastomoses entre l'artère de l'hôte et la greffe synthétique, par des mesures faites sur une prothèse en Dacron placée dans l'aorte abdominale de chiens. Les résultats indiquent que le stress minimum au niveau de l'anastomose survient quand le rapport des rayons entre la greffe et l'artère de l'hôte est d'environ 1.4. La comparaison des degrés de stress indique que, pour tout rapport de 1.0 à 1.6, le stress au niveau de l'anastomose est inférieur au trentième du stress que subit une suture 6-0. Ceci permet de croire qu'il s'agit d'un déchirement de la suture à travers la paroi artérielle mais non d'une rupture de la suture.**

IN a previous paper, our group has shown that prosthetic vascular grafts are essentially non-distensible, whereas the host artery has a diameter change of 10% over the cardiac cycle of pressure.[1] Follow-up studies[2] have shown that the prosthetic graft becomes more rigid as time passes, whereas host-artery distensibility remains constant. This observation of large distensibility difference prompted us to investigate the magnitudes of the stresses existing at the anastomosis of the graft to the host artery. Fig. 1 shows such an anastomosis as well as the three stresses acting on the suture line. This figure indicates that both the axial stress and the shear stress are acting parallel to the suture. A mathematical model which relates these stresses to the intravascular pressure and the physical properties of the vessel wall was devised by our group.[3] This model indicated that because of the large distensibility difference, the shear stress in the arterial wall just distal to the anastomosis is significantly larger than that found in the normal healthy artery. The model predicted that the minimum shear stress occurred at a graft:host-artery radius ratio of approximately 1.4. Previous studies of the optimal ratio of graft:host-artery radius have been based on blood flow.[4, 5] From these studies Szilagyi *et al*[5] concluded that the ratio should be less than 1.6 in order to ensure laminar flow, and greater than 1.4 in order to accommodate the taper of the artery. Also, as shown by Furuse *et al*,[6] the ratio of graft:host-artery radius is an important consideration in that the velocity of the blood flowing in the graft triples as the ratio decreases from 3.0 to 1.5. If the blood velocity is too low there is a chance of coagulation of the blood and loss of graft patency. In order to obtain some verification of the above ratio we have carried out experiments in the dog in which measurements were made to permit calculation of shear stresses at anastomoses.

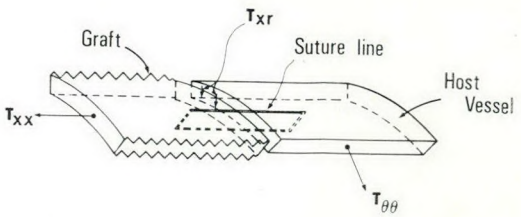


**Fig. 1.**—Graft-host vessel anastomosis showing stresses acting on the suture line. $T_{xx}$ = axial stress, $T_{\theta\theta}$ = hoop stress, $T_{xr}$ = shear stress.

## METHODS

Experiments were performed on five healthy mongrel dogs, ranging in weight from 18 to 22 kg. The animals were anesthetized with pentobarbital sodium (30 mg/

*From the Department of Surgery, Faculty of Medicine, Dalhousie University, Halifax, N.S.

Supported by Canadian Heart Foundation Grant 1200-365-018.

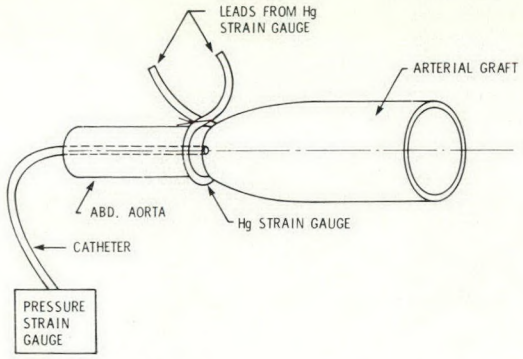


**Fig. 2.**—Measurement apparatus used for acquisition of intravascular pressure and strain data near the anastomoses.

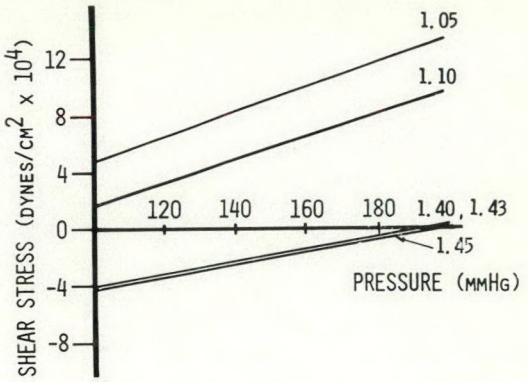


**Fig. 3.**—Shear stress *versus* intravascular pressure for five graft:host-artery radius ratios.

kg body weight) and intubated. At laparotomy a 4- to 5-cm segment of the abdominal aorta was replaced by a Dacron prosthesis. This prosthesis was selected so that the graft:host-artery radius ratio at normal diastolic pressure (i.e. 80 mm Hg) was in the range of 1.0 to 1.5. The anastomosis was end-to-end using simple continuous 4-0 Dacron. The abdominal incision was closed and normal activity permitted over a period of time which allowed the prosthesis to be enveloped by fibrous tissue. The animals were again anesthetized and the anastomoses exposed at laparotomy for measurements. The lateral intravascular pressure was measured at the anastomotic site using a U.S.C.I. no. 7F catheter coupled to a Hewlett Packard transducer and a Hewlett Packard 7858A recorder. The strain was measured on the host artery 1 mm distal to the anastomosis using a mercury-in-Silastic strain gauge coupled to a Wheatstone bridge and the Hewlett Packard 7858 recorder. A diagram of the measurement apparatus is shown in Fig. 2. Strain was continuously recorded for an intravascular pressure range of 100 to 200 mm Hg. The higher pressures were induced by administration of 0.4 ml of adrenalin.

## Results

The strain measurements obtained from the five experiments were converted to stress by first calculating the modulus of elasticity from the strain and pressure data using equations given by Paasche *et al.*[3] The shear stress data were plotted for a pressure range of 100 to 200 mm Hg as shown in Fig. 3 for five ratios of graft:host-artery radius. Each line on the graph shows the change in shear stress with pressure for a given graft:artery radius ratio. It will be noted that as the ratio increases from 1.05 to 1.45 the shear stress changes from a positive value of $10 \times 10^4$ to a negative value of $-2 \times 10^4$ dynes/cm$^2$. This change in shear stress from positive to negative can be explained as a change in the direction of the shear stress vector. In the mathematical model the shear stress was taken as positive when directed radially inwards towards the centre of the artery. For the higher ratios the shear stress has an outward direction for lower pressures, which causes the shear stress to be negative. When the pressure increases to 200 mm Hg the direction of the stress vector changes and a positive shear stress is developed. For the lower ratios the inward direction of the shear stress is maintained for all pressures.

## Discussion

These experimental results seem to confirm the theoretical model's prediction that the minimum anastomotic shear stress occurs at a graft:host-artery ratio of 1.4. However, the shear stresses determined are in the order of one-thirtieth of the tensile breaking stress of the suture materials used in this study. This suggests that disruption of suture lines at the arterioprosthetic anastomosis is not due to suture-line shearing but to the tearing of the artery by the suture. This is a result of excess shear stress due

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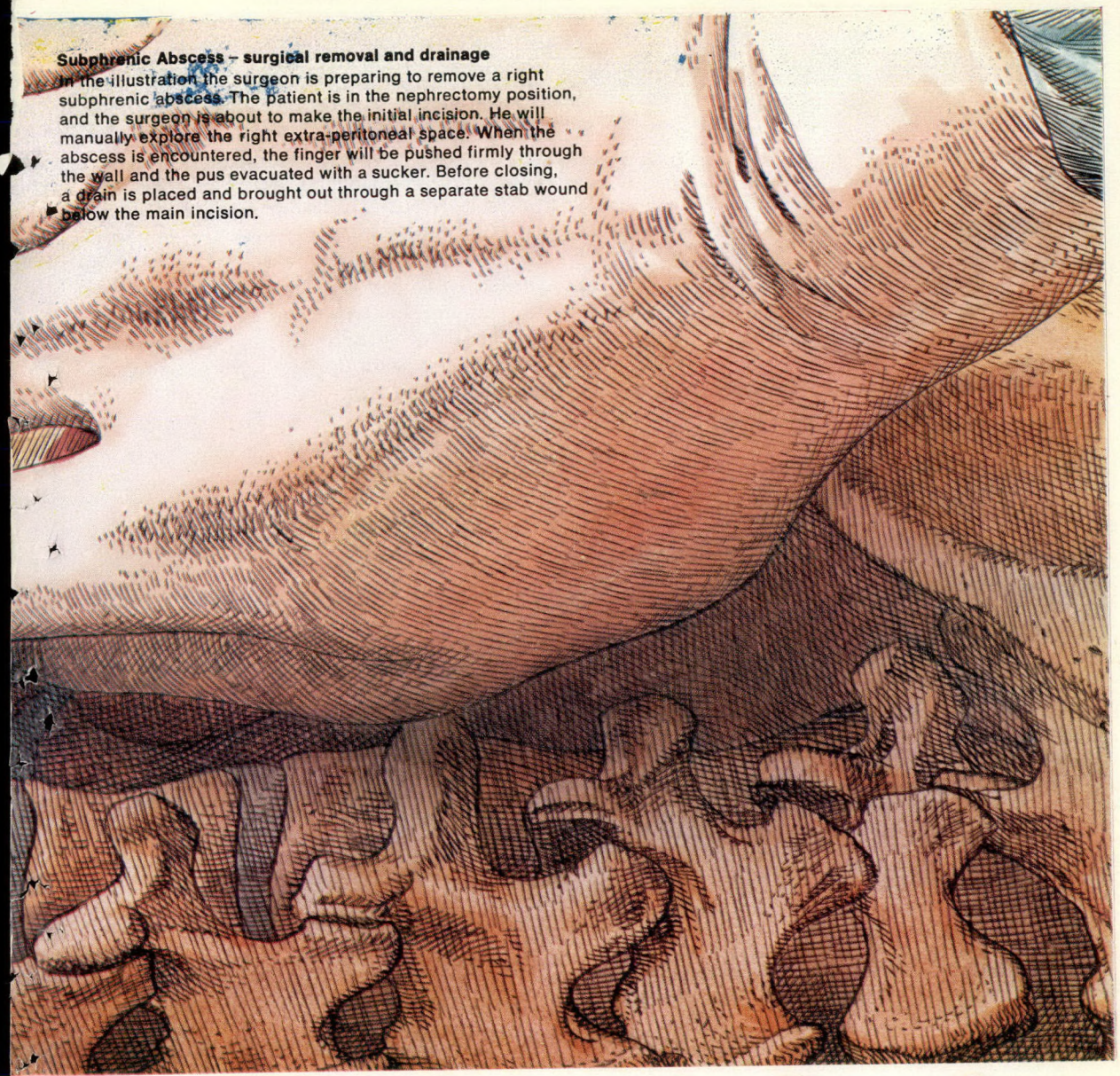
Tracy, O., et al. (29 Jan.'72).
Brit. med. J., p. 280.

"Our experience with this series of seriously ill patients provides clinical confirmation to complement recent in vitro evidence that clindamycin is the antibiotic of choice for use in bacteroides infections. Not only was the response in 17 of the 18 patients favourable, but in several it was dramatic."

Haldane, E. V. and van Rooyen, C. E. (1972).
C.M.A.J., p. 1177.



**Subphrenic Abscess – surgical removal and drainage**
In the illustration the surgeon is preparing to remove a right subphrenic abscess. The patient is in the nephrectomy position, and the surgeon is about to make the initial incision. He will manually explore the right extra-peritoneal space. When the abscess is encountered, the finger will be pushed firmly through the wall and the pus evacuated with a sucker. Before closing, a drain is placed and brought out through a separate stab wound below the main incision.

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to the marked contrast in graft:host-artery distensibility. Work by others[7, 8] has shown that a truly non-absorbable suture is required for permanent security of synthetic vascular grafts. Silk is not suitable because the silk fibres fragment and are removed by mononuclear phagocytes as was demonstrated by Cutler and Dunphy.[9] Three possible approaches to the problem are: an investigation to determine the best pattern for suturing grafts to host arteries; the use of the ratio of 1.4; and finally, the design of grafts which, in their elastic properties, simulate the host arteries.

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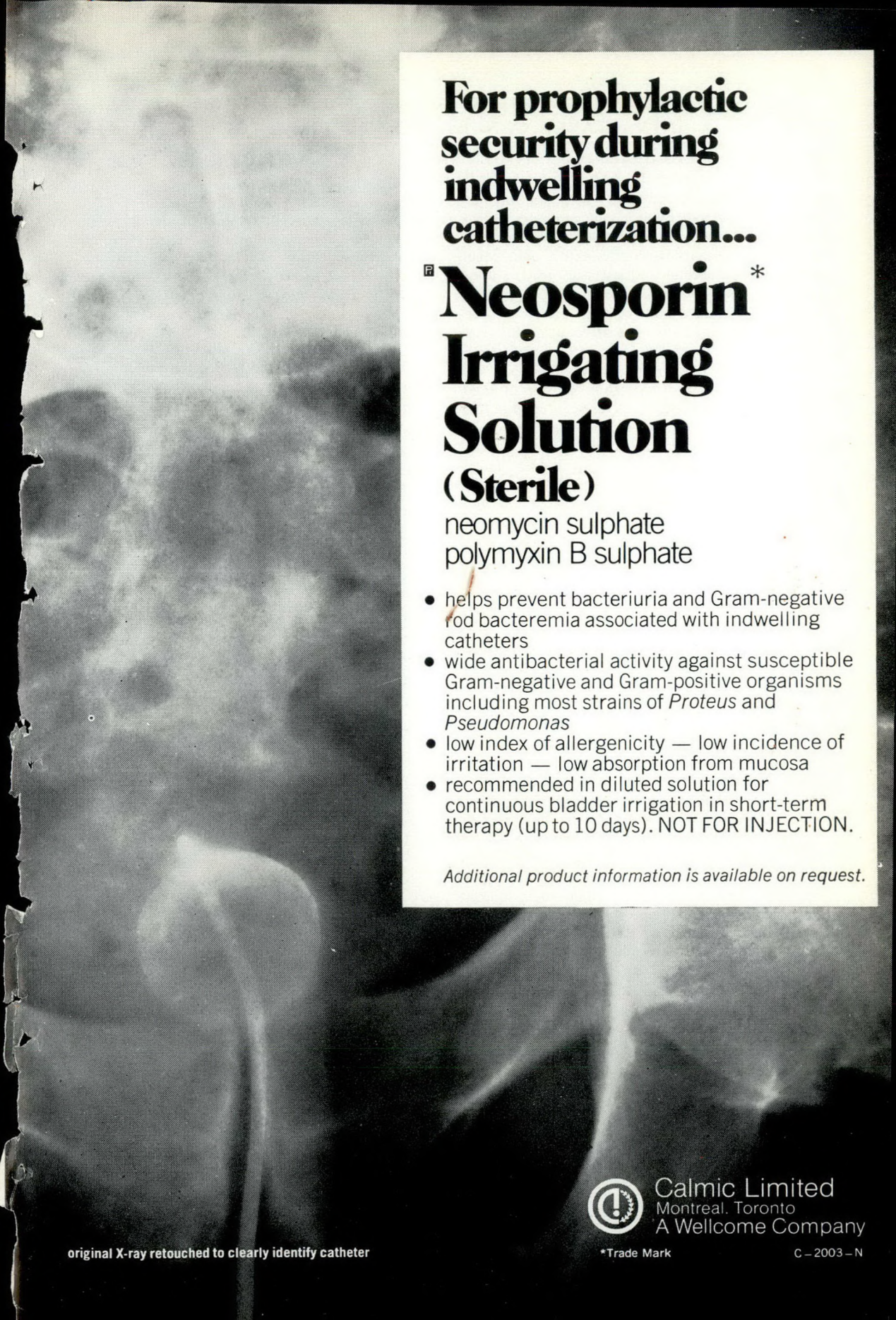

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# AORTA-TO-CORONARY ARTERY BYPASS OPERATION FOR CHRONIC INTRACTABLE CONGESTIVE HEART FAILURE*

ALAIN SOLIGNAC, M.D.,† JACQUES LESPÉRANCE, M.D., PIERRE GRONDIN, M.D. and LUCIEN CAMPEAU, M.D., *Montreal, Que.*

**Summary: Eleven patients selected on the basis of objective clinical and radiological evidence of congestive heart failure and pulmonary venous hypertension obtained a poor result from aorta-to-coronary artery vein graft. All except two vein grafts, assessed angiographically at 12 to 30 months after operation or at necropsy, were patent. The operative mortality was acceptable (two of 11), but the overall three-year mortality was extremely high (64%). This mortality curve is comparable to that of medically treated patients. It is concluded that this operation is not helpful in cases of intractable congestive heart failure because the severe diffuse left ventricular asynergy which is invariably present is seldom reversible and is so extensive that segmental resection of the ventricular wall is of doubtful value. Furthermore, complete revascularization is frequently not feasible because of diseased arteries with a poor distal run-off.**

**Résumé: Nous avons étudié 11 patients ayant des pontages veineux aorto-coronariens pour insuffisance cardiaque congestive avec manifestations objectives cliniques et radiologiques (hypertension pulmonaire veineuse). Nous insistons sur le fait qu'avant l'intervention, la défaillance cardiaque était réfractaire à un traitement médical optimal et que dans tous les cas, existait une asynergie ventriculaire gauche sévère et diffuse. Tous les pontages sauf deux étaient perméables lors d'angiographies faites 12 à 30 mois après l'opération ou lors de l'autopsie; neuf patients sur 11 avaient des greffons perméables aux artères descendante antérieure et coronaire droite. La mortalité opératoire est acceptable (2/11), mais la mortalité tardive est trop élevée (64%). Cette courbe de mortalité est identique à celles rapportées dans la littérature pour des patients traités médicalement. Seul un patient s'est trouvé amélioré après intervention. La conclusion de cette étude est que le pontage aorto-coronarien n'est d'aucune aide dans l'insuffisance cardiaque réfractaire au traitement médical. En effet, l'asynergie ventriculaire sévère, présente dans tous les cas, est rarement réversible et si étendue qu'une résection de tissu cicatriciel est de valeur douteuse; de plus, un revascularisation complète est rarement possible à cause de la fréquence élevée de mauvais lits d'aval chez ces patients avec athéromatose coronarienne diffuse.**

ALTHOUGH the aorta-to-coronary artery bypass operation using a saphenous vein graft is now an acceptable procedure for the treatment of incapacitating angina pectoris, its efficacy in the treatment of congestive heart failure due to coronary artery disease is still controversial. Some authors have found it to be beneficial whereas others conclude that it is not helpful.[1-3] It is recognized that angina associated with heart failure may be relieved by this operation[4-6] but the course of cardiac insufficiency is less well known. It is also accepted that heart failure associated with true left ventricular aneurysm is usually improved following its resection.[7, 8] We report the results of direct revascularization in patients with intractable chronic congestive heart failure, without ventricular aneurysm, with particular emphasis on the postoperative clinical status and survival.

## MATERIAL AND METHODS

Eleven men were studied; their mean age at the time of operation was 53 years (range 44 to 63 years). These patients were part of a larger group of 221 patients operated on for coronary artery disease between September 1969 and February 1971. Only cases with objective clinical and radiological evidence of congestive heart failure were included. These patients had pulmonary rales and radiological evidence of pulmonary edema and/or pulmonary venous hypertension in spite of optimal medical therapy. They belonged to NYHA Classes III and IV. Moderate to severe angina was present in eight patients. Seven had had at least one episode of myocardial infarction.

Selective coronary arteriography, obtained in multiple planes, and left cineven-

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triculography in the right anterior oblique projection were carried out by previously described techniques.[9] All patients had severe atheromatosis characterized by either complete obstruction or at least 75% stenosis of three major coronary arteries. Left ventriculography demonstrated extensive areas of akinesis and/or severe hypokinesis. The degree and extent of the abnormal ventricular contraction was assessed by a semiquantitative analysis of wall motion, which consisted of comparisons of tracings of the projected images in end-systole and end-diastole,[10, 11] or by qualitative evaluation whenever the former technique was not possible, i.e. when the heart was too large to be visualized in all its contours without travelling. Three segments of the ventricular cavity were considered—anterior, apical and inferior, excluding the basal region of the left ventricle corresponding to the deep constrictor muscles (Fig. 1). Segmental

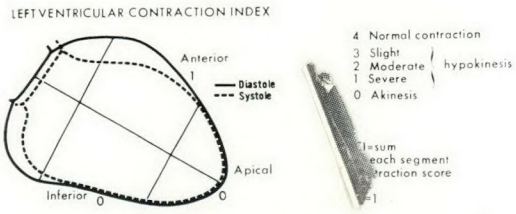


**Fig. 1.**—Determination of the contraction index—the sum of contraction scores from each of the three segments—may range from 0 (diffuse akinesis) to 12 (normal contraction).

contraction was graded from 0 to 4: 4, normal wall motion; 3, slight hypokinesis or slight decrease of wall motion; 2, moderate hypokinesis; 1, severe hypokinesis; and 0, akinesis or absent wall motion. The sum of these contraction grading scores for each of the three wall segments was considered as a contraction index which could vary from 0 (akinesis of all three segments) to 12 (normal contraction of all segments). As shown in Table I, these patients all had a very low contraction index, ranging from 0 to 3, compatible with diffuse and severe asynergy.

The resting left ventricular end-diastolic pressure varied from 18 to 40 mm Hg, with a mean of 28 mm Hg.

All major coronary arteries having proximal stenosis greater than 75% and good distal run-off received a graft. Ten patients had a bypass to the anterior descending as well as to the right coronary artery; the latter was dominant in all cases. The other patient had an aorta-to-right coronary artery graft. No other surgical procedure was carried out, such as internal mammary implantation, resection of wall segments or mitral valve correction.

Graft patency was assessed by angiography 12 to 30 months after operation in five patients and at necropsy in the others. All five patients who had one- to three-year postoperative angiographic studies also had left ventriculography and selective coronary cinearteriography.

## Results

The overall mortality after three years was 64% (seven of 11 patients). Two patients died of cardiogenic shock in the early postoperative period, the others died between the third and twenty-second postoperative months. The clinical course of the nine patients who survived beyond the first postoperative month was considered with respect to angina and congestive heart failure. Angina was relieved completely in all patients who were so afflicted before operation, but congestive heart failure was improved in only one patient. In the others heart failure persisted unaltered or was only temporarily improved. All vein grafts were patent except two, both to the anterior des-

TABLE I.—Preoperative Left Cineventriculography

| Patient | Degree of increase of left ventricular volume | Contraction | | | |
|---|---|---|---|---|---|
| | | Anterior | Apical | Inferior | Index |
| 1 | ↑ ↑ | 0 | 0 | 0 | 0 |
| 2 | ↑ | 1 | 1 | 0 | 2 |
| 3 | ↑ | 0 | 0 | 0 | 0 |
| 4 | ↑ ↑ ↑ | 1 | 1 | 1 | 3 |
| 5 | ↑ | ? | ? | 1 | — |
| 6 | ↑ ↑ | 1 | 0 | 1 | 2 |
| 7 | ↑ ↑ ↑ | 0 | 0 | 1 | 1 |
| 8 | ↑ ↑ | 0 | 0 | 0 | 0 |
| 9 | ↑ ↑ | 1 | 1 | 0 | 2 |
| 10 | ↑ ↑ | 0 | 0 | 0 | 0 |
| 11 | ↑ | 0 | 0 | 0 | 0 |

0 = akinesis; 1 = severe hypokinesis; 2 = moderate hypokinesis; 3 = mild hypokinesis; 4 = normal contraction.

cending artery. In the five patients in whom postoperative angiography was performed, left ventricular asynergy was not improved and the severity of the coronary artery lesions had not increased.

## Discussion

It should be stressed that this study is concerned exclusively with patients suffering from severe intractable congestive heart failure, demonstrated by objective clinical and radiological evidence. Functional incapacity based on subjective evaluation was not retained as a selection criterion whenever objective evidence of congestive heart failure was absent. Indeed, symptoms such as dyspnea, orthopnea and paroxysmal nocturnal dyspnea may be the only clinical manifestations of heart failure in coronary artery disease (in these circumstances they usually indicate mild failure) and cannot be unequivocally accepted as such. On the other hand, an abnormally high left ventricular end-diastolic pressure and/or an abnormal left ventricular contraction, when these are isolated findings, do not necessarily indicate congestive heart failure but may only imply myocardial ischemia. Finally, only patients who had not responded to optimal medical therapy were included in this study because we suspected that they belonged to a distinct group of patients in whom we had hoped that direct myocardial revascularization might succeed where heart transplantation had failed.[12] Less severe heart failure amenable to medical therapy yet associated with an acceptable functional impairment may indeed improve following operation when this is advocated primarily for the relief of angina.

It was found that all these patients, selected on the basis of objective evidence of congestive heart failure refractory to medical therapy, had almost invariably suffered one to many previous episodes of myocardial infarction and, more important, severe diffuse left ventricular asynergy. All cases had an enlarged left ventricular cavity and the ejection fraction was below 0.30. This was estimated from a table obtained by relating the contraction index described above to the calculated ejection fraction

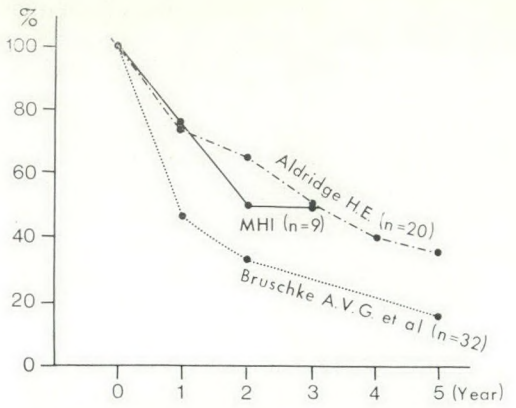


**Fig. 2.**—Survival rate of patients with congestive heart failure compared to the survival in two series (Aldridge and Bruschke, Proudfit and Sones) of unoperated patients. MHI = patients operated upon at the Montreal Heart Institute.

using Dodge's technique derived from a large sample of patients with coronary artery disease.[11]

Operation in these patients did not improve their clinical status nor did it increase their survival. Survival curves obtained from unoperated patients with severe congestive heart failure, as described by Aldridge[13] and by Bruschke, Proudfit and Sones,[14] are no different from those obtained in our series of operated patients (Fig. 2). Diffuse severe asynergy, a constant finding in our patients, has also been reported by Bruschke, Proudfit and Sones[14] to have a high yearly mortality. The survival curve in their unoperated patients is also equiva-

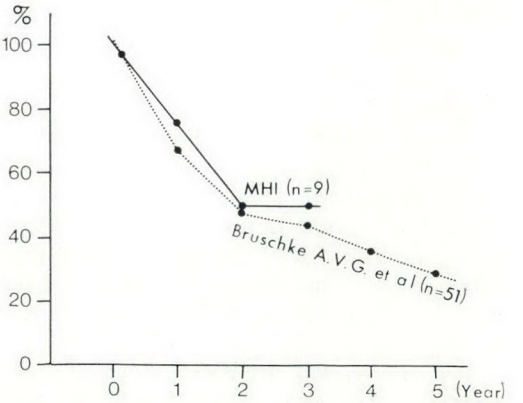


**Fig. 3.**—Survival rate of nine patients with severe diffuse asynergy (MHI) compared to that in a series (Bruschke, Proudfit and Sones) of unoperated patients.

lent to that obtained in our operated series, at least for the three-year duration of our follow-up study (Fig. 3). Although the operative mortality is not high in this small series (two out of seven), it has been reported to be as high as 25% to 50% in patients with heart failure.[2] On the other hand, the late and overall mortality have been significantly higher in this group of patients with heart failure compared with that observed in a group of patients without heart failure operated upon during the same period in our institution (Figs. 4 and 5).

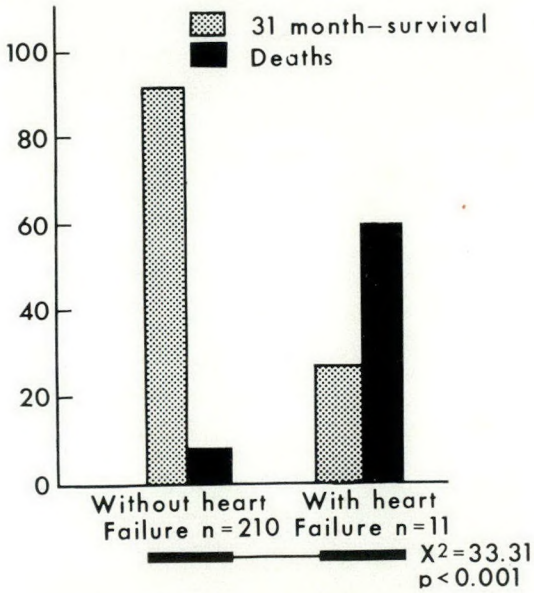


**Fig. 4.**—Thirty-one-month survival and overall mortality in operated patients with heart failure compared with those of operated patients without heart failure.

There are three possible explanations for the failure of aorta-to-coronary artery bypass in our patients: the irreversible nature of the severe asynergy; its wide extent prohibiting segmental resection of the ventricular wall; and the lack of complete revascularization. Severe abnormalities of segmental motion of the ventricular wall are not usually improved by this operation; this is particularly true in respect of akinesis which is almost always due to previous myocardial infarction.[15] Indeed, increasing coronary blood flow cannot be expected to improve the contraction of predominantly scar tissue. The value of segmental resection of

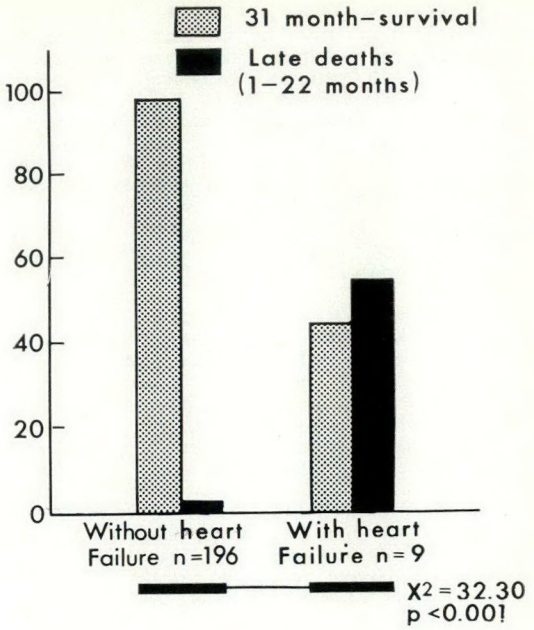


**Fig. 5.**—Thirty-one-month survival and late mortality in operated patients with heart failure compared with those of operated patients without heart failure.

the ventricular wall in such cases is questionable because of the diffuseness of the asynergy. Such resections would still leave a diffusely asynergic left ventricle, albeit one with a smaller cavity.[16] Even with a smaller cavity it is doubtful whether its function would be improved on the basis of Laplace's law since asynergy persists in the wall that remains. Furthermore, several authors have found such resections of ventricular wall have had no beneficial effects.[2, 8, 17]

Such severe ventricular dysfunction, almost invariably associated with previous myocardial infarctions, was related in this series to marked three-vessel involvement. In all patients at least one diseased artery was not amenable to surgery because of a poor distal run-off, resulting in incomplete revascularization. It is postulated that such severe heart failure is almost always accompanied by diffuse coronary atheromatosis which prohibits grafting of all affected arteries.

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# INTRACELLULAR IONIC AND ADENOSINE TRIPHOSPHATE CHANGES IN THE MYOCARDIUM DURING CARDIOPULMONARY BYPASS AND ANOXIA*

K. PRASAD, M.D., Ph.D.,† S. S. NAKAI, M.D., J. C. RUSSELL, Ph.D., L. P. STERNS, M.D. and J. C. CALLAGHAN, M.D., *Edmonton, Alta.*

**Summary: The effect of duration of anoxic cardiac arrest upon the intracellular concentrations of $Na^+$, $K^+$, $Ca^{++}$, adenosine triphosphate and the inulin space was measured in dogs. The $Na^+$ concentration did not change significantly at times up to one hour, while the $K^+$ concentration decreased steadily to 60% of control values by one hour. The $Ca^{++}$ and adenosine triphosphate concentrations fell considerably in the first 15 minutes, were stable for a further 15 minutes and fell to very low values in the period of 30 to 60 minutes of anoxia. The inulin space (a measure of extracellular space) was stable during the first 30 minutes of anoxia, then rose rapidly to approach unity by 60 minutes. It is suggested that the $Ca^{++}$ and adenosine triphosphate concentrations are indicators of the extent of myocardial damage and correlate strongly with the rapid rise in the inulin space.**

**Résumé: Nous avons mesuré chez le chien l'effet produit par la durée de l'arrêt cardiaque anoxique sur les concentrations intracellulaires du $Na^+$, du $K^+$, du $Ca^{++}$, de l'ATP et sur l'étendue de l'inuline. Jusqu'à l'étape d'une heure, la concentration de $Na^+$ n'avait guère changé, tandis que celle du $K^+$ avait diminué régulièrement jusqu'à atteindre 60% de sa valeur initiale. Les concentrations du $Ca^{++}$ et de l'ATP ont diminué beaucoup durant les 15 premières minutes, sont restées stables pendant les 15 minutes suivantes pour atteindre des valeurs extrêmement faibles durant la période d'anoxie de 30 à 60 minutes. L'étendue de l'inuline (mesure d'étendue intracellulaire) est resté stable pendant les 30 premières minutes d'anoxie, puis a été l'objet d'une remontée rapide pour s'approcher de l'unité à 60 minutes. Il est permis de croire que les concentrations de $Ca^{++}$ et d'ATP sont de bons indicateurs de l'ampleur de la lésion du myocarde et sont en étroite corrélation avec la montée rapide de l'étendue de l'inuline.**

ANOXIC cardiac arrest is now an established procedure during open-heart surgery. Decrease in myocardial contractility during anoxia has been reported in man and animals.[1-3] Myocardial ischemia has been known to produce cardiac arrhythmias in the dog and guinea pig.[4, 5] Arrhythmias during anoxia have been postulated to be due to a shortening of the action-potential duration and effective refractory period, and a decrease in the resting potential.[6] The electrophysiological mechanism involved in the anoxic type of arrhythmia seems to be related to the changes in the intracellular ions and the available energy.

The present investigation was undertaken to study the changes in adenosine triphosphate (ATP) and intracellular ions in the myocardium with varying degrees of anoxia during cardiopulmonary bypass. It was hoped that this would help elucidate the mechanism of decrease in myocardial contractility and the genesis of cardiac arrhythmias and arrest during anoxia in open-heart surgery. We also hoped to determine the stage in time when the changes become irreversible.

## METHODS

Thirty-four dogs of both sexes weighing 15 to 25 kg were used. They were anesthetized with 30 mg/kg Nembutal intravenously and ventilated artificially using room air by means of a Mark VIII (Bird) respirator. A Travenol 2 LF disposable bubble oxygenator primed with Ringer's lactate solution, and buffered to equate its pH and ionic concentrations with those of plasma, was used for bypass. Heparin was administered in a dose of 250 mg/kg body weight.

The animals were assigned to the following experimental groups, using a random number sequence:

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*Group I.*—Perfused control group of five dogs placed on total cardiopulmonary bypass for one hour. Tritium-labelled inulin was then injected as described below, and plasma and ventricular muscle samples were taken for the measurement of plasma and intracellular $Na^+$, $K^+$, $Ca^{++}$, ATP, and inulin;

*Group II.*—Anoxic group of five dogs subjected to 30 minutes of myocardial anoxia;

*Group III.*—A second anoxic group; six groups of four dogs each were exposed to 15, 20, 25, 30, 40, and 60 minutes of anoxia respectively. As in Group I the dogs were placed on bypass for one hour, following which the aorta was clamped and the coronary arteries were perfused with Ringer's lactate solution. This solution had been rendered anoxic ($Po_2 < 5$ mm Hg) by bubbling nitrogen through it in a closed system. The pH and the ionic concentrations of the solution used were similar to those of the dog blood. Radioactive inulin was injected into this coronary perfusate 10 minutes before sampling. The use of this perfusate to render the myocardium anoxic was essential in order to maintain a continuous open system and allow measurement of ionic changes and inulin space. An atrial vent was made to drain the excess fluid, thereby maintaining the open system and preventing distension of the heart.

Muscle samples for ATP measurement were immediately deep-frozen in liquid nitrogen and maintained at −90° C until processed. They were weighed and then ground in liquid nitrogen in a mortar with eight times their weight of 6% perchloric acid. After the resulting mush had been allowed to thaw slowly, the protein-free supernatant solution was used for the measurement of the ATP concentration by the method of Bergmeyer.[7] For the cation measurements 0.5- to 1-g samples were digested overnight at 40° C in a mixture of 2 ml of concentrated nitric acid, 2 ml of 70% perchloric acid and 1 ml of water. After boiling for 30 minutes the solutions were made up to 10 ml with water. $Na^+$ and $K^+$ concentrations were then measured using an Instrument Laboratories model 143 flame photometer. $Ca^{++}$ concentrations were measured by the method of Kingsley and Robnett.[8] Water contents were measured by drying in an oven at 100° C.

Separate 50-mg muscle samples were taken for the estimation of the inulin space. These samples were weighed, dried and combusted in a Packard model 300 tricarb sample oxidizer. The combustion products were counted in Brays' mixture[9] in a Nuclear Chicago Mark I liquid scintillation counter. Plasma samples were treated similarly. The counting efficiency was determined by the channels ratio method.

The extracellular space was computed from the radioactivity values for the muscle and plasma. It was assumed that the extracellular concentration of inulin and the ions was equivalent to the plasma value. The intracellular concentrations were then computed. In the cases in Group III, where the measured inulin space became very large, the average value for Groups I and II was used. As it was apparent that concentration gradients across the cell walls existed for $Na^+$ and $K^+$, but not for inulin, this was believed to be justified. In any event, calculations on the basis of the experimental inulin spaces for Group III gave nonsensical results.

Statistical analysis was done following Kenny and Keeping,[10] using Student's t test.

Enzymes and enzyme substrates were obtained from Sigma Chemical Company Ltd., St. Louis, Mo. All other chemicals were reagent grade. Inulin-methoxy-$^3H$ (162 mC/g, molecular weight = 56,000) was obtained from New England Nuclear, Boston, Ma. Solutions were made to 5 mC/l without added carrier. Ten millilitres of this solution was used for each experiment.

## Results

Table I and Figs. 1 to 5 summarize the results. The intracellular $Na^+$ concentration might appear to have increased during anoxia, but the changes were not significant. The $K^+$ concentration on the other hand decreased steadily, the values from 20 minutes on being significantly lower than the control. The value at 60 minutes was about 60% of the control. In comparison the intracellular $Ca^{++}$ concentration fell rapidly

TABLE I.—INTRACELLULAR CONCENTRATIONS AND EXTRACELLULAR SPACE. FIGURES INDICATE MEANS AND STANDARD DEVIATIONS

| | $Na^+$ *mEq/l* | $K^+$ *mEq/l* | $Ca^{++}$ *mEq/l* | *ATP* *μmoles/g* | *Inulin space* |
|---|---|---|---|---|---|
| Group I — perfusion 60 min... | 27.6 ±12.2 | 94.3 ± 7.1 | 26.7 ± 6.5 | 5.5 ± 0.6 | 0.26 ± 0.08 |
| Group II — anoxia 30 min.... | 39.8 ±13.1 | 74.2 ±11.5 | 15.9 ± 4.2 | 3.7 ± 0.2 | 0.22 ± 0.10 |
| Group III — anoxia 60 min... | 39.4 ±23.7 | 54.1 ±15.8 | < 2* | 0.91 ± 0.07 | 0.72 ± 0.14 |

*2 mEq/l is the lower limit of the method used.

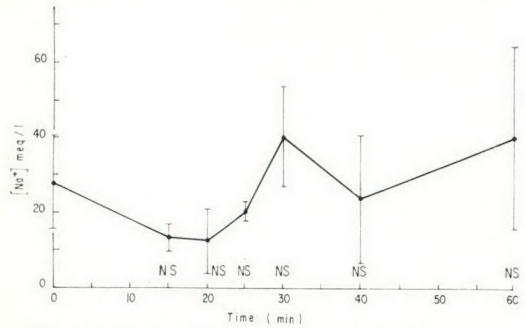


**Fig. 1.**—Intracellular $Na^+$ concentrations as a function of the duration of anoxia. The vertical bars represent the standard deviations. None of the concentrations was significantly different (at the 0.05 level) from the value before anoxia.

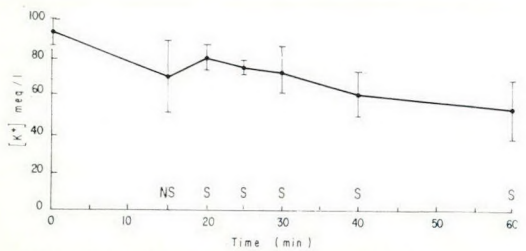


**Fig. 2.**—Intracellular $K^+$ concentrations as a function of duration of anoxia. The vertical bars represent the standard deviations. The significance of the differences from the values before anoxia is indicated by S ≡ P < 0.05, NS ≡ P > 0.05.

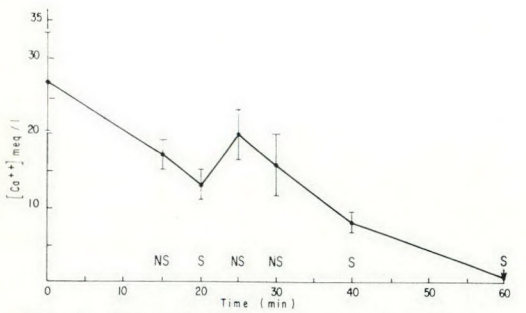


**Fig. 3.**—Intracellular $Ca^{++}$ concentrations as a function of duration of anoxia. The vertical bars represent the standard deviations. The significance of the differences from the values before anoxia is indicated by S ≡ P < 0.05, NS ≡ P > 0.05.

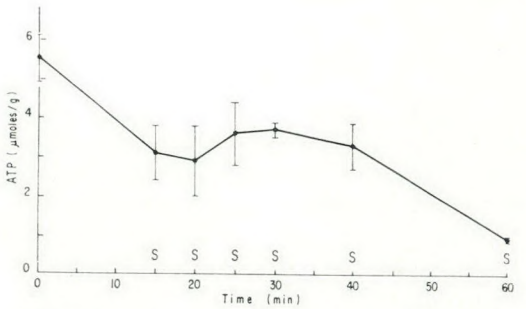


**Fig. 4.**—Tissue ATP content as a function of duration of anoxia. The vertical bars represent the standard deviations. The significance of the differences from the values before anoxia is indicated by S ≡ P < 0.05, NS ≡ P > 0.05.

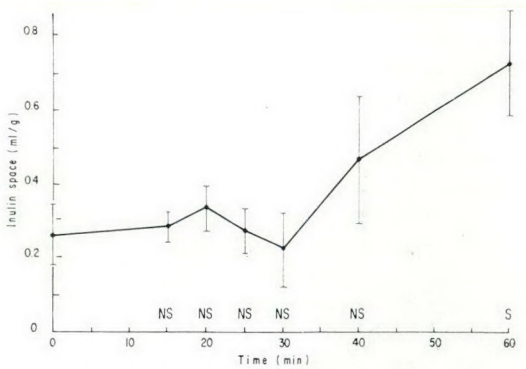


**Fig. 5.**—Cardiac tissue inulin space as a function of duration of anoxia. The vertical bars represent the standard deviations. The significance of the differences from the values before anoxia is indicated by S ≡ P < 0.05, NS ≡ P > 0.05.

and reached extremely low values at 60 minutes. The ATP content of the muscle also fell dramatically, being 16% of the control value at one hour. The inulin space remained relatively constant for the first 30 minutes of anoxia. Thereafter it rose rapidly to values approaching unity at one hour.

Table II shows the concentrations of $Na^+$, $K^+$ and $Ca^{++}$ in the perfusates used, as measured during each experiment.

TABLE II.—PERFUSATE ION CONCENTRATIONS. FIGURES INDICATE MEANS AND STANDARD DEVIATIONS

| | $Na^+$ mEq/l | $K^+$ mEq/l | $Ca^{++}$ mEq/l |
|---|---|---|---|
| Group I — perfusion 60 min | 156.1 ± 4.6 | 3.0 ±0.4 | 4.9 ±0.8 |
| Group II — anoxia 30 min | 158.5 ± 13.5 | 4.2 ±0.4 | 4.5 ±0.5 |
| Group III — anoxia 60 min | 134.8 ± 29.2 | 4.0 ±1.1 | 3.7 ±0.4 |

## DISCUSSION

In the anoxic hearts, the inulin space increased from 0.26 to 0.72, indicating that in some way the cell membranes had become permeable to the inulin. The mechanism by which this occurs is not known but must involve some sort of selective membrane defect, as the affected muscles still retained a $Na^+$ and $K^+$ concentration gradient.

The active transport of $Na^+$ and $K^+$ across cell membranes depends upon ATP and adenosine triphosphatase.[11] The ATP content was markedly reduced during anoxia, as expected with anaerobic metabolism. Lowered ATP levels would be expected to lower the ion pumping rate. The lowered intracellular $K^+$ and slightly elevated intracellular $Na^+$ concentrations are undoubtedly a reflection of this rate change. The lower intracellular $Ca^{++}$ concentration during anoxia might be due to decreased binding or uptake into the sarcoplasmic reticulum.

The data in Figs. 3 and 4 for $Ca^{++}$ and ATP may be interpreted in terms of an initial fall in concentration, followed by a stable period from 15 to 30 minutes. After this both concentrations fell drastically. The inulin space showed a similar pattern, with no change for 30 minutes, followed by a marked increase. It is possible that the lower intracellular $Ca^{++}$ might be due to a membrane defect, the same as, or related to, the defect allowing passage of the inulin. Both correlate with the fall in ATP content. Decrease in myocardial contractility is probably due to a decrease in the available energy (ATP) and the decrease in the intracellular $Ca^{++}$. The genesis of cardiac arrhythmias during or following operation is probably due to lowered intracellular $K^+$ as well as ATP content.

The results do not allow any statement as to the reversibility of changes. It seems probable that reversibility is related to the severity of the disturbance, as reflected in such parameters as the ATP concentration and the cation concentration gradient. The $Ca^{++}$ concentrations decreased to very low values at times over 30 minutes, and this decrease may relate to reversibility. Whether this is actually so can only be elucidated by a further series of experiments.

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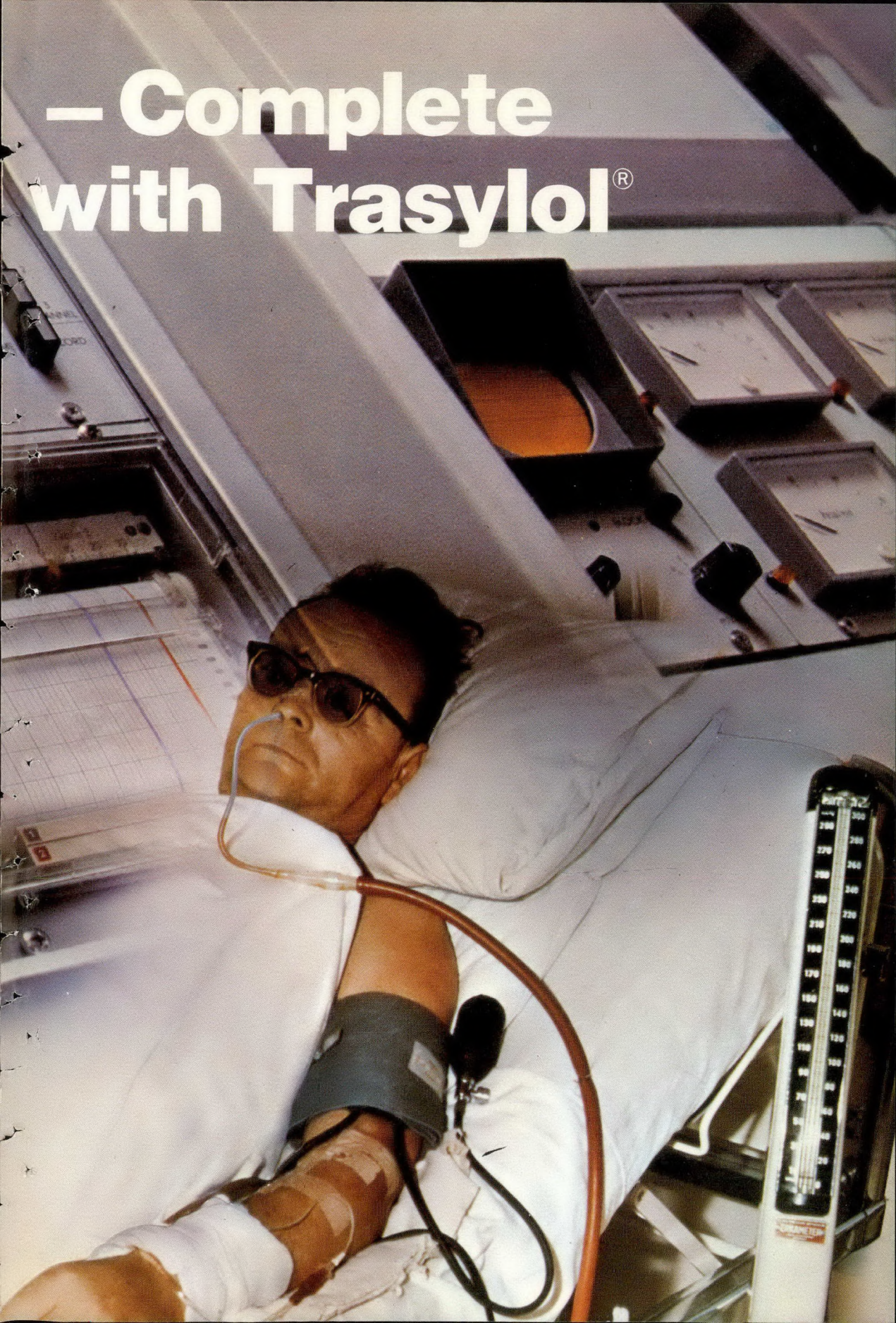
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# ACUTE MYOCARDIAL INFARCTION AND MUSCLE SALVAGE: A POTENTIAL ROLE FOR PHARMACOLOGICAL AGENTS*

ELDON R. SMITH, M.D., F.R.C.P.[C], *Halifax, N.S.*

**Summary: Because most in-patient deaths from acute myocardial infarction result from "pump" failure secondary to excessive muscle necrosis, recent investigation has been aimed at decreasing infarct size by improving the balance between myocardial oxygen supply and demand. Experimental studies in dogs have shown that the use of nitroglycerin, beta-receptor blockade, glucocorticoids, hyaluronidase, glucose-insulin-potassium solution and intra-aortic balloon counterpulsation can reduce the size of infarction resulting from acute coronary artery occlusion. These results suggest the exciting possibility that such agents, alone or in combination, may prove efficacious in limiting muscle necrosis during acute myocardial infarction in man.**

**Résumé: Etant donné que la majorité des décès par infarctus aigu du myocarde est causée par un défaut de la "pompe" cardiaque, secondaire à une nécrose excessive du myocarde, on a cherché récemment à réduire la dimension de la zone de nécrose en améliorant l'équilibre entre l'apport d'oxygène et les besoins de l'organe. Des essais effectués chez le chien ont montré que l'emploi de nitroglycérine, d'inhibiteurs des bêta-récepteurs, de glucocorticoïdes, d'hyaluronidase, de solution à base de glucose-insuline-potassium et d'une contrepulsation par ballon intra-aortique sont autant de mesures susceptibles de réduire la dimension de l'infarctus résultant de l'occlusion aiguë d'une artère coronaire. Ces résultats expérimentaux permettent de croire qu'en utilisant ces agents, isolément ou associés, on pourrait limiter l'étendue de la zone de nécrose au cours de l'épisode aigu d'infarctus du myocarde chez l'homme.**

In the USA approximately 600,000 persons die each year from acute myocardial infarction. Of these deaths 50% occur before the patients reach hospital,[1, 2] and presumably they are due to ventricular fibrillation.[3] In patients who survive long enough to be admitted to a coronary-care unit, however, primary rhythm disturbance is an uncommon cause of death; "pump" failure followed by development of the shock syndrome is responsible for death in most of these cases.[4, 5] Therefore it is not surprising that at necropsy large areas of infarcted myocardium are demonstrable in virtually all patients who die in cardiogenic shock.[6, 7] Similarly, a study[8] using creatine phosphokinase release as a reflection of infarct size showed a direct relationship between in-patient mortality and the amount of necrotic cardiac muscle, and indicated larger infarcts in survivors in whom Class III or IV symptoms developed than in those with minimal or no subsequent limitation. Therefore, as both recovery from the acute episode and the degree of postinfarct reduction in function apparently relate to the amount of necrotic muscle, efforts to reduce in-patient mortality and the incidence of severe postinfarct left ventricular dysfunction should be directed at limiting the area of ischemic myocardium.

Recent experimental studies have indicated that, even in the early stages of acute myocardial infarction, a portion of myocardium is blighted, and that this will become necrotic despite treatment. However, there is a surrounding area of muscle that is compromised yet can survive if the balance between oxygen supply and demand is improved,[9] and considerable data from animal studies and preliminary trials in humans suggest that some pharmacological agents have the potential to influence the fate of this jeopardized area of myocardium.

## Anatomic and Physiological Considerations

The coronary circulation can be divided into two functional components, the large epicardial or conductive vessels and the small arteriolar resistance vessels. The major portion of total coronary resistance is the result of arteriolar tone. Although coronary arteries receive adrenergic innervation, neurohumoral mechanisms appear to play no significant role in regulating coronary

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Supported in part by Medical Research Council of Canada Grant MA-5175.

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vascular resistance and blood flow;[10] rather, metabolic substances, notably adenosine, finely regulate tone in the resistance vessels and govern coronary arterial blood flow. As myocardial oxygen extraction is almost maximal even during rest, this metabolic vasodilation is the only reserve mechanism available for augmenting myocardial oxygen delivery.

Recent studies by James[11] and others clearly documented the presence of collateral coronary vasculature in normal human hearts; the extent and calibre of the channels differed considerably, but almost every heart contained vessels greater than 100 $\mu$ in diameter. Many of these intercoronary anastomoses arise from conductive vessels and therefore are proximal to the arteriolar resistance vessels. Normally, because there is no pressure differential between the proximal and distal ends, no flow occurs within the channels. With the development of atherosclerotic narrowing of the large vessels, however, a pressure differential develops between the normal portion of the artery and the distal segment of the narrowed vessel and induces flow through the collateral channel. Continued exposure to pulsatile flow enlarges the channels, which develop a muscular wall and may become visible on coronary angiograms.

Relatively few factors appear to influence coronary collateral flow: (1) Collateral flow, like flow in any vessel, is dependent upon driving pressure—in this instance, pressure in the root of the aorta. (2) The duration of diastole is a major determinant of coronary and coronary collateral flow since both are primarily diastolic events. Experiments in which the influence of these two factors was measured as retrograde flow in a proximally occluded coronary artery demonstrated their independent effects;[12] therefore intervention that either decreases aortic diastolic blood pressure or increases cardiac rate decreases collateral blood flow. (3) Studies in animals have shown that nitroglycerin, also, can increase flow through such anastomoses.[12] The mechanism of this action is not clear; nitrates may dilate large coronary vessels or collaterals directly, but it seems equally possible that their beneficial effects stem from their peripheral action, causing redistribution of coronary blood flow to ischemic myocardium.

Since all patients have collateral channels, it is still unexplained why some patients with coronary atherosclerosis suffer massive myocardial necrosis whereas others with similar anatomy have only a limited infarction or even no muscle damage. Obviously a great deal remains to be learned concerning the mechanisms involved in the utilization of these collateral pathways. Meanwhile, attempts to improve the clinical course of acute myocardial infarction are limited to techniques that might: (a) increase myocardial oxygen delivery and/or improve distribution; (b) decrease myocardial oxygen demand; or (c) alter both and, therefore, improve the relationship between oxygen supply and demand.

## Increased Myocardial Oxygen Delivery

Aortocoronary bypass surgery is a valuable adjunct to therapy for chronic ischemic heart disease but its usefulness in cases of acute myocardial ischemia has not been established. Even if the current, multicentre, random study of medical *versus* surgical management of the unstable-angina syndrome shows that operative intervention is efficacious in this situation, such therapy will not help the majority of patients in coronary-care units who already have myocardial necrosis. Such patients would benefit most from some form of intervention that would limit the size of infarction during the acute event, permitting revascularization if warranted by symptoms during convalescence.

Other methods of increasing oxygen delivery are limited. The administration of 40% oxygen reduces infarct size in dogs,[13] and this measure is used routinely in most coronary-care units. Experimental studies have shown that several other agents, not clearly related to increasing the oxygen supply, can reduce the degree and extent of myocardial ischemia; these include glucocorticoids, hyaluronidase and glucose-insulin-potassium solution.[14-16] The mechanism of their action is not clear but it seems likely that their effectiveness depends on collateral blood flow into the ischemic zone.

### Decreased Myocardial Oxygen Demand

Beta-adrenergic blockade with propranolol, which decreases both heart rate and contractile force, is the most widely used method of reducing myocardial oxygen needs. Unfortunately, this agent tends to precipitate left ventricular failure in patients with acute infarction, thereby precluding its wider use. By contrast, some patients with unstable angina respond to rest, sedation, and propranolol therapy, and do not progress to acute infarction. The situation becomes complex when unstable angina thus treated does not respond, as many oppose open-heart surgery in the presence of $\beta$-blockade.[17] This brings about a situation in which the indication for operation is failure of medical management, and the medical management of choice is contraindicated if urgent operative intervention is contemplated.

When acute myocardial infarction is complicated by left ventricular failure, digitalis and diuretics may decrease the oxygen demand. Diuretics act by decreasing intravascular volume and left ventricular dimensions and, therefore, myocardial wall tension—a major determinant of myocardial oxygen consumption. Similarly, during left ventricular failure cardiac glycosides may reduce wall tension enough to more than compensate for the increased oxygen cost of the positive inotropism, the net effect being decreased oxygen demand.

### Increased Myocardial Oxygen Supply With Decreased Oxygen Demand

The concept of aortic balloon counterpulsation evolved from knowledge of the factors that influence myocardial oxygen supply and demand. Inflation of an intra-aortic balloon during each diastole increases coronary perfusion pressure during the period when coronary flow occurs, and deflation during systole decreases systolic pressure and, therefore, left ventricular work. The former increases oxygen delivery and latter diminishes oxygen demand. Experiments in dogs have shown that intra-aortic counterpulsation reduces infarct size,[18] and considerable clinical experience has been gained with this technique in several centres. Unfortunately, in patients with acute infarction and cardiogenic shock, the long-term results are discouraging,[19] probably reflecting the large area of necrotic muscle present by the time counterpulsation is instituted.

More recently the balloon pump has been used to facilitate urgent hemodynamic and angiographic study of patients with pre-infarction states.[20] Although the concept of counterpulsation is sound, the usefulness of the method is limited. Its operation requires expensive equipment and highly trained staff, and the procedure is invasive and cannot be maintained for long periods. These factors render unlikely its prophylactic use to prevent ischemia which is severe enough to induce the shock state.

To effectively limit infarct size and the hemodynamic consequences of a large area of necrosis, a procedure should be inexpensive, easy to perform and suitable for prolonged use. No procedure that meets these criteria is available at present, although recent experiments in animals and some preliminary human studies suggest that vasoactive substances can significantly limit the degree of ischemia and therefore the extent of ultimate muscle necrosis during acute myocardial infarction. In a recent series of experiments with closed-chest, sedated dogs at the National Heart and Lung Institute, Bethesda, Md., myocardial ischemic injury following acute coronary occlusion was more extensive when the heart rate was increased or the systemic arterial pressure was decreased.[21] By contrast, increasing the arterial pressure by the infusion of $\alpha$-receptor agonists resulted in less ischemia. In view of these findings it was somewhat surprising that nitroglycerin administered intravenously during coronary occlusion resulted in significantly less myocardial ischemia, despite decreased mean arterial pressure and increased heart rate.[22] With venous hemorrhage sufficient to produce the same change in arterial pressure and heart rate as that produced by nitroglycerin, the degree of resultant ischemia tended to increase. Moreover, prevention of the nitrate-induced hypotension and the reflex heart-rate increase by the simultaneous intravenous administration of methoxamine potentiated the beneficial effect of nitroglycerin

on the degree of ischemia; even when infused as long as two hours after coronary occlusion, these drugs promptly induced a marked decrease in myocardial ischemia. It seems clear that nitroglycerin, when given with an $\alpha$-receptor agonist in a dose sufficient to abolish the nitrate-induced decrease in coronary perfusion pressure and the reflex heart-rate increase, can decrease the extent of myocardial ischemia following experimental coronary occlusion.

To ascertain whether this beneficial effect on the ischemic process enhances the electrical stability of the myocardium, we measured the amount of current necessary to induce ventricular fibrillation following acute reversible ligation of the anterior descending coronary artery.[23] In dogs pretreated with nitroglycerin the ventricular fibrillation (VF) threshold was significantly increased. Moreover, when phenylephrine was given simultaneously in a dose sufficient to reverse the nitroglycerin-induced hypotension, the VF threshold was further increased, to a value not significantly different from control. In a more recent study,[24] using a canine model in which death from ventricular fibrillation usually occurred within 30 minutes of proximal coronary occlusion, nitroglycerin plus methoxamine significantly increased the survival rate.

These experimental observations imply that nitroglycerin combined with an $\alpha$-adrenergic agonist not only reduces the extent of ischemic injury following coronary artery occlusion but also decreases the predisposition for ventricular arrhythmias. Although the effects of these agents in man are not known, recent studies[25, 26] have shown that the administration of nitroglycerin or sodium nitroprusside (both non-specific vasodilators) to patients with acute myocardial infarction and congestive cardiac failure can improve their hemodynamic state.

## Discussion

Although nitroglycerin has been used for more than a century in the treatment of angina pectoris, traditionally it has been considered contraindicated in acute infarction. This belief is based on the assumption that the nitrate-induced reduction in coronary perfusion pressure and the reflex increase in heart rate would extend the ischemic process. However, the experiments referred to above demonstrate that nitroglycerin can reduce the degree of ischemia following coronary occlusion in dogs. These findings imply that nitroglycerin exerts its beneficial effect independently of reduction in ventricular afterload, and despite a decrease in coronary perfusion pressure and increase in heart rate. These observations do not prove, however, that nitroglycerin acts directly on the coronary vasculature. The effects of nitroglycerin on the venous system could result not only in increased myocardial blood flow with decreased oxygen demand but also in a favourable redistribution of flow to ischemic myocardium.

Regardless of the mechanism of its action, it is clear that nitroglycerin plus an $\alpha$-receptor agonist can reduce ischemic injury during experimental acute infarction. Whether a similar reduction in ischemic injury can be achieved during acute myocardial infarction in man is unknown: the effects of these agents may be entirely different when more than one vessel is diseased. However, experimental results are encouraging and indicate a need for clinical studies.

If such studies confirm the experimental observations, a valuable adjunct to the therapy of acute myocardial infarction may be available. Combinations of vasoactive drugs with other pharmacological agents or with balloon counterpulsation may prove more effective than any single form of intervention. Such therapeutic regimens could provide major clinical benefits. First, the need for urgent operative intervention in the unstable anginal patient might be reduced, permitting elective study and operation for more patients at a time when risks are minimal. Second, for those patients who do require emergency operation such therapy might reduce the risks of infarction developing during hemodynamic investigation, operation and the early postoperative period. Finally, and perhaps more exciting, is the possibility that the prophylactic administration of these agents early in the course of acute myocardial infarction might prevent excessive muscle necrosis and thereby significantly reduce the incidence of both cardiogenic shock and severe postinfarction left ventricular dysfunction.

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# INTRACARDIAC PRESSURES DURING INDUCED VENTRICULAR FIBRILLATION AND ANOXIC ARREST*

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**Summary: The left heart is commonly vented during aortocoronary bypass operations on the assumption that without it, left ventricular distension and excessive left-sided pressures will inevitably occur. To test this hypothesis, a series of experiments were carried out in 25 dogs. These showed that distension of the left heart and a rise of intracardiac pressures are not the inevitable consequences of ventricular fibrillation or anoxic cardiac arrest. These phenomena were more likely to occur in the fibrillating than in the arrested heart. Adequate drainage of the right heart usually suffices to decompress the left heart as well but inadequate drainage of the right heart regularly leads to excessive left-sided pressures and distension. A few animals showed left-sided distension despite adequate right heart decompression. The reasons for this are not clear from the present experiment.**

**Résumé: Dans la majorité des opérations intracardiaques, on considérait comme essentiel de décomprimer la partie gauche du coeur. Nous avons étudié sa nécessité chez 25 chiens chez lesquels on avait provoqué expérimentalement une fibrillation ventriculaire ou un arrêt cardiaque anoxique. On a observé que la distension du coeur gauche et l'augmentation des pressions intracardiaques ne se produisaient pas nécessairement et qu'il y avait plus de chances qu'elles soient provoquées par la fibrillation que par l'arrêt cardiaque. Un bon drainage du coeur droit suffira généralement à opérer la décompression du coeur gauche, mais drainage incomplet du coeur droit provoque généralement des pressions excessives du côté gauche et distension. En dépit d'une décompression adéquate du coeur droit quelques animaux ont présenté une distension du coeur gauche. Ceci est un phénomène que nos expériments n'ont pas pu expliquer.**

FOR many years it has been common practice to vent the left side of the heart in operations for acquired valvular and congenital heart disease. More recently this maneuver has been generally adopted for operations for ischemic heart disease without any proof of its necessity or desirability in this situation. The practice has been based upon the premise that without venting cardiac distension and excessive pressures in the left heart will inevitably develop. The experiment described below was designed to test this assumption and was stimulated in part by the observation of Evans *et al*[1] that in a closed-chest dog retrograde flow through the lungs and right heart occurred during ventricular fibrillation and supported circulation. Cardiac distension was not observed in their experiments and it seemed reasonable to us to suppose that the same relationships would hold with the chest and pericardium open.

## METHOD

Twenty-five mongrel dogs were anesthetized and subjected to thoracotomy and whole-body perfusion using a disposable bubble oxygenator and non-hemic priming solution. Uncrossmatched whole blood was added during perfusion as necessary to maintain the hematocrit at 25% to 30%.

Before perfusion, catheters were placed in the left ventricle, left atrium and right atrium for pressure recording, and the azygos vein was ligated. Pressures were measured with Statham P23 AC transducers and recorded on a Grass Model 5C polygraph. Both venae cavae were cannulated through the right atrium. The left side of the heart was not vented. Arterial return was through the femoral artery.

Ten minutes after the onset of perfusion, anoxic arrest was induced by cross-clamping the ascending aorta. After 30 minutes of anoxia the clamp was released, the heart was defibrillated and perfusion was terminated as soon as the heart was capable of sustaining the circulation.

The group of animals was divided into three experimental subgroups as follows: In Group A (13 dogs) ventricular fibrillation was induced electrically five minutes after the start of perfusion and five minutes before the induction of cardiac anoxia. In

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Supported by grants from the Saskatchewan Heart Foundation and the Medical Research Council of Canada.

TABLE I.—INTRACARDIAC PRESSURES. MEAN ± SEM*

| | *Before perfusion* | *After 10 minutes' perfusion* | *After 30 minutes' arrest* | *Before resuscitation* | *After perfusion* |
|---|---|---|---|---|---|
| *Group A* | | | | | |
| RA | 5.2 ± 0.6 | 5.6 ± 0.8 | 4.8 ± 0.8 | 4.5 ± 0.8 | 5.7 ± 0.7 |
| LA | 5.3 ± 0.6 | 11.1 ± 1.7 | 9.0 ± 1.7 | 8.1 ± 0.9 | 7.5 ± 0.7 |
| LV | 3.9 ± 0.7 | 14.5 ± 2.5 | 9.8 ± 1.8 | 9.1 ± 0.6 | 3.6 ± 0.9 |
| *Group B* | | | | | |
| RA | 4.0 ± 1.0 | 2.3 ± 0.7 | 2.6 ± 1.1 | ——— | 5.8 ± 1.0 |
| LA | 4.9 ± 1.2 | 2.7 ± 0.7 | 9.0 ± 2.9 | 8.8 ± 0.6 | 6.3 ± 1.2 |
| LV | 2.4 ± 1.2 | 4.6 ± 0.9 | 9.0 ± 2.4 | 9.5 ± 0.5 | 2.3 ± 0.8 |
| *Group C* | | | | | |
| RA | 7.6 ± 1.0 | 6.3 ± 0.8 | 28.4 ± 3.4 | 67.0 ± 2.9 | 8.7 ± 0.7 |
| LA | 8.0 ± 0.9 | 6.4 ± 1.4 | 28.6 ± 3.3 | 80.3 ± 7.3 | 1.0 ± 0.5 |
| LV | 6.3 ± 1.3 | 7.0 ± 0.6 | 27.8 ± 3.6 | 81.8 ± 6.5 | 4.5 ± 0.5 |

*In the beating heart left ventricular end-diastolic pressure is recorded. In the fibrillating or arrested heart mean left ventricular pressure is recorded.

Group B (seven dogs) arrest was induced directly without prior fibrillation. In Group C (five dogs) the right heart was excluded from the extracorporeal venous drainage system by means of tourniquets about the caval cannulas.

## RESULTS (Table I)

The results in Group A subjects are shown in Fig. 1. There was a moderate but significant rise ($P < 0.005$) in both left ventricular pressure (3.9 mm Hg ± 0.7 to 14.5 ± 2.5) and mean left atrial pressure (5.3 ± 0.6 mm Hg to 11.1 ± 1.7) during the period of induced ventricular fibrillation prior to arrest. However, this was not observed in all dogs. The apparent reverse gradient across the mitral valve seen after 10 minutes of perfusion (five minutes of fibrillation) is not significant ($P > 0.05$). Mean left ventricular pressure has been plotted in the fibrillating or arrested state and left ventricular end-diastolic pressure in the beating state. Left-sided pressures declined during the 30-minute arerst and did not rise following termination of anoxia or during resuscitation of the heart. In only two of these 13 animals was gross cardiac distension observed. Two animals died before the end of perfusion because of hemorrhage, but in the remaining 11 perfusion was successfully concluded. No significant changes in right atrial pressure were observed.

The results in Group B are shown in Fig. 2. There was no significant change in intracardiac pressures during the pre-arrest

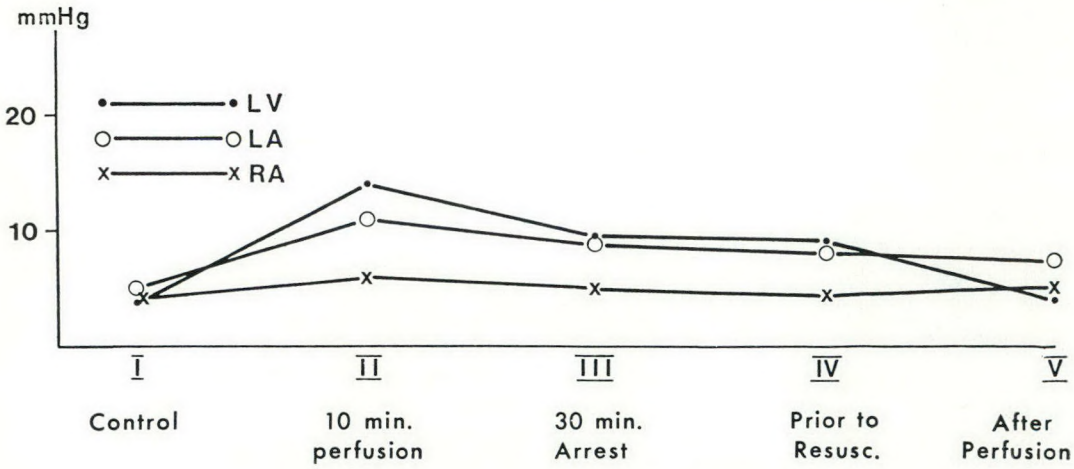


**Fig. 1.**—Intracardiac pressures, Group A (13 dogs).

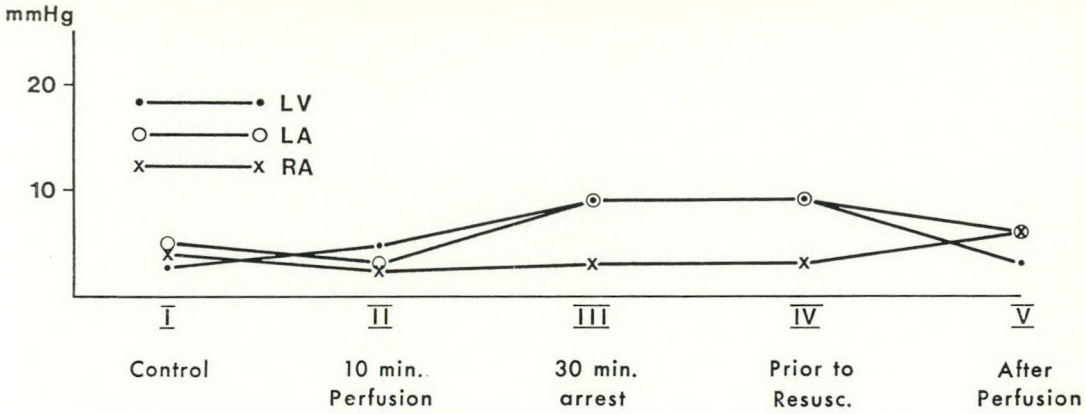


**Fig. 2.**—Intracardiac pressures, Group B animals (seven).

period of perfusion. During the time of anoxic arrest left ventricular and left atrial pressures slowly rose to a mean value of 9.0 ± 2.9 mm Hg ($P < 0.05$). There was no further change in the average of left-sided pressures in this group during the period of cardiac resuscitation, but one of the animals did display gross cardiac distension. In six dogs bypass was successfully concluded, but in the seventh the procedure was terminated because of an aortic tear. There was no significant change in right atrial pressure at any point in the experiment.

A comparison of left atrial pressure events in these two groups is shown in Fig. 3. The difference observed between the fibrillating and non-fibrillating heart after 10 minutes of perfusion is significant at the $P < 0.005$ level. The behaviour of these two groups at other points in the experiment was similar.

Fig. 4 demonstrates the influence on the left atrial pressure of tightening tourniquets about the caval catheters and is essentially a repetition of the information in Fig. 3 to which has been added the left atrial pressures in Group C animals. Left atrial pressure began to rise during the period of anoxic arrest and reached a level of 37.0 ± 4.5 mm Hg at the end of 30 minutes of anoxia. All hearts had become grossly distended by the time of release of the aortic clamp, at which point there was a further precipitous rise in left atrial pressure (to 61.0 ± 10.0 mm Hg) and extreme cardiac distension developed. Right and left atrial pressures were identical in this group. Following release of the caval tourniquets there was prompt cardiac decompression, and defibrillation could not be performed until this occurred. In two of these five dogs the heart was incapable of sustaining the circulation unaided by mechanical means.

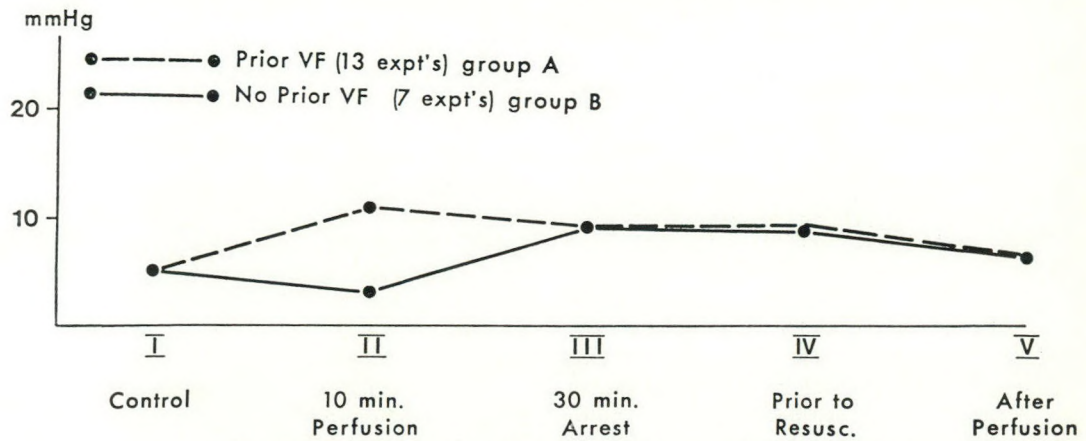


**Fig. 3.**—Influence of ventricular fibrillation on left atrial pressure.

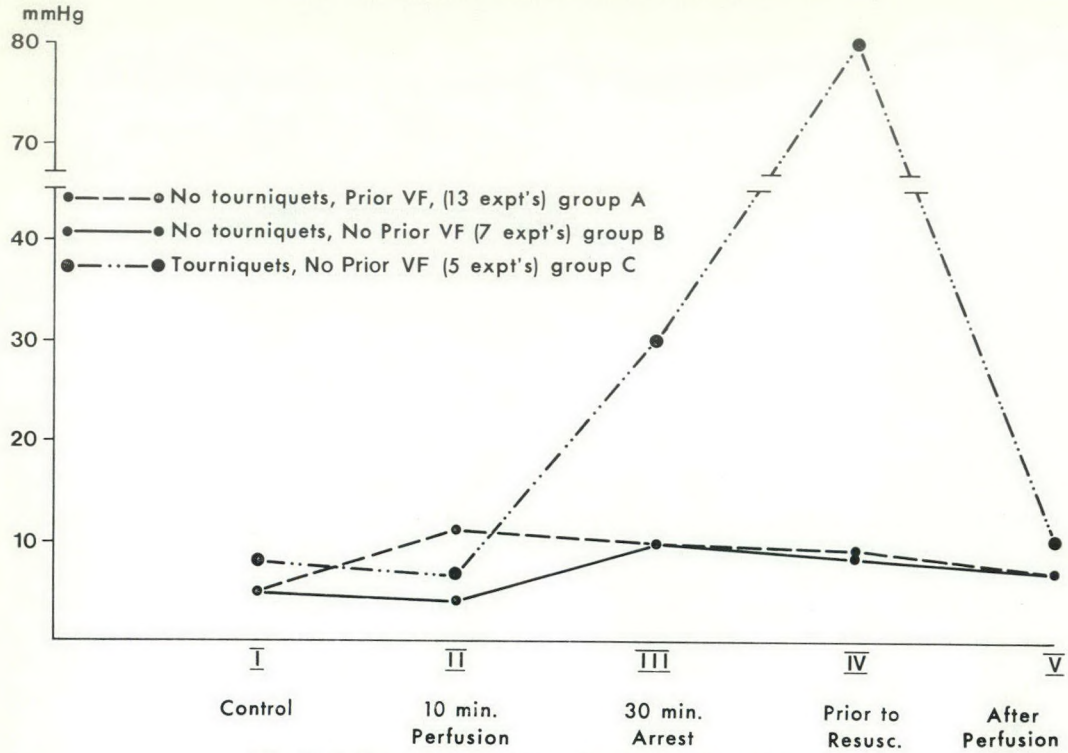


**Fig. 4.**—Influence of caval tourniquets on left atrial pressure.

## Discussion

The left side of the heart is vented in a wide variety of operations for acquired valvular and congenital heart disease in order to prevent cardiac distension, to provide a bloodless operative field and to permit egress of air and other possible embolic material. This practice has been widely applied in surgery for ischemic heart disease, in which no cardiac chamber is entered and in which the valves are all usually intact.

Venting of the left heart can be carried out either through the left atrium or the apex of the left ventricle.[2] As well as being a slight inconvenience to the surgeon from an extra cannulation, neither route is entirely free from hazard. Major hemorrhage can occur from either site and, with the heart closed, mismanagement of the vent can easily introduce air rather than eliminate it. In addition, in a chronically ischemic heart important collateral vessels can traverse the apex and may be compromised by the the introduction of the vent or in the repair of the resulting stab wound. The authors have seen small aneurysms at the left ventricular apex at cardiac catheterization after open-heart operations or transventricular mitral valvotomy.

Proctor[3] has shown that after eight hours of induced ventricular fibrillation and circulatory support in the closed-chest dog, defibrillation can be carried out and survival achieved. Although intracardiac pressures were not measured in his experiments, the survival of his animals suggests that no serious impairment of left ventricular function, from either distension or other cause, had occurred.

Evans *et al,*[1] using a similar preparation, showed that intracardiac pressures did not rise, left ventricular distension did not occur and retrograde flow of blood through the lungs could be demonstrated. They suggested that in the fibrillating heart the mitral, pulmonary and tricuspid valves become incompetent and they pointed out that the retrograde movement of blood through the lungs could be more accurately decribed as "seepage" than as flow.

The present investigation shows that much the same relationships hold with the chest and pericardium open. Cardiac dis-

tension and excessive left-sided pressures during ventricular fibrillation or arrest were infrequently observed in hearts in which the right side was left in communication with the extracorporeal venous drainage system. Why these undesirable events occurred in some animals and not in others is unclear. It is possible that atrial sinus rhythm in the presence of ventricular fibrillation is sufficient to propel some blood in the forward direction, and it is possible that simultaneous atrial fibrillation may protect against this. Unfortunately, the present experiment does not answer this question.

The rise in intracardiac pressures observed in the arrested heart once tourniquets are applied to the caval catheters shows that, despite a lack of coronary sinus flow, blood must continue to enter the right atrium from some source. We presume that this represents the retrograde bronchial and Thebesian return demonstrated by Evans *et al* and that once this retrograde avenue is closed by application of tourniquets, distension of the arrested or fibrillating heart becomes inevitable.

Venting the left heart is essential to the conduct of many intracardiac operations and has been practised since the early days of open-heart surgery. The belief that, without it, cardiac distension and dysfunction will inevitably occur, seems to have arisen from the elegant experiments of Ross *et al.*[4] However, it is possible that some of the deleterious effects on cardiac and pulmonary function which they observed following arrest in the unvented heart may have been related to the potassium citrate they used to arrest the heart in their experiments.[5] Further, although it is not entirely clear, it seems likely that caval tourniquets were applied in their experiments. Our data support the idea that the left heart must be decompressed if arrest or ventricular fibrillation is induced and the right heart is not completely drained.

The present study suggests that venting is not necessary for all operations for ischemic heart disease and at present we do not employ it for most operations involving the anterior descending or right coronary arteries. We continue to use a vent if there is doubt concerning the integrity of the aortic valve or if we anticipate performing a graft to the left circumflex coronary artery. We are concerned that the forceful retraction occasionally required to expose this artery may cause temporary aortic insufficiency and thus left ventricular distension. Our current preference in aorto-coronary bypass is to vent via the left atrial rather than the left ventricular route. Our results also suggest that an undesirable rise in intracardiac pressure is more likely to occur in the fibrillating than in the arrested heart and that it is probably desirable to keep the pre-arrest period of ventricular fibrillation to a minimum.

## Conclusions

Distension of the left heart and rise of intracardiac pressures are not inevitable consequences of ventricular fibrillation or anoxic cardiac arrest.

These phenomena are more likely to occur in the fibrillating than in the arrested heart.

Adequate drainage of the right heart will usually suffice to decompress the left heart as well. Retrograde bronchial and Thebesian return through the lungs and right heart likely occurs.

Venting of the left heart may not be necessary in all operations for ischemic heart disease.

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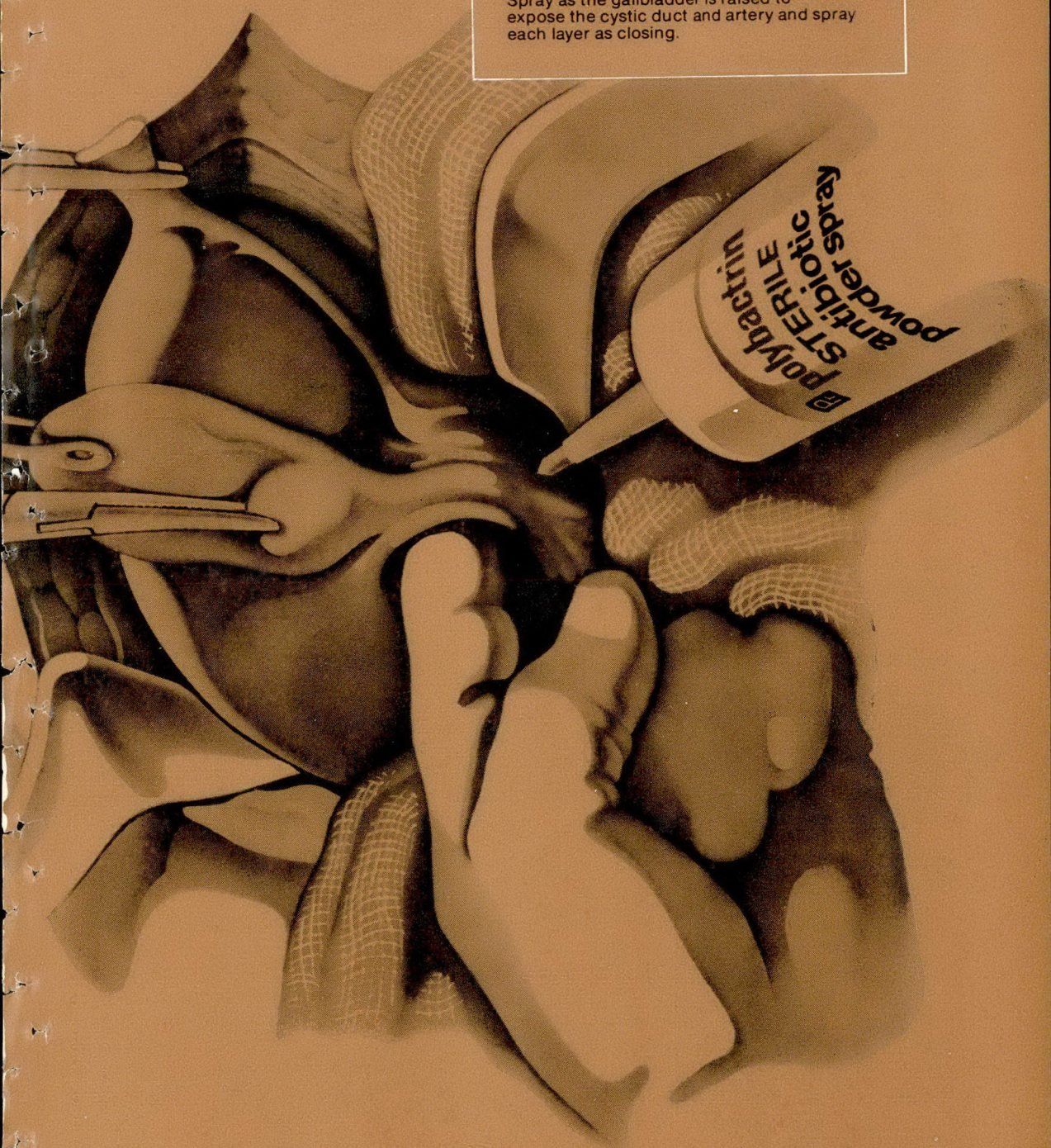

# CLINICAL EXPERIENCE WITH THE INTRA-AORTIC BALLOON IN ASSISTING THE CIRCULATION*

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**Summary: Over a nine-month period, intra-aortic balloon pumping has been used on 14 patients. Of the seven patients in whom the indication for the procedure was inability to discontinue cardiopulmonary bypass following open-heart operation, three survived. Four patients suffered from postoperative cardiogenic shock and one of these survived. The use of intra-aortic balloon pumping for the relief of intractable angina pectoris produced some relief in one patient but brought about no improvement in the other two in whom it was tried.**

**Résumé: Pendant neuf mois, nous avons utilisé la contrepulsion par ballonnet intra-aortique chez 14 malades. Chez sept de ces malades, l'indication de cette méthode était l'impossibilité d'arrêter la dérivation cardiopulmonaire après une opération à coeur ouvert. Trois de ces malades ont survécu. Quatre patients ont souffert d'un choc cardiogénique dont un a survécu. La contrepulsion par ballonnet intra-aortique pour soulager une angine de poitrine rebelle a réussi chez un malade, mais n'a pu améliorer l'état des deux autres, chez lesquels elle avait été tentée.**

SINCE the principle of balloon pumping was first reported by Moulopoulos, Topaz and Kolff[1] and Clauss *et al*[2] in 1962, intra-aortic balloon pumping has been established experimentally and clinically as an effective method of mechanical circulatory assistance for the failing heart.[3-6]

In this report we summarize our experience with this promising method in three different clinical situations.

## METHOD

From June 1972 to March 1973 intra-aortic balloon pumping (IABP) was performed on 14 patients, 12 men and two women. Their ages ranged from 44 to 64 years. The Avco intra-aortic balloon pump, console model IABP-7, was used in combination with the three-segmented 40-ml balloon which is designed to inflate from its central segment toward the ends. The balloon catheter was introduced through the femoral artery into the descending thoracic aorta, just distal to the origin of the left subclavian artery. Phasic function of the balloon was accomplished by the console, utilizing the electrocardiogram to trigger its inflation during ventricular diastole and deflation during ventricular systole.

## RESULTS

### *Group I*

In seven patients the indication for balloon pumping was inability to remove patients from cardiopulmonary bypass following open-heart surgery. Four patients in this group died (Table I). One patient had pulmonary embolectomy and expired with IABP in progress. The other three patients had undergone emergency revascularization for cardiogenic shock following acute myocardial infarction and none of these survived.

Three patients out of seven in this group survived (Table I). One developed a "stone heart"[7] following aortic valve replacement and his successful removal from cardiopulmonary bypass can be credited to IABP; after an additional 1½ hours of balloon assistance this patient recovered. Two patients with severe left ventricular dysfunction had undergone elective myocardial revascularization and left ventricular aneurysmectomy; both were removed from cardiopulmonary bypass with the assistance of IABP and ultimately survived.

### *Group II*

Four patients had IABP for postoperative cardiogenic shock (Table II). Two of these patients became hypotensive two to four hours after myocardial revascularization; one died shortly after mechanical failure of the balloon pump. The third patient became hypotensive and went into cardiogenic shock on the second postoperative day and died shortly after, while IABP was in progress. Two weeks after operation the last patient in this group developed shortness of breath, hypotension and, ultimately, car-

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TABLE I.—IABP WHEN CARDIOPULMONARY BYPASS CANNOT BE DISCONTINUED. GROUP I

| Patient (Sex) | Age (years) | IABP (hours) | Preoperative condition | Operation | Blood pressure (mm Hg) | | | Central venous pressure (mm Hg) | | | Urine output |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Before | During | After | Before | During | After | |
| FATAL CASES | | | | | | | | | | | |
| J.L. (F) | 56 | 3 | Pulmonary embolus | Pulmonary enbolectomy | 60-65 | 70/95 | | 20 | | | Nil |
| G.B. (M) | 59 | ½ | Acute MI | Emergency R, LAD, C grafts | 65 | 70/95 | 120/80 | 25 | 20 | 10 | Increased |
| A.N. (M) | 50 | 52½ | Cardiogenic shock | Emergency LAD graft; resection of infarct | 65-70 | 60/100 | | 25-30 | 15-20 | | Increased |
| A.B. (M) | 62 | 1 | MI, CHB | Emergency LAD and R grafts | 60-65 | 60/95 | | 20-25 | 15-18 | | Nil |
| SURVIVALS | | | | | | | | | | | |
| F.B. (F) | 64 | 1½ | Aortic stenosis | Aortic valve replacement (developed stone heart) | 60-65 | 70/90 | 100/75 | 18 | 12 | 14 | Good after IABP |
| D.W. (M) | 44 | 7½ | 3 MI, CHF | LAD graft and aneurysmectomy | 65-70 | 60/100 | 100/85 | 30 | 20 | 22 | Good with IABP |
| J.H. (M) | 52 | 6 | MI, CHF | R, LAD grafts and aneurysmectomy | 60-65 | 65/110 | 115/65 | 18 | 14 | 11 | Good with IABP |

MI = myocardial infarction; LAD = left anterior descending coronary artery; R = right coronary artery; C = circumflex coronary artery; CHB = complete heart block; CHF = congestive heart failure.

diac arrest. He was resuscitated but remained in shock and IABP was instituted. After 12 hours of balloon assistance he recovered.

### *Group III*

Three patients underwent elective IABP for the relief of intractable angina pectoris which was not amenable to surgical treatment (Table III). One of these patients had relief of angina but the other two were not essentially improved.

## DISCUSSION AND CONCLUSIONS

Because of its simplicity and safety IABP is gaining wide clinical acceptance in the treatment of cardiogenic shock[8] and as a supportive modality for patients undergoing cardiac catheterization and emergency revascularization.[9] Our clinical experience, like that of others,[5] has demonstrated the usefulness of IABP in patients suffering from cardiogenic shock following open-heart surgery.

TABLE II.—IABP IN THE IMMEDIATE POSTOPERATIVE PERIOD. GROUP II

| Patient (Sex) | Age (yrs) | IABP (hrs) | Reason for pump | Pre-operative condition | Operation | Blood pressure (mm Hg) | | | Central venous pressure (mm Hg) | | | Urine output | Outcome |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Before | During | After | Before | During | After | | |
| R.D. (M) | 64 | ½ | Became hypotensive 2nd day postop. | MI | LAD, C grafts, LIM | 40/- | 75/60 | — | 16 | 12 | — | Nil | Died |
| B.P. (M) | 44 | 1¼ | Hypotension immediately postop. | MI CHF | Emergency R, LAD grafts | 60/- | 60/55 | — | 36 | 25 | — | Nil | Died |
| W.K. (M) | 47 | 12 | Acute pulmonary edema and hypotension 2 weeks postop. | MI CHF | R, LAD grafts, aneurysmectomy | 50/- | 75/100 | 115/80 | 30 | 15 | 13 | Good | Survived |
| D.M. (M) | 49 | 13 | Hypotension immediately postop. | MI | R, LAD, C grafts, LIM | unrecordable | 65/60 | — | — | — | — | — | Died |

MI = myocardial infarction; CHF = congestive heart failure; LAD = left anterior descending coronary artery; R = right coronary artery; C = circumflex coronary artery; LIM = left internal mammary (implant).

TABLE III.—IABP FOR RELIEF OF INTRACTABLE ANGINA. GROUP III

| *Name (Sex)* | *Age (years)* | *Operation* | *IABP (hours)* | *Blood pressure (mm Hg)* | | *Result* |
|---|---|---|---|---|---|---|
| | | | | *Before* | *During* | |
| J.K. (M) | 57 | LAD graft, LIM, RIM, 1971 | 1½ | 160/110 | 110/150 | Little or no improvement |
| B.R. (M) | 48 | LAD graft, LIM, 1970 | 2 | 120/80 | 115/95 | Improved |
| E.T. (M) | 50 | Double Vineberg | 2⅓ | 135/80 | 170/90 | No improvement |

LAD = left anterior descending coronary artery; LIM = left internal mammary implant; RIM = right internal mammary implant.

It appears that three patients out of seven who could otherwise not be removed from cardiopulmonary bypass following cardiac surgery were saved with the use of this device. We are convinced that these patients would have died had this procedure not been available. The only other patient in our series to survive with the use of IABP for acute pump failure was one who had developed cardiogenic shock following cardiac arrest two weeks after myocardial revascularization. We believe that this patient's survival also can be attributed to the use of this device.

Further experience is necessary before definite conclusions can be reached as to the indications and uses of the intra-aortic balloon in assisting circulation. At present we feel that its principal use lies in assisting patients suffering from acute pump failure immediately after open-heart surgery. It may also be useful in patients who develop cardiogenic shock for which there is no immediate surgical treatment. We believe that the device can contribute to the support of the patient in cardiogenic shock while cardiac catheterization and angiographic studies are being carried out.

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# EFFECT OF MYOCARDIAL REVASCULARIZATION ON VENTRICULAR FIBRILLATION THRESHOLDS IN DOGS*

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**Summary: Occlusion of the origin of the left anterior descending coronary artery of dogs causes an immediate decrease in the ventricular fibrillation threshold to below 50% of control values. Release of the coronary occlusion after periods of one or two hours is associated with a return of the thresholds to normal values within a two-hour period. Our study suggests that early revascularization of myocardial infarcts will be associated with an improvement of the electrical stability of the heart.**

**Résumé: L'occlusion de l'origine de l'artère coronaire gauche chez le chien provoque une diminution immédiate du seuil de la fibrillation ventriculaire, à moins de 50% de sa valeur initiale. L'arrêt de cette occlusion après une période variant d'une heure à deux heures se traduit, dans un laps de temps de deux heures, par le retour du seuil à sa valeur première. Cette étude permet de croire qu'une revascularisation précoce des infarctus du myocarde améliorera la stabilité électrique du coeur.**

CARDIAC arrhythmias and pump failure account for most of the deaths following myocardial infarction. The importance of ventricular fibrillation and related arrhythmias is emphasized by the fact that 20% of all persons developing symptomatic coronary atherosclerosis die suddenly within one year of the onset of symptoms.[1] Prior to the aggressive treatment of arrhythmias in modern coronary monitoring units, ventricular fibrillation accounted for approximately one-third of these deaths,[2] the most critical period being within the first two days of infarction. The exact cause for abnormal impulse production remains unclear. With the advent of the aortocoronary bypass grafting, isolated cases of emergency coronary revascularization for the management of intractable ventricular arrhythmias have been reported.[3, 4] For this reason information concerning the electrical stability of the heart following coronary occlusion and revascularization becomes of considerable importance.

To date, ventricular-fibrillation-threshold (VFT) studies conducted during the early phase of myocardial revascularization have not been reported. This report concerns the effects on dogs of restoring blood flow following occlusion of the left anterior descending artery for periods of one and two hours and compares the results with those noted following permanent ligation.

## MATERIALS AND METHODS

Sixteen mongrel dogs of both sexes, weighing 9 to 23 kg, were anesthetized with Nembutal (30 mg/kg) and ventilated with 100% oxygen using a Harvard pump while an intravenous line was kept open with normal saline. Additional anesthetic was given during the procedure when necessary in doses of 50 mg. Temperatures were measured using an esophageal thermometer and remained within about 1.5° C of the preoperative temperature. A thoracotomy was carried out through the left fifth interspace, the pericardium opened and VFTs were measured by the method of Shumway, Johnson and Stish.[5]

The area supplied by the ligated left anterior descending coronary artery (LAD) was stimulated using electrodes consisting of two 30-gauge needles embedded 1 cm apart in a Silastic block; the terminal 2 mm of the needles was left bare. The LAD was occluded approximately 2.5 cm from its origin by a loop of 0 silk applied by a snare. Electrocardiographic leads were connected and the signal was fed into a Grass model S4 stimulator, which then fired a DC stimulus of known amplitude and duration, at a pre-set delay, from the QRS of the electrocardiographic tracing (Fig. 1). The stimulus impulse and ECG could be viewed simultaneously by means of an oscilloscope. By gradually increasing the current strength and sweeping the interval of the cardiac cycle to ensure application of the stimulus during the vulnerable period, we obtained

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Supported by grants from the Quebec Heart Foundation and the Medical Research Council of Canada.

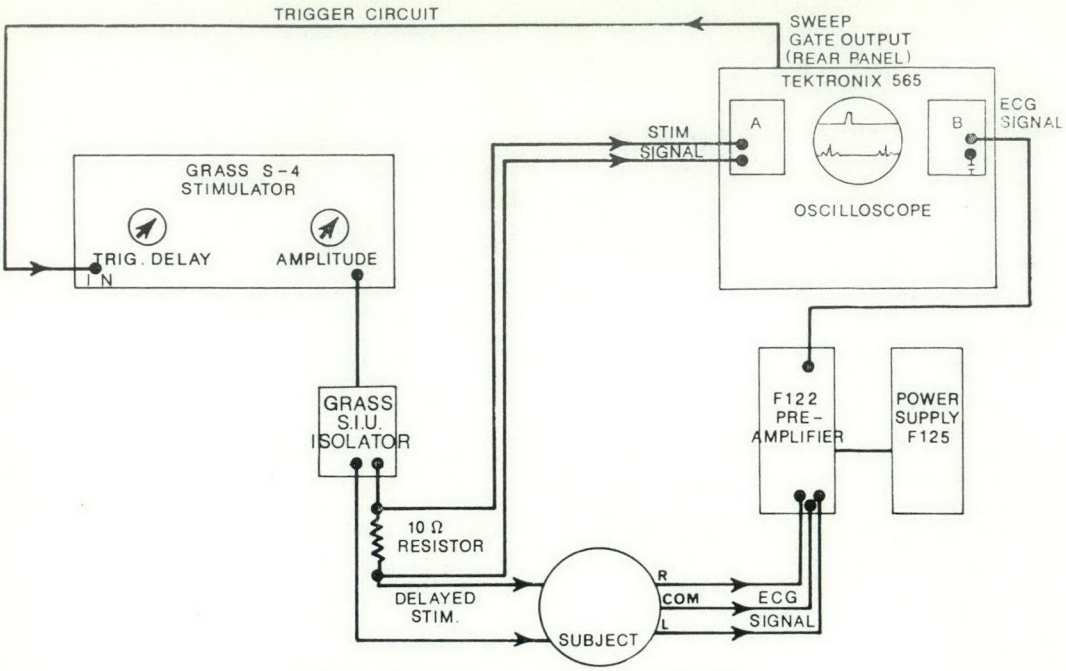


**Fig. 1.**—Apparatus for VFT determination.

a measure of the smallest stimulus required to produce ventricular fibrillation, i.e. the VFT. The duration of the stimulus was constant at 12 msec, and the amplitude was measured in millimetres on the oscilloscope screen. The impulse could be recorded as well on photographic film during the procedure. The current was calculated from the formula: $I = \frac{E}{R}$ where I = current in amperes, E = scope height of stimulus in centimetres and R = constant circuit resistance (10 ohms).

Following the production of ventricular fibrillation the heart was immediately defibrillated using an AC defibrillator (1/10 sec, 125 to 175 v), no drugs being used in resuscitation. After the determination of the control VFT for each heart the LAD was occluded for a variable period of time, and VFTs were measured repeatedly every 15 to 30 minutes throughout a three-hour period.

Three groups of animals were studied, distinguished as follows: (1) permanent occlusion (five animals), (2) 60-minute occlusion (six animals), (3) 120-minute occlusion (five animals).

Blood gases were measured at the start of each experiment and before alternate determinations. The animals were sacrificed at the end of the experiment.

## Results

In all groups the VFTs are plotted as percentages of the control value for each heart against time, the occlusion being applied immediately after zero time.

*Group 1—Permanent Occlusion* (Fig. 2)

In this group the VFT dropped initially to 30% to 40% of the control value, rose after the first hour and then remained at approximately 50% for the 3½ hours during which measurements were taken.

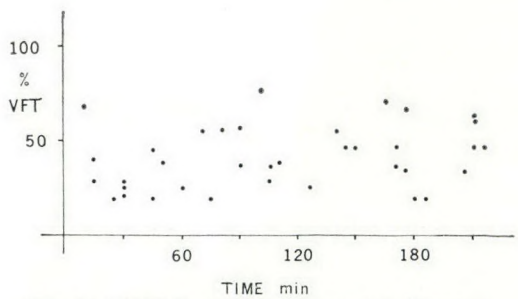


**Fig. 2.**—VFTs in the permanent-occlusion group.

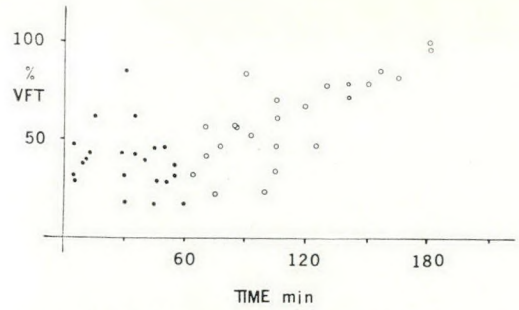


**Fig. 3.**—VFTs in the 60-minute occlusion group.

*Group 2—60-Minute Occlusion* (Fig. 3)

In this group the drop in VFT during the occlusion period is comparable to that observed during the corresponding period in the permanent occlusion group, but following release of the occlusion the VFT rose progressively towards control values, reaching 90% to 100% at three hours.

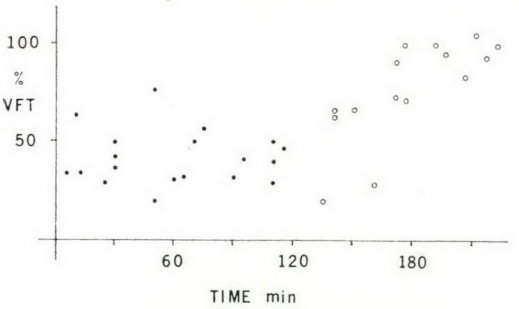


**Fig. 4.**—VFTs in the 120-minute occlusion group.

*Group 3—120-Minute Occlusion* (Fig. 4)

The VFT remained at levels comparable to those of the permanent occlusion group during the period of occlusion, but rose from 90% to 100% of the control values during the hour after release.

In Fig. 5 the mean values for each 30-minute interval for each of the groups are plotted and demonstrate the changes in VFT with revascularization of the ischemic myocardium. A significant difference ($P = 0.01$) was noted between groups where the circulation was temporarily or permanently occluded. The average blood-gas levels were as follows: pH 7.36, $Po_2$ 368.5 mm Hg and $Pco_2$ 28.4 mm Hg. Only one animal was markedly acidotic and in that instance the VFT was similar to those for other animals over the same period. Patency of the LAD following release of the snares was confirmed by the immediate return of pink colour to the myocardium and by injection studies following sacrifice of the animals.

## Discussion

From research carried out in the past we know that ventricular fibrillation frequently follows high coronary occlusion in dogs,[6] the ectopic ventricular activity usually occurring within 48 hours and most commonly during the first few hours.[7] Studies on VFT were begun 40 years ago by Wiggers and Wegria,[8] who reported the first quantitative study of electrical stimuli applied directly to the heart and adjusted to fall in the vulnerable period of the cardiac cycle. The VFT was defined as the smallest electrical stimulus that would precipitate ventricular fibrillation. These authors demonstrated that thresholds could be altered by administration of drugs such as procaine. In 1957 the circuitry of the instrument was modified by Shumway so that the electrocardiogram could be used to trigger a stimulus of known strength and duration at any point in the cardiac cycle. Using this method subsequent studies have demonstrated fairly constant thresholds with repeated testing on the same animal under constant conditions.[9] A direct relationship was established with the rise and fall in temperature from 23° to 40° C[9] and a drop in the VFT was seen with acidosis (pH 7.1).[10] It was noted that animals ventilated

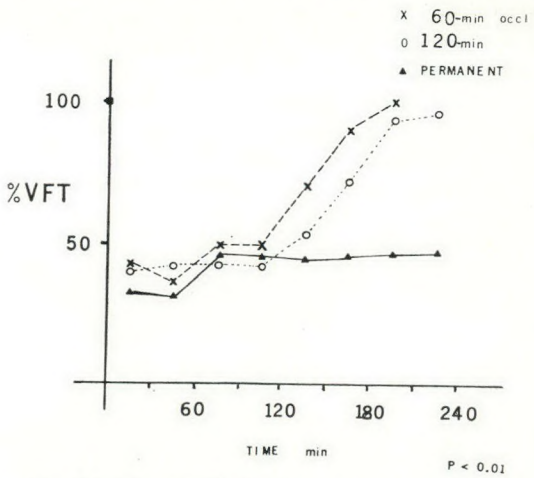


**Fig. 5.**—Changes in VFT with revascularization of ischemic myocardium.

with cigarette smoke had lower VFTs[11] and a similar effect was noted with large intravenous doses of caffeine.[12] The VFT was raised by the administration of lignocaine and bretyllium;[13] the effects of the intravenous lignocaine were rather brief (10 to 15 minutes) and correlated well with the sharp fall-off in blood level.

Ventricular fibrillation threshold has been studied in relation to coronary occlusion. It was noted that a drop in the VFT following coronary occlusion could be partly reversed by an infusion of dextrose, insulin and potassium,[14] bearing out the suggestion that this treatment decreased infarct size.[15] In animals who had had a previous revascularization procedure (Vineberg) the drop in the VFT with left anterior descending artery occlusion was minimized.[16] A similar effect was noted in animals in which an infarctectomy had been performed.[17] Other workers[18] have found that the VFT two months after coronary ligation rises to normal levels, probably owing to impaired conduction in the area of fibrosis.

Our results demonstrate a consistent change in the electrical stability of the canine myocardium associated with coronary occlusion and revascularization. Occlusion of the LAD causes a distinct fall in the threshold in the ischemic area to below 50% of control values. If occlusion is maintained the VFT rises to approximately 50%, then stays constant for the next 2½ hours. On the other hand, if the occlusion is released, i.e. if revascularization occurs, there is a rapid return to normal values within two hours of release. Our findings indicate that revascularization of ischemic myocardium within two hours of occlusion results in a complete return of electrical stability in the ischemic area within a few hours. This is in contrast to the persistence of electrical instability in areas of myocardium where ischemia is allowed to persist.

Extrapolation of our results to the human situation must be made with extreme caution. Important differences between our model and patients with acute myocardial infarction include the level of coronary obstruction, the presence of intercoronary anastomotic channels and differences in the basal level of electrical stability. In coronary care units more than 20% of patients with acute myocardial infarction develop ventricular tachycardia and almost one-quarter of those then develop ventricular fibrillation.[19] A combination of medication and countershock can be expected to prevent most deaths due to cardiac arrhythmias.[20] However, it would appear that in some refractory cases emergency coronary revascularization to restore electrical stability to the heart may be beneficial. Our study suggests that if revascularization is performed within a few hours of coronary occlusion the electrical stability of the heart will be enhanced.

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# MUSTARD OPERATION IN INFANCY FOR TRANSPOSITION OF THE GREAT ARTERIES: A SEVEN-YEAR EXPERIENCE*

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**Summary: Our experience suggests that about two-thirds of infants with d-transposition of the great arteries and an intact ventricular septum can derive palliative benefit from balloon septostomy alone, and undergo an elective Mustard operation at about 12 months of age. When palliation provided by septostomy is short-lived heart catheterization should be done, and a second balloon septostomy is indicated if there is an interatrial pressure gradient.**

**When these possibilities have been excluded we believe a Mustard operation is to be preferred to palliative surgery. We are satisfied that the small patients can undergo the operation without undue risk, but it remains to be seen whether there will be a higher incidence of venous obstruction due to shrinkage of the baffle and its adherence to intracardiac structures in smaller babies.**

**Résumé: D'après notre expérience personnelle, nous croyons que près des deux-tiers des nourrissons qui présentent une transposition des grandes artères et dont le septum ventriculaire est intact, peuvent bénéficier, tout au moins à titre palliatif, de la seule septostomie par introduction d'un ballon. Ils peuvent alors attendre et subir l'intervention de Mustard vers l'âge de 12 mois. Si l'effet palliatif obtenu de la septostomie est de trop courte durée, on procède à un cathétérisme cardiaque. Une seconde septostomie est indiquée s'il existe un gradient de pression interauriculaire.**

**Si ces possibilités sont exclues, nous estimons que l'opération de Mustard est préférable à une intervention purement palliative. Nous croyons que les petits patients peuvent supporter l'opération sans courir de risques inutiles, mais il reste à vérifier le risque éventuel d'une plus grande fréquence d'obstruction veineuse par rétrécissement du déflecteur ("baffle") et son adhérence à des structures intracardiaques chez les plus petits nourrissons.**

Of infants born with one of the various forms of complete d-transposition of the great arteries, about 60% have an intact ventricular septum and inadequate atrial mixing. These patients characteristically are seen in the early days, or even hours, of life with critical hypoxia and metabolic acidosis. Balloon atrial septostomy is the initial step in the management since it decompresses the left atrium and improves interatrial mixing. As our experience will illustrate, more than half the infants receiving this palliative treatment can be carried safely through the first year of life to become candidates for an elective intracardiac operation to reroute pulmonary and systemic venous blood by means of an interatrial baffle as described by Mustard.[1]

In a smaller group, constituting about 30%, the palliation provided by septostomy is either transient or inadequate. In these young infants whose condition is precarious we have generally proceeded early to perform the Mustard operation rather than a preliminary palliative operation.

## Patient Material and Early Management

In this study we include all 23 infants with complete d-transposition of the great arteries in whom we performed a Mustard operation during the first two years of life in the six-year period from February 1967 to April 1973. Excluded from the series are those with associated ventricular septal defect and/or pulmonic stenosis. Included are four patients who had an associated patent ductus arteriosus, which was ligated soon after septostomy in two infants and at the time of intracardiac operation in the other two.

For the majority of these patients the sole means of palliation used was balloon atrial septostomy (Table I).[2] The procedure

TABLE I.—Palliative Procedures Preceding Corrective Surgery in 23 Infants

| *Procedure* | *No. of patients* |
|---|---|
| BAS only | 18 (4 had 2 BAS) |
| BAS + Hanlon-Blalock | 3 (4, 7 and 8 months after BAS) |
| BAS + Sterling-Edwards | 1 (6 months after BAS) |
| BAS + Waterston shunt | 1 (4 days after BAS) |

BAS = balloon atrial septostomy.

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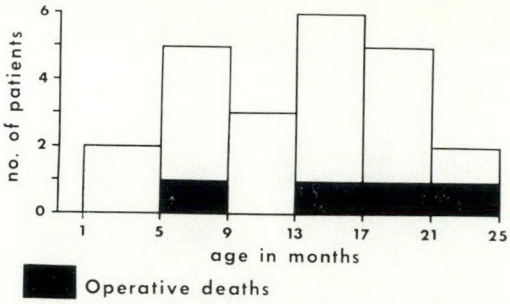


**Fig. 1.**—Age distribution for the 23 patients at the time of the Mustard operation. The four operative deaths, depicted in black, were at ages 24, 20, 13 and 7 months.

was performed during the diagnostic catheterization. Five infants had septostomy in the first 24 hours of life and the mean age at the time of the procedure was 14 days. In four patients the septostomy was repeated after an interval ranging from five days to 3½ months, and this second procedure brought about considerable improvement. Prior to 1970 an occasional palliative operation was performed (Table I). Significant improvement was documented in two of the three Hanlon-Blalock operations. In one infant the decision to perform a Waterston shunt was inappropriate as there was no pulmonic stenosis; however, the patient survived a Mustard operation five weeks later.

## Intracardiac Surgery

Fig. 1 shows the age distribution at the time of intracardiac surgery. The mean age was 13 months with a range from 1 to 24 months. There was no relationship between age and postoperative mortality.

The weight range was from 3.8 to 11 kg, with a mean of 7.3 kg. The infants tended to be poorly developed, 13 being below the third percentile for weight and only three above the tenth percentile. There was no relationship between weight and operative mortality.

Preoperative aortic oxygen saturations were highly variable and ranged from 43% to 86%. The lower values were not specifically noted in those infants who required earlier operation. In 12 of the 23 patients the left ventricular pressures were low, that is less than 50% of the systemic (right ventricular) pressure. A higher left ventricular pressure was noted in eight patients (34%). In two of these infants the left ventricular pressure was systemic, although at operation there was no ventricular septal defect or pulmonic stenosis. There was no correlation between the preoperative left ventricular pressure and the operative mortality.

A standard bypass technique was used and the venae cavae were cannulated at their entrance to the right atrium. Moderate hypothermia (27° C) and intermittent aortic cross-clamping were used to provide optimal operating conditions. Extracorporeal flow was reduced if bronchial flow prevented excellent exposure of the posterior wall of the left atrium. The posterior, superior and inferior portions of the atrial septum were excised and re-endothelialized. The anterior septum was left near the tricuspid valve and the interatrial baffle was attached to this remnant. The baffle was fashioned of pericardium in most patients but in some an elasticized Dacron baffle was used. The material was cut to the shape of a valentine heart, about as wide as it was long, and the point was sutured behind the base of the left atrial appendage and anterior to the left pulmonary veins. The remainder of the baffle was attached[3] so as to direct systemic venous blood to the mitral valve and pulmonary venous blood to the tricuspid valve. The flared shoulders of the valentine heart were sutured about the caval entrances to the right atrium. The indented neck was sutured to the anterior septal remnant, thus preventing excessive billowing towards the free atrial wall which could obstruct pulmonary venous flow. Coronary sinus flow was directed to the mitral valve along with the caval flow. In one patient a small right atrium was enlarged by interposing a patch of fabric in the atrial incision.

In the first nine patients operated on before 1969 there were four postoperative deaths. These deaths were discussed in detail in a previous publication.[4]

In the last 14 consecutive operations there have been no postoperative deaths.

## Long-Term Results

The 19 survivors have now been followed up for a period of 78 months with a mean follow-up of 33.6 months. In this group

there were two late deaths. The first occurred in a 5-month-old infant who had undergone the Mustard operation at 6 weeks of age and whose postoperative course had been uncomplicated. She died suddenly at home four months after operation. Autopsy demonstrated massive aspiration pneumonia and severe pulmonary venous obstruction due to adherence of the baffle of pericardium to the free wall of the atrium at the site of excision of the posterior rim of the atrial septum. The other late death was due to hemorrhage at a second operation seven years after the initial procedure. Again, pulmonary venous obstruction had occurred. We would currently reoperate through a right anterior thoracotomy in these patients in whom the pericardium has been widely excised to provide the material for the construction of the baffle so that the right atrium is adherent to the sternum, making it extremely vulnerable during performance of a sternotomy.

There has been considerable interest in conduction disturbances in patients after the Mustard operation. Seven of the survivors (36.8%) have had normal sinus rhythm throughout the follow-up period (one patient has first degree atrioventricular block). The remaining 12 patients showed various atrial arrhythmias in the early postoperative period. In eight of these (42.1%) there was some form of nodal rhythm but spontaneous return to normal sinus rhythm in the early months after operation. In four patients (21.1%) the atrial arrhythmia seems permanent; three have nodal rhythm and one has a wandering atrial pacemaker. One child with nodal rhythm developed atrial flutter three years after operation. After cardioversion and return to nodal rhythm he received digitalis to prevent recurrences.

The growth pattern of the surviving patients is shown in Fig. 2. Preoperatively nine patients were below the third percentile for

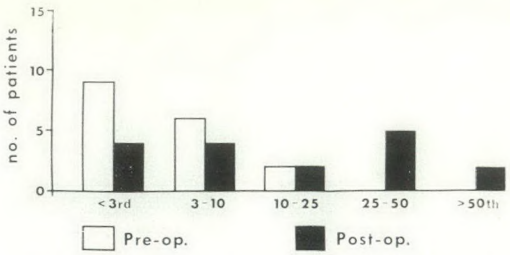


**Fig. 2.**—Growth status before and after the Mustard operation by weight percentile.

weight and only two were above the tenth percentile. At follow-up only four patients are below the third percentile and more than half are now above the twenty-fifth percentile.

With one exception the survivors are clinically acyanotic and show near-normal exercise tolerance. The exception is a patient who, 19 months after operation, has clinical and hemodynamic evidence of pulmonary and systemic venous obstruction at the atrial baffle level.

Three patients have persistent neurological deficits. One 6-year-old child is mentally retarded and has a spastic left hemiplegia attributed to severe cerebral anoxia which occurred in the neonatal period prior to septostomy. Two patients have mild and improving hemiparesis first noted after the Mustard operation.

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# LEIOMYOBLASTOMA OF THE STOMACH

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**Summary: Six cases of leiomyoblastoma of the stomach treated in our institution over the past five years are reviewed. Three patients presented with gastrointestinal bleeding, two tumours were discovered incidentally at laparotomy and one patient presented with vague epigastric discomfort. A brief review of the literature indicates that these are uncommon tumours which are frequently misdiagnosed. They are commonly benign and can be adequately treated by wide local excision.**

**Résumé: L'article passe en revue six cas de léiomyoblastome de l'estomac qui ont été traités dans notre institution depuis cinq ans. Trois malades présentaient une hémorragie gastrointestinale, deux autres une tumeur découverte par hasard au cours d'une laparotomie et le dernier ne se plaignait que de vagues malaises épigastriques. Une brève revue de la littérature indique qu'il s'agit de tumeurs rares, dont le diagnostic est souvent méconnu. Elles sont généralement bénignes et peuvent être traitées adéquatement par une excision locale.**

IN 1962 Stout[1] described a group of 69 bizarre, smooth muscle tumours of the stomach which he had collected in the surgical pathology laboratory of Columbia University. Six of these tumours had previously been described in the French literature by Martin *et al.*[2] These tumours varied considerably in histological appearance from the usual leiomyoma and had been previously misdiagnosed as neurilemoma, neurogenic sarcoma, liposarcoma, leiomyosarcoma, glomus tumour, hemangiopericytoma, anaplastic carcinoma, etc. Despite their unusual appearance, Stout determined that these were in fact smooth muscle tumours of a bizarre nature. The great majority were considered to be benign although two tumours eventually metastasized. Fourteen of these tumours were incidental findings, eight of them being discovered at laparotomy for other conditions, and six at autopsy.

In 1966, Fournier and Magner[3] described six cases collected in the Canadian Tumour Registry; five had presented with gastric hemorrhage and one was an incidental finding at autopsy. All were considered benign. Since then 11 additional cases have been added to the Registry.[4]

De Castro, Olsen and Littler[5] in 1972 described a leiomyoblastoma in a 16-year-old girl who presented with anemia and was found to have a large intramural tumour of the stomach on barium meal examination. Their patient was treated by radical subtotal gastrectomy, although the tumour proved to be benign. These authors point out that only four cases of leiomyoblastoma have been reported in patients under the age of 20 years.

In a recent article Lavin, Hajdu and Foote[6] reported 26 cases over a 40-year period. Surprisingly, nine of their patients died of metastatic disease.

Abramson,[7] in a more recent collective review, reported a total of 190 cases of gastric leiomyoblastoma in the literature. Twenty-three, or 12% of the reported cases, were malignant as evidenced by metastases.

We have recently treated two patients with leiomyoblastoma of the stomach, and in reviewing our pathology records have discovered four additional cases occurring in our institution over the past five years (Table I). Two of these tumours were initially diagnosed histologically as neurilemoma, but review of the sections has led to their reclassification as leiomyoblastoma. Three of these patients presented with gastrointestinal bleeding, one with vague epigastric distress, and two tumours were incidental findings at laparotomy for other lesions. All were considered benign. One of our recent cases is reported below.

## CASE REPORT

A.S., a 68-year-old Italian man was admitted to hospital on July 30, 1971 with the diagnosis of chronic pulmonary fibrosis. He also complained of epigastric discomfort of undetermined duration. There had been no evidence of gastrointestinal bleeding at any time.

Physical examination was essentially negative. Admission hemoglobin was 13.3 g/100

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TABLE I.—AUTHORS' SERIES OF CASES

| Case | Sex | Age (years) | Presenting symptom | Tumour size (cm) | Treatment |
|---|---|---|---|---|---|
| H.M. | M | 71 | Melena | 5 | Local excision |
| M.A. | F | 28 | Hematemesis | 3 | Local excision |
| E.T. | F | 69 | Incidental (aneurysmectomy) | 2.5 | Local excision |
| J.E. | F | 69 | Anemia | 7 | Local excision |
| A.S. | M | 68 | Epigastric discomfort | 4 | Gastric resection |
| M.G. | F | 43 | Incidental (cholecystectomy) | 1 | Local excision |

ml. Three gastric washings were negative for malignant cells. Fasting gastric pH was 2.5. Chest radiograph revealed bilateral pulmonary fibrosis involving the mid-lung fields with pleural thickening over the right apex.

An upper gastrointestinal series on August 11 disclosed a large filling defect situated posteriorly in the distal part of the stomach and measuring approximately 4.5 cm in diameter. It appeared fixed to the posterior wall without an evident stalk (Fig. 1). No ulceration was noted on its surface. Repeat barium meal examination on August 13 confirmed the initial findings.

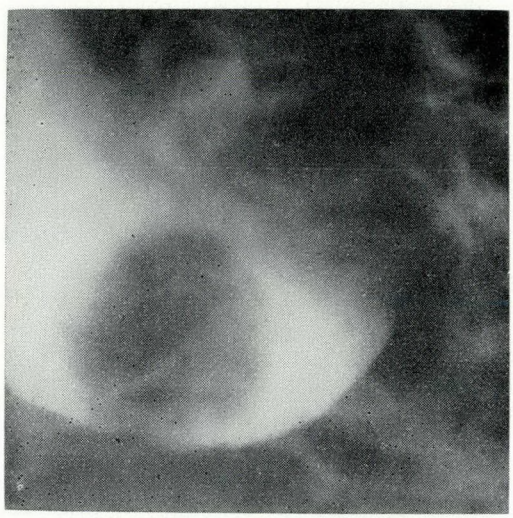

**Fig. 1.**—Patient A.S. Spot film of barium meal showing a filling defect in the gastric antrum.

Gastroscopy was carried out on August 16 under local anesthesia. A polypoid lesion, measuring 4 cm in diameter, was seen in the antrum proximal to the pyloric canal. This was sessile and appeared to be located in the submucosa. There was no evidence of ulceration of the overlying mucosa. The lesion appeared to move quite well with peristalsis. The remainder of the stomach was normal. Biopsy was not taken due to difficulty in stabilizing the lesion because of its extreme mobility.

It was the final impression that this was either a benign submucosal tumour such as a leiomyoma or lipoma, or possibly a slowly growing lymphoma or reticulum cell sarcoma. In view of the patient's pulmonary condition, it was thought that operation should not be carried out at this time, but that follow-up radiographs be taken to detect any change in the size of the lesion.

The patient was readmitted on November 6, 1971 after a follow-up barium meal examination had indicated possible increase in the size of his lesion. There was no change in his symptomatology or physical findings and no evidence of gastrointestinal bleeding. After repeat consultation it was concluded that this patient was in satisfactory condition from the pulmonary standpoint to undergo operation.

On November 10, 1971 laparotomy was carried out through a left upper paramedian incision. A fairly large, firm, discrete, localized tumour was found arising in an exogastric fashion from the posterior wall of the greater curvature in the region of the antrum (Fig. 2). The lesion was mobile and there was no evidence of secondary involvement in either the regional nodes or the liver. Because of the

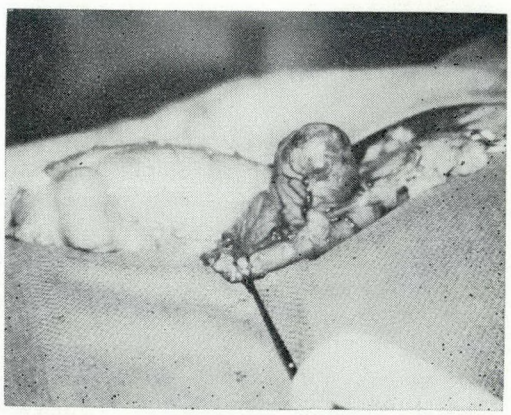

**Fig. 2.**—Patient A.S. The exogastric, bosselated tumour mass arising from the posterior aspect of the greater curvature. Note the dilated veins on the surface of the tumour.

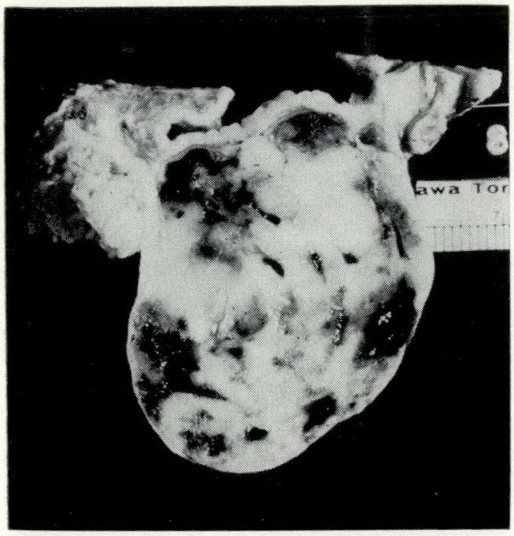

**Fig. 3.**—Patient A.S. Gross appearance of the operative specimen. The tumour is completely intramural and well circumscribed. The overlying mucosa and the surrounding serosa are intact. The sectioned surface is wet and smooth without any evident trabeculations. It is irregularly white and tan in colour with many areas of recent hemorrhage.

uncertain nature of the tumour and the fact that there were large dilated veins over its surface, a sleeve type of gastric resection was carried out, removing the tumour and a portion of stomach on either side, followed by an end-to-end anastomosis to restore continuity.

The patient had an uneventful postoperative recovery and was discharged from hospital on November 20, 1971.

The pathologist described a 10-cm segment of stomach containing a 4-cm circumscribed globular tumour protruding outwardly from the gastric wall and completely covered by serosa. The outer surface was somewhat bosselated. The tumour was confined entirely to the gastric wall. The overlying mucosa was not involved and was not ulcerated. On cross-section the tumour appeared to arise in the external muscle layer and was soft, pale, hemorrhagic and moist (Fig. 3).

The histological diagnosis was leiomyoblastoma or bizarre smooth muscle tumour of the stomach.

## Pathology

### *Gross Features*

All six tumours were discrete, nodular, well-circumscribed masses which measured from 0.8 to 7.0 cm in greatest diameter and were located within the gastric wall. The sectioned surfaces were wet, glistening and varied in colour and appearance. They were pale, tan-pink to white, with occasional interlacing trabeculations suggestive of a smooth muscle tumour. Some showed small areas of hemorrhage. In all cases the overlying mucosa was intact and uninvolved, despite the occurrence of bleeding in three cases.

### *Histological Appearance*

In patient J.E., although grossly the nodule was discrete, it irregularly infiltrated the muscle coat of the stomach for short distances and separated normal muscle fibres of the gastric wall. The other five tumours were all round or bosselated and had formed a pseudocapsule of varying thickness suggesting a slow expansive growth.

With minor variations, the histology was similar in all six cases. All contained sheets of mildly to moderately pleomorphic cells with well-delineated cytoplasmic borders and granular, vacuolated or completely clear cytoplasm, resembling an epithelial syncytium (Fig. 4). The nuclei were vesicular with

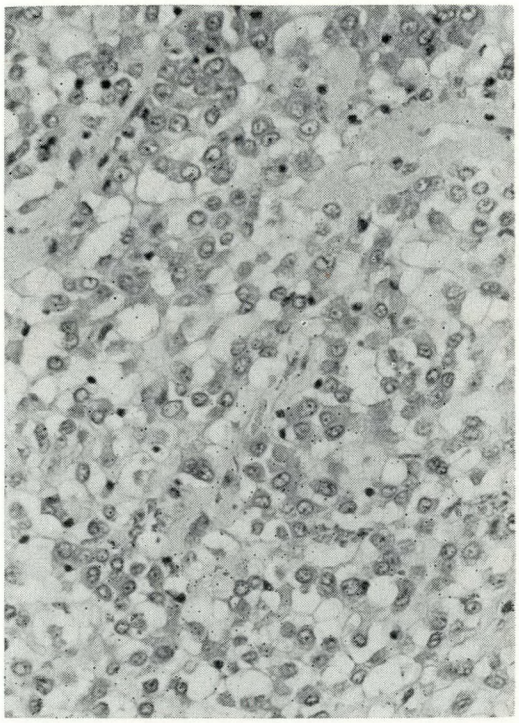

**Fig. 4.**—Microscopic section showing sheets of clear, vacuolated and pink-granulated cells with well-delineated cytoplasmic borders and more or less regular vesicular nuclei with prominent nucleoli (H & E x 280).

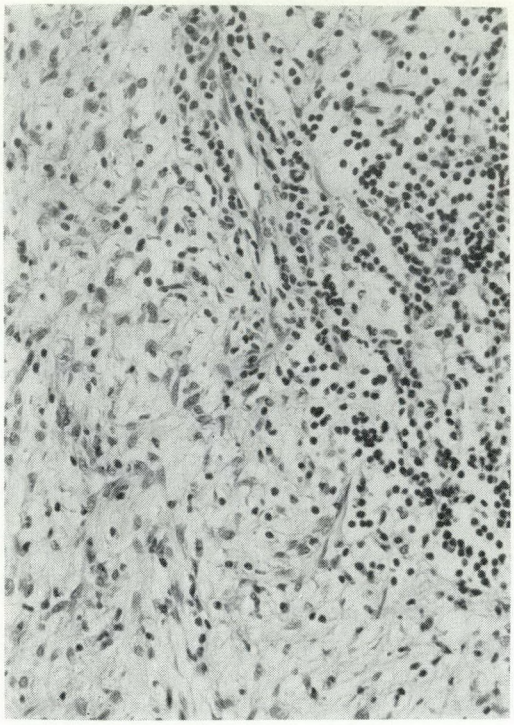

**Fig. 5.**—Microscopic section showing a mixture of spindle and clear epithelioid cells with focal lymphocytic infiltrate in a loose edematous stroma (H & E x 280).

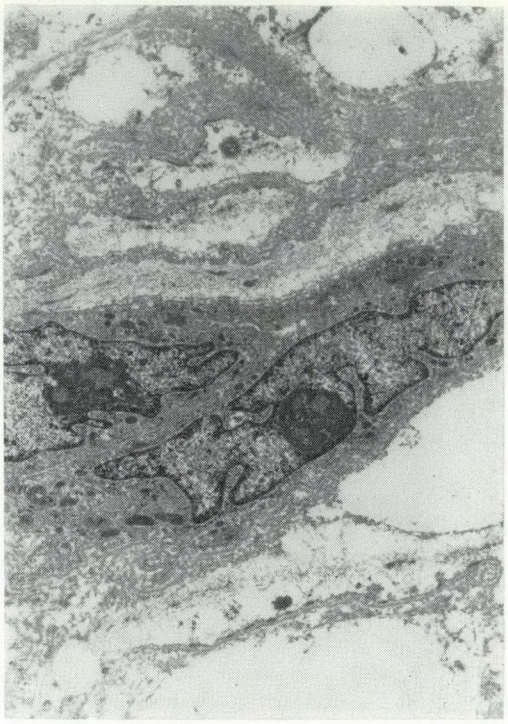

**Fig. 6.**—Electron photomicrograph of two adjoining cells. The nuclei show deep infoldings of their membrane and a prominent nucleolus which are characteristic features of smooth muscle nuclei. A basal lamina (basement membrane) normally present in smooth muscle at the cytoplasmic borders between cells is not present. Several mitochondria cluster around the nuclei. Numerous bundles of filaments are arranged longitudinally parallel to the long axis of the nucleus and cell. They are in parts separated and distorted by large empty clear spaces without bordering membranes (x 12,000).

a small nucleolus. Some were hyperchromatic and of somewhat bizarre shape. All tumours, in addition, contained spindle cells with or without transitional forms between spindle and epithelioid cells (Fig. 5). Most spindle cells had vesicular nuclei, with the occasional spindle cell nucleus revealing the characteristic shape of a mature, smooth muscle nucleus with straight borders, and blunt edges and corners resembling the shape of a cigarette. All tumours were very vascular and showed some sprinkling by lymphocytes or follicular aggregates of lymphocytes with occasional plasma cells (Fig. 5).

In none of the six cases, including Case J.E. in which the growth was infiltrative, were there any noticeable mitoses. The relative absence of mitotic figures is generally considered to be an important histological feature of these tumours.[1]

Electron micrographs were prepared from formalin-fixed tumour tissue of Case M.G. (Fig. 6). The tumour cell nuclei showed deep infoldings of their membrane, which is a characteristic feature of smooth muscle nuclei. A basal lamina, normally present in smooth muscle nuclei, was absent from all cells examined. Numerous myofibrils were present in all cells. Large irregular and round empty spaces devoid of any structural border or lining were evident in many cells. They are believed to be artefacts of slow formalin fixation (Fig. 6).

The nature of the tumour cells as altered smooth muscle is recognizable only in electron micrographs, which consistently reveal the presence of myofibrils.[8, 9] Myofibrils cannot be recognized in light microscopic sections and evidence of their derivation from smooth muscle by light microscopy alone is only circumstantial. They originate in sites which normally contain smooth muscle and sometimes one or another cell

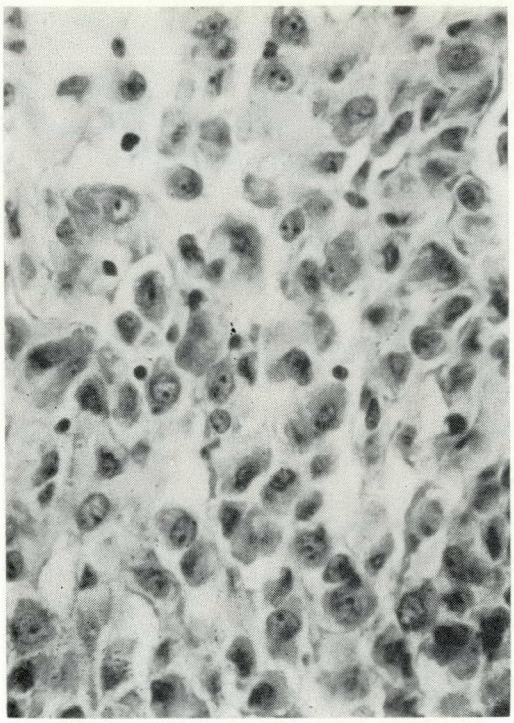

**Fig. 7.**—Frozen section of tissue block corresponding to the formalin-fixed tissue section illustrated in Fig. 4. Note the complete absence of "clear cells" (polychrome methylene blue stain x 440).

exhibits a nucleus with the characteristic features of a mature smooth muscle nucleus (see above).

Cornog[8] suggests that the cytoplasmic clear zones, which are so characteristic of leiomyoblastomas as seen by light microscopy, are an artefact caused by slow fixation, since they are absent in frozen sections (Fig. 7) and in tissue prepared by immediate fast fixation for electron micrography. The large, apparently artefactual, empty spaces visible within cytoplasm of the tissue prepared from Case M.G. (Fig. 6) appear to confirm Cornog's suggestion. This tumour was routinely fixed in 10% buffered formalin for a period of approximately two hours before a representative block was cut and fixed in 2% glutaraldehyde.

Stout and Lattes[10] pointed out that leiomyoblastomas have probably received a greater number of erroneous diagnoses than any other tumour. This circumstance appears to reflect the rarity of these tumours. Once the surgical pathologist is familiar with the characteristic histological appearances, these tumours usually do not pose a major diagnostic problem. When attempting a frozen-section diagnosis he must be aware of the fact that the characteristic "clear cells" (Fig. 4) are formalin fixation artefacts and are never present in frozen-section material (Fig. 7).

Like most smooth muscle tumours, the majority are benign. However, 12% of the cases reported in the literature metastasized, primarily to the liver and less frequently to regional lymph nodes. The uncommon malignant forms differ from the benign type only by a higher incidence of mitoses, which is the morphological manifestation of their growth potential.[1] Accordingly, the average size of the malignant leiomyoblastoma is larger.[2]

### *Clinical Features*

Smooth muscle tumours of the stomach are relatively uncommon and few surgeons have extensive experience with them.[11] Leiomyoblastoma is of particular importance since, as indicated above, it is frequently misdiagnosed and may erroneously be considered a malignant neoplasm. Unfortunately frozen-section examination of these tumours at the time of operation may not be reliable.

The tumours usually present as circumscribed, intramural masses which frequently project into the lumen or may even be exogastric as in our reported case. Although the tumour does not directly involve the overlying mucosa, there may be secondary ulceration producing hemorrhage. Hemorrhage may also occur without actual ulceration of the mucosa as in three of our cases.

Leiomyoblastoma has a slight preponderance in men with a sex ratio of 9:7. It is commoner in the older age groups, the average age being 56.6 years; 84% of patients are over the age of 40.

The commonest presenting symptoms are gastric bleeding and secondary anemia. Epigastric discomfort is a less common symptom. Large tumours may be palpable on clinical examination. Frequently the tumours are found as incidental findings at laparotomy as in two of our cases.

Barium meal examination usually reveals the presence of a filling defect or an intramural tumour mass commonly located in the antrum of the stomach but also in the body or the cardia. The tumours are frequently mobile. The adjacent mucosal folds appear normal and peristalsis is usually present in the area of the lesion. Frequently the radiologist will suggest the diagnosis of a smooth muscle tumour on the basis of its intramural location, its circumscribed nature, and the frequent small central ulceration of the overlying mucosa which may account for gastric bleeding. However, the precise histological diagnosis must always await surgical excision.

Gastroscopy, although carried out in a few cases, has not yet proved to be a precise tool in diagnosis.

Treatment of these lesions is always surgical. The majority of them can be treated by wide local excision although often some form of gastric resection may be necessary because of their size or location. The surgeon should never hesitate to carry out extensive resection of even very large smooth muscle tumours, since even if the lesion proves to be a leiomyosarcoma, a reasonably high five-year survival rate, in the range of 40%, can be expected.[12, 13] These tumours rarely metastasize to regional lymph nodes and do not extend in the stomach wall beyond their gross margins. Consequently total gastrectomy and *en bloc* lymph-node dissection are not indicated. Leiomyoblastomas are not usually radiosensitive and therefore radiotherapy is not recommended in their management.

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# SUCCESSFUL MESENTERIC ARTERY EMBOLECTOMY WITHOUT BOWEL RESECTION: A CASE REPORT

W. G. JAMIESON, B.A., M.D., F.R.C.S.[C & Eng.], F.A.C.S.* and R. L. HOLLIDAY, M.D., *London, Ont.*

**Summary: A case of successful mesenteric artery embolectomy without bowel resection is described. Early diagnosis and prompt treatment are of the essence. Central abdominal pain, a source for an embolus and fecal incontinence best suggest the diagnosis. Emergency operation is indicated with removal of the embolus.**

**When the correct diagnosis has been made, the results are extremely gratifying if the embolus is removed before intestinal infarction occurs.**

**Résumé: Nous présentons ici un cas d'embolectomie de l'artère mésentérique que nous avons réussi sans reséquer l'intestin. Pour cela, il faut nécessairement poser un diagnostic précoce et traiter rapidement. Les meilleurs éléments du diagnostic sont une vive douleur abdominale, la recherche de la source d'un embolus et l'incontinence fécale. Il faut alors intervenir d'urgence et enlever l'embolus.**

**Une fois posé un diagnostic exact, les résultats de l'opération sont très satisfaisants si l'embolus est enlevé avant que ne survienne l'infarctus intestinal.**

EMBOLIC occlusion of the superior mesenteric artery was first described in 1843. Approximately 40% of superior mesenteric artery occlusions are due to embolism, usually associated with heart disease and myocardial infarction.[1]

The first successful peripheral embolectomy was reported by Labey in 1910.[2] In 1951 Klass[3] of Winnipeg reported a successful superior mesenteric artery embolectomy. Since then 30 cases of superior mesenteric artery occlusion without bowel resection have been described.[4, 5]

The purpose of the present report is to emphasize the acute symptoms of superior mesenteric artery embolism and the absolute necessity for prompt diagnosis followed by emergency operation.

## CASE REPORT

A 67-year-old white man was admitted to Westminster Hospital, London, Ontario on March 13, 1970. He had rheumatic heart disease and had been admitted to hospital many times for control of fibrillation, and on one occasion for myocardial infarction. On admission to the Cardiac Unit he had auricular fibrillation and a heart rate of 140/min; blood pressure was 150/90 mm Hg. Heart murmurs were audible consistent with mitral insufficiency, mitral stenosis and aortic stenosis. Attempts to convert his auricular fibrillation to sinus rhythm with quinidine were unsuccessful.

On March 23, at 7.30 a.m., he had an episode of severe abdominal pain and fecal incontinence. The pain was continuous in the centre of the abdomen, did not radiate and was associated with profuse sweating and peripheral cyanosis. On examination the entire abdomen was tender, no rigidity was present and bowel sounds were absent. His blood pressure was 110/70 mm Hg and heart rate was 120/min. The diagnosis of superior mesenteric artery embolism was made.

Three hours after the pain began, laparotomy was performed through a midline abdominal incision. The bowel was grey-white and contracted from a point 12 inches distal to the ligament of Treitz to the transverse colon. Pulsations in the mesentery of this segment of the bowel were absent.

The superior mesenteric artery was approached through the inferior surface of the transverse mesocolon. The superior mesenteric vein was dissected free from the artery and the latter exposed for about two inches. The obstruction was readily apparent owing to the forceful pulsation proximal to the block and the absence of pulsation distal to it. This area was controlled between no. 8 rubber catheters.

The first jejunal branch of the superior mesenteric artery was open and pulsating, and arterial clamps were placed just distal to it. The artery was opened by a longitudinal incision and the embolus, 1 cm x 0.5 cm, was removed.

The proximal clamp was released and good blood flow was obtained. The distal clamp was opened and a no. 4 Fogarty catheter was inserted distally but no thrombus was found beyond the embolus. The distal tree was irrigated with heparinized saline (1,000 units in 500 ml of normal saline). After the artery was closed with 6-0 silk sutures the clamps were opened. Excellent pulsations were now evident in the superior mesenteric artery and the bowel immediately developed a reactive

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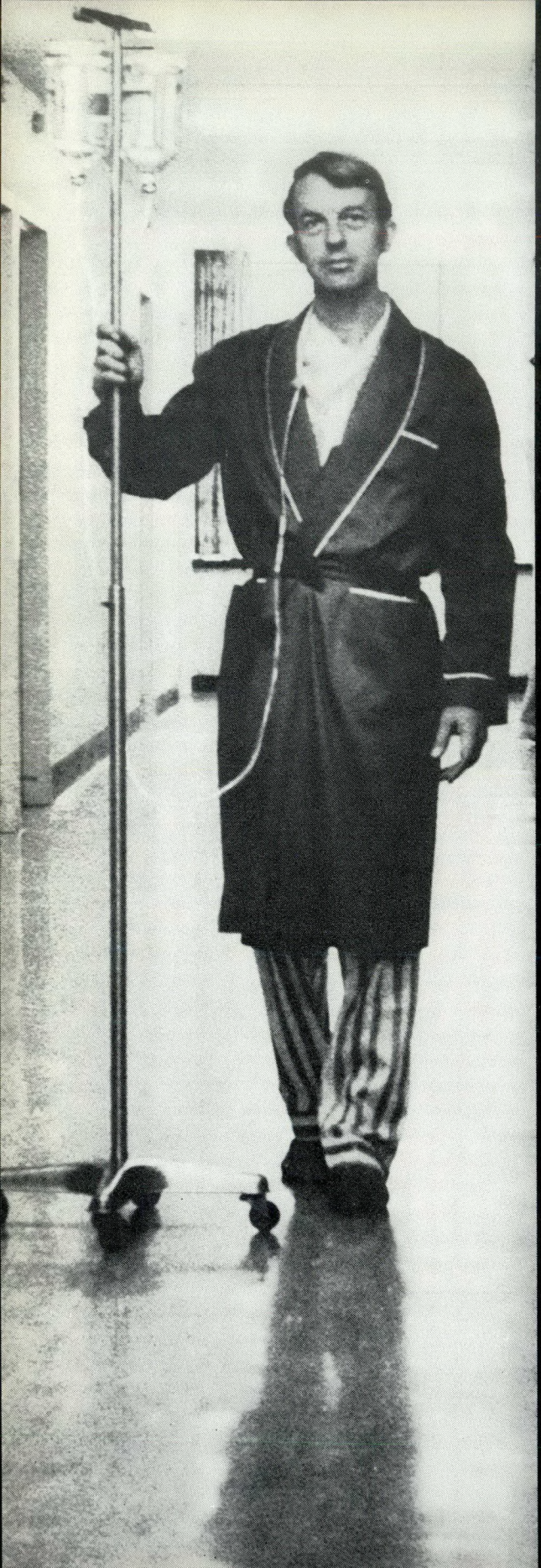

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pink hue. The abdomen was closed after observing the intestine for 15 minutes.

The patient's recovery was straightforward. Four weeks after the operation the fat content of a 24-hour stool sample was normal. He was discharged 47 days after admission, still fibrillating and on anticoagulants.

## Discussion

Time is of the utmost importance in determining the fate of the patient with a superior mesenteric artery embolus. In this case the time interval was three hours but there is no definite agreement as to when this "golden time" of possible embolectomy is past. Some reports of up to 30 hours are to be found in the literature.

Diagnosis must be immediate and accurate. Some of the diagnostic aids are: (1) sudden onset of central abdominal pain, (2) a potential source for an embolus, (3) forceful emptying of the rectum and (4) suspicion of the possible diagnosis. Other than these there are no reliable physical, laboratory or radiographic findings that are specific.

The surgical approach is via the base of of the mesentery of the transverse colon. Some have favoured the approach through the gastrocolic omentum and others via the left paracolic gutter with reflection of the colon, spleen and pancreas.

The most difficult and worrisome aspect of this operation is the decision as to the viability of the bowel at laparotomy. If there is the slightest chance that the bowel is viable, attention should be directed toward the artery with the object of accomplishing embolectomy or thrombectomy.

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# THE MOTOR DEFECT OF ESOPHAGITIS

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**Summary: Esophageal manometric studies were done on 20 normal subjects and 50 patients with hiatus hernias to investigate the motor changes associated with this condition. The motor defect in the patients with hiatus hernias was compared with the defect produced experimentally in dogs. In the animals, esophagitis was induced by perfusing the esophagus with a mixture of bile and acid. In both the human and the dog studies, it was found that similar motor changes at the gastroesophageal junction and in the body of the esophagus were present in esophagitis. These findings suggest that the motor defects of hiatus hernia are related to reflux and esophagitis, rather than to the mechanical effects of the hernia.**

**Résumé: Une étude manométrique de l'œsophage a été entreprise chez 20 sujets normaux et chez 50 malades souffrant de hernie hiatale. Ces études avaient pour objet de mettre en évidence les modifications motrices qui accompagnent la pathologie. Le trouble moteur chez les malades présentant une hernie hiatale a été comparé au défaut provoqué artificiellement chez le chien. Chez les animaux, nous avons créé une œsophagite en perfusant l'œsophage avec un mélange de bile et d'acide. Tant chez l'homme que chez le chien, nous avons constaté que des modifications similaires au niveau de la jonction gastro-œsophagienne et dans le corps même de l'œsophage accompagnaient l'œsophagite. Ces diverses constatations laissent supposer que les défauts majeurs de la hernie hiatale sont la conséquence du reflux et de l'œsophagite, plutôt que des effets purement mécaniques de la hernie.**

MANY workers have studied the motor defect present in patients with hiatus hernias[1-3] and have shown disordered motor activity (DMA) in the body of the esophagus and a reduction in the tone of the gastroesophageal junction. Although these major motor defects have been related to the presence of esophagitis, it has not been possible in humans to determine how much of the defect is due to the hiatus hernia and how much to associated reflux and esophagitis.

To investigate the motor defect of esophagitis, two studies were carried out. The first was done in 20 normal subjects and 50 patients with hiatus hernias. From this we concluded that the hiatus hernia was associated with DMA in the body of the esophagus. These changes were more severe when esophagitis was present and often were associated with a fall in the tone of the high pressure zone (HPZ) and a reduction in the degree of relaxation in response to deglutition. In the second study, esophagitis was produced in dogs[4] without hiatus hernias and the secondary motor defect was correlated with the stage of esophagitis. As esophagitis became more marked, the dogs developed severe DMA. In the HPZ there was a fall in tone and a decrease in relaxation in response to deglutition. Comparison of the results of these two studies gives a better understanding of the development of the motor defect in patients with hiatus hernias and esophagitis. In the dog experiment the motor defect was secondary to esophagitis alone. The defect produced is very similar to that found in humans with a hiatus hernia.

## EXPERIMENT 1

### *Material and Methods*

Twenty normal subjects were chosen, none of whom gave a history of esophageal disease. Each subject had one esophageal motility examination in the morning after an overnight fast. The same technique was used for normal subjects and for hiatal hernia patients.

Three PE 190 tubes were fused together with the side openings 5 cm apart. Constant water infusion was maintained by a modified 2202 Harvard pump using 220-ml syringes and infusion at 3.6 ml/tube/min. Statham P23De strain gauges were used as sensing devices and a 1508 Honeywell ultraviolet visicorder as the recording device.

Reprint requests to: Dr. R. D. Henderson, Room 139, University Wing, Toronto General Hospital, Toronto, Ont. M5G 1L7.

A similar study was done on 50 patients with hiatus hernias. As well as a history of hiatal hernia disease, all had radiological evidence of a hernia and esophagoscopy was carried out on 41 of the 50 patients during their investigation. The results obtained from these manometric studies were analyzed and compared and in the hiatal hernia patients they were also related to the history of their disease and to the endoscopic findings.

*Results*

*Normal subjects.* — The HPZ was analyzed to determine the mean high tone and to quantitate its relaxation. The mean high tone of the HPZ is the mean high pressure in the respiratory positive HPZ *minus* gastric pressure, or the mean high pressure in the respiratory negative HPZ *minus* esophageal pressure (Fig. 1). Relaxation in the HPZ is expressed as a percentage of tone in the HPZ as measured immediately before relaxation.

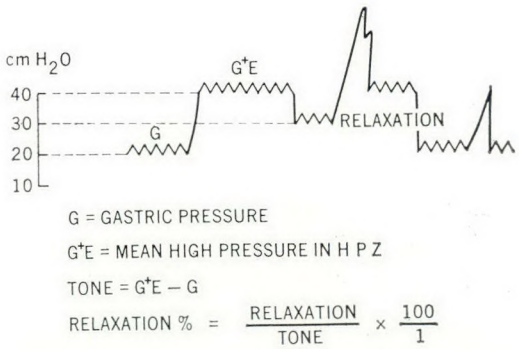


**Fig. 1.**—Tone in the HPZ is measured as the mean high pressure in the respiratory positive zone of the HPZ minus gastric pressure, or the mean high respiratory negative pressure minus the esophageal pressure. Relaxation is measured in cm $H_2O$ and expressed as a percentage of tone.

Disordered esophageal motor activity was expressed as the percentage of DMA present in each examination, counting all motor waves present.

In the normal subjects the average tone of the HPZ was 12 cm $H_2O$. In five the sphincter tone was low (from 7 to 9 cm $H_2O$), in two it was between 17 and 22 cm $H_2O$ and the remaining 13 subjects had a sphincteric tone of between 10 and 16 cm $H_2O$ (Table I).

TABLE I.—TONE OF THE GASTROESOPHAGEAL HIGH PRESSURE ZONE*

| *Tone (cm $H_2O$)* | *Normal subjects (20)* | *Hiatal hernia patients (50)* |
|---|---|---|
| 0 — 6 | 0 | 14 |
| 7 — 9 | 5 | 18 |
| 10 — 16 | 13 | 16 |
| 17 — 22 | 2 | 2 |

*Average tone in normal subjects was 12 cm $H_2O$ and in hiatal hernia patients 8.1 cm $H_2O$.

TABLE II.—RELAXATION AND SPHINCTER TONE

| *Tone (cm $H_2O$)* | *% relaxation in 20 normal subjects* | *% relaxation in 50 hiatal hernia patients* |
|---|---|---|
| 0 — 6 | 0 | 11 |
| 7 — 9 | 80 | 47 |
| 10 — 16 | 72 | 61 |
| 17 — 22 | 84 | 63 |

*Average relaxation in normal subjects (96 swallows) was 75%; in hiatal hernia patients (113 swallows) it was 54%.

Relaxation in the HPZ in response to deglutition averaged 75% of tone in 96 recorded swallows (Table II). In two-thirds of all swallows the relaxation was greater than 70%. The percentage relaxation did not alter in relation to the tone of the HPZ, although the absolute relaxation was less in subjects with a low-tone HPZ than in those with a high-tone HPZ.

Disordered motor activity as indicated in the body of the esophagus was always less than 15% of the recorded motor waves in the normal subjects.

*Patients with hiatus hernias.*—Data were analyzed in the same way as for normal subjects. The tone of the HPZ in this group averaged 8.1 cm $H_2O$ (Table I). In 14 patients the tone was from 0 to 6 cm $H_2O$. This very low tone was not seen in normal subjects.

In 113 recorded swallows, percentage relaxation of the HPZ in response to deglutition averaged 54%. In sharp contrast to normal subjects the percentage relaxation in hiatal hernia patients decreased as the tone of the HPZ decreased; patients with a low-tone HPZ had a very low percentage relaxation (Table II).

The frequency of DMA in the body of the esophagus varied considerably from less than 10% up to 90% of recorded swallows. More than 50% DMA was found

in all patients with HPZ tone of less than 6 cm $H_2O$.

From the clinical history of reflux, four stages were recognized: Stage I—minimal infrequent symptoms; Stage II—moderate symptoms, no complications; Stage III—severe symptoms, no complications; Stage IV—severe symptoms, night aspiration or mechanical stricture.

Applying this classification, patients with a history of severe heartburn had a low-tone HPZ.

Esophagoscopy was performed on 41 patients withs hiatus hernias. Esophagitis was staged as follows: Stage 0—no esophagitis, Stage I—erythema, Stage II—superficial ulceration, Stage III—deep ulceration and Stage IV—stricture.

When the tone of the HPZ was related to the stage of esophagitis, Stages III or IV were found only in those patients with a low-tone HPZ.

## Experiment 2

In the second study we examined the effect of esophagitis upon the body of the esophagus and the gastroesophageal junction in 11 normal dogs.

Previously[5] we had developed a technique that allowed us to produce controlled esophagitis and, using repeated manometric examination, we are able to follow the motor changes in the esophagus during the development and healing of esophagitis in the dog.

### *Material and Methods*

Eleven adult dogs, average weight 15 to 20 kg, were studied. Each dog was trained to swallow esophageal motility tubes and to lie quietly during the study. The techniques of continuous perfusion and of recording were the same as in the first experiment. Each dog had three normal motility runs before esophagitis was produced.

Esophagitis was produced by a continuous drip into the esophagus through a PE 320 tube introduced through the mouth, while the animals were lying quietly sedated by Innovar.

The solution was introduced into the esophagus over a four-hour period daily for between 15 and 30 days.[6-9] The dogs were divided into three major groups:

*Group I.*—Two dogs, saline drip to the mid-esophagus.

*Group II.*—Four dogs, 50 ml 0.1N HCl and 50 ml of bile. The drip was given 3 cm above the gastroesophageal junction.

*Group III.*—Drip given to the mid-esophagus, divided into three subgroups: (a) two dogs, 50 ml 0.1N HCl and 50 ml of dogs' bile—sacrificed at 13 and 18 days respectively; (b) two dogs, 50 ml 0.1N HCl and 50 ml of dogs' bile dripped for 21 days, followed to complete resolution of the esophagitis (15 days) and then sacrificed; (c) one dog, 50 ml 0.1N HCl and 50 ml glycholate (1%) dripped for 21 days, followed to complete resolution of the esophagitis (15 days) and then sacrificed.

Esophageal manometry and esophagoscopy and biopsy were carried out at three-day intervals during the study. The dogs were sacrificed and autopsies were performed at its conclusion. All biopsies and tissues taken at autopsy were examined by an independent pathologist.

### *Results*

*Group I.*—The saline-dripped dogs did not develop endoscopic or histological evidence of esophagitis. On manometry, no changes were observed in the body of the esophagus or at the gastroesophageal junction.

*Group II.*—Three of the four dogs in this group developed Stage III esophagitis at the gastroesophageal junction after 10 to 12 days and one by the eighteenth day.

The tone of the gastroesophageal junction,[10] measured by subtracting the mean gastric pressure from the mean high gastroesophageal junctional pressure (Fig. 1), did not alter immediately. The tone began to fall as Stage II esophagitis developed and continued to fall until Stage III esophagitis was reached.

With relaxation and contraction at the gastroesophageal junction, the deglutition complex was also altered. Relaxation at the gastroesophageal junction was measured both directly in centimetres of water and as a percentage of the tone of the gastroesophageal junction (Fig. 2). During the

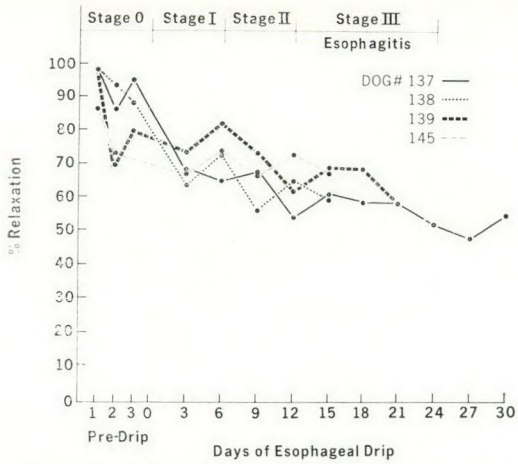


**Fig. 2.**—Relaxation at the gastroesophageal HPZ — the effects of bile drip. The percentage relaxation in the HPZ fell early in the study before visible esophagitis developed. The fall in percentage relaxation then slowly continued until Stage III esophagitis was reached.

experiment there was an immediate fall in relaxation which was noted at the time of the first manometric study. The reduction in relaxation continued as the experiment progressed, but the change was not as marked in the remainder of the study. There was no significant change in the duration of relaxation, or in the amplitude and duration of the contraction phase of deglutition.

*Group III.*—In all the animals in this group, as esophagitis developed, a major motor defect also developed in the body of the esophagus: DMA, estimated by counting the number of simultaneous motor waves, reached a maximum when Stage III esophagitis was reached. In subgroups (b) and (c) the dogs were allowed to recover by stopping the drip. As the esophagitis resolved, the motor defect completely regressed to the pre-drip normal.

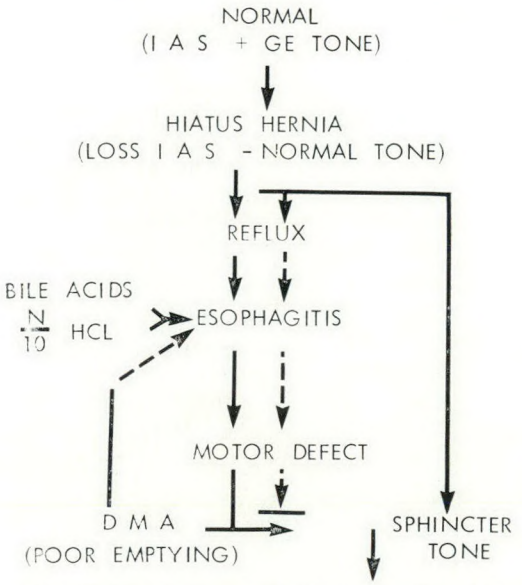


**Fig. 3.**—Production and effect of reflux. The dogs in Group IIIb and IIIc developed esophagitis and the DMA progressed as in Group IIIa. After 21 days the drip was stopped and the esophagitis resolved. With the resolution of the esophagitis, DMA decreased to its pre-drip normal level.

## Discussion

In both studies motor changes were seen in the esophagus. Each of the human subjects had a hiatus hernia but the motor defect in these patients was more severe in those who also had esophagitis. The dogs did not have hiatus hernias but with the production of Stage III esophagitis, motor changes developed similar to those seen in humans.[11] The major parameters of motor changes were DMA in the body of the esophagus and tone and relaxation in the HPZ.

The importance of these motor changes in patients with hiatus hernias becomes evident when one considers what happens in a hiatus hernia with reflux (Fig. 3). The normal subject has many possible antireflux mechanisms, but probably the most important are the HPZ and the intra-abdominal segment (IAS) of the esophagus. When a hiatus hernia is present, the IAS of the esophagus is lost and the gastroesophageal HPZ is left as the major barrier to reflux. Reflux, when present, may produce esophagitis. From previous studies we concluded that the quality of the refluxed bolus was important because we could produce esophagitis more readily by a drip of bile and HCl combined than with bile or acid alone.

The present study shows that two of the major motor defects of esophagitis are DMA of the body of the esophagus and a reduction in tone of the HPZ. In human studies DMA has been shown to be associated with delayed emptying of the esophagus.[12, 13] Delayed emptying exposes the esophagus to the refluxed bolus for a

longer period and potentially increases the irritative effect of the reflux.

Decreased tone in the HPZ reduces the major barrier to reflux and potentially will increase reflux. These two factors, once activated, tend to increase reflux progressively and decrease the emptying time of the esophagus, resulting in more severe esophagitis.

## Summary

In Experiment 1, 20 normal subjects and 50 patients with hiatus hernias were studied. The hiatal hernia patients had motor defects which were more severe if esophagitis was also present. The body of the esophagus showed a variable frequency of disordered motor activity from 10% to 90%. In those patients with Stage III or Stage IV esophagitis the frequency of disordered motor activity was always greater than 50%.

In the group with a history of severe reflux or endoscopic findings of Stage III esophagitis, the tone of the gastroesophageal high pressure zone was always decreased.

In the high pressure zone of the hiatal hernia patients there was a decrease in relaxation in response to deglutition. Relaxation averaged 54% compared with 75% in normal subjects. This reduction was more marked in those with Stage III esophagitis and a low-tone high pressure zone.

In Experiment 2, 11 dogs were studied. Esophagitis was not produced in the two dogs who received a saline drip and there was no motor defect. In the other nine animals we produced esophagitis at the gastroesophageal junction or in the body of the esophagus. The body of the esophagus developed progressive disordered motor activity which increased to affect at least 80% of the recorded motor waves when Stage III esophagitis developed. When the drip was stopped and the process allowed to resolve, the esophagitis totally cleared and disordered motor activity subsided to zero. When Stage III esophagitis was produced at the gastroesophageal junction, the tone of the high pressure zone fell progressively until it was less than 25% of the pre-drip level. Associated with the fall in tone, there was a fall in relaxation at the high pressure zone in response to deglutition. The relaxation declined sharply to an average of 70% at Stage I esophagitis, then more gradually until it reached approximately 50% of the pre-drip level at Stage III esophagitis.

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# PRIMARY LYMPHOSARCOMA OF THE LUNG: A CASE REPORT AND REVIEW OF THE LITERATURE*

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**Summary: A survey of the literature shows that fewer than 100 cases of primary lymphosarcoma of the lung have been reported to date. To be accepted as primary lymphosarcoma the lesion must be confined to one lung without mediastinal or distant disease. One-half of patients reported in the literature had respiratory symptoms preceding diagnosis of their disease. Of the others, approximately one-third were asymptomatic at the time of diagnosis. Radiological findings are non-specific, and the most common presentation is diffuse lobar involvement with indistinct margins. A preoperative diagnosis is not possible in the majority of patients. Treatment has included surgical excision, radiotherapy, or both. Five-year survival rates are 43.9% with operation and 41.6% with radiotherapy. This survival rate increases to 46.2% when radiotherapy is combined with operation. The case report of a patient with primary lymphosarcoma, who presented at the University of Alberta Hospital, Edmonton in 1972, is included.**

**Résumé: D'après une revue de la littérature, on a jusqu'ici rapporté un peu de moins de 100 cas de lymphosarcome primaire du poumon. Pour être acceptée comme telle, la lésion doit être limitée à un seul poumon, sans être accompagnée d'une atteinte du médiastin ou d'une pathologie à distance. La moitié des malades signalés dans la littérature présentaient des symptômes respiratoires avant le diagnostic. Environ un tiers des autres étaient asymptomatiques au moment du diagnostic. Les signes radiologiques ne sont pas spécifiques et l'image la plus fréquente est une atteinte lobaire diffuse, dont les marges sont vagues. Chez la majorité des malades, il est impossible de poser un diagnostic préopératoire. Le traitement comporte une excision chirurgicale, la radiothérapie ou les deux modes thérapeutiques. La survie de cinq ans est de 43.9% chez les opérés, et de 41.6% avec l'irradiation. Le taux de survie augmente à 46.2% quand les deux traitements sont combinés. On trouvera également dans le présent article la présentation d'un malade atteint de lymphosarcome primaire qui a été admis, en 1972, à l'Hôpital universitaire de l'Alberta, à Edmonton.**

PRIMARY lymphosarcoma of the lung is a rare entity. Recently a patient with this condition presented at the University of Alberta Hospital, Edmonton. This report presents the findings in the case and a review of the literature.

## CASE REPORT

The patient, a 67-year-old white woman, was admitted because at routine radiological examination at a mobile tuberculosis unit on March 30, 1972 she had been found to have an asymptomatic mass in the left lung field.

The patient had no respiratory or cardiovascular symptoms at the time of her admission, apart from paroxysmal tachycardia and occasional palpitations. One sister had died of pulmonary tuberculosis 20 years earlier. She was a non-smoker. Her medical history included the occurrence of long-standing Raynaud's phenomenon, stress incontinence, recurring bladder infections and severe superficial bilateral varicosities. Her weight was constant at 165 lbs.

Clinical examination of the respiratory system was negative. There were no palpable lymph nodes. Her blood pressure was 200/90 mm Hg. An ejection click could be heard at the apex, and a grade II/VI ejection systolic murmur was present which radiated to the neck. Apart from total blindness in the left eye and a nominal aphasia, the remainder of the physical examination disclosed no abnormal findings.

The results of laboratory investigation on admission were as follows: hemoglobin 12 g/100 ml, leukocytes 5,300/cmm with a normal differential count, sedimentation rate 26 mm in one hour, blood glucose 97 mg/100 ml, uric acid 4.7 mg, blood urea nitrogen 19 mg, creatinine 0.7 mg, bilirubin 0.5 mg and total protein 6.9 g/100 ml. The SGOT level was normal at 23 units/ml. The LDH and alkaline phosphatase values were within normal limits. Cultures of expectorated specimens were negative.

Radiological examination showed an ill-defined "water density" lesion in the posterior segment of the lower lobe of the left lung,

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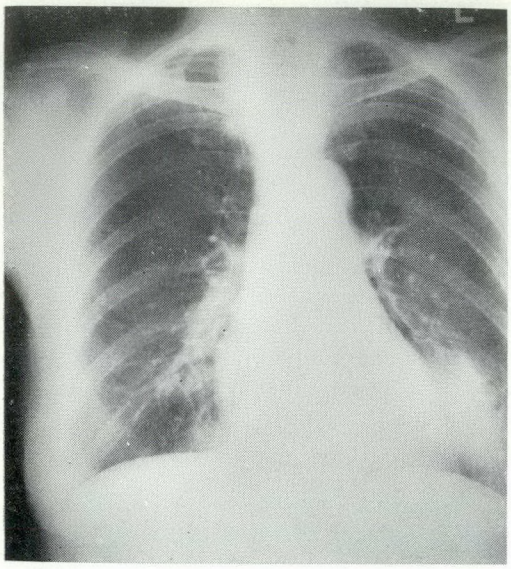

**Fig. 1.**—Frontal projection of the chest showing an ill-defined lesion measuring approximately 5 x 8 cm in the lower portion of the left lung.

which measured approximately 5 x 8 cm (Figs. 1 and 2). The mass had indistinct margins fading into contiguous lung tissue with no evidence of an air bronchogram effect. Both these features were thought to be characteristic of an interstitial consolidation. Tomography revealed no hilar or mediastinal lymph-node enlargement. A $^{131}I$ lung scan revealed an area of decreased activity in the left lower lobe corresponding accurately to the size and location of the lesion on the plain roentgenogram. Liver, spleen and brain scans showed no evidence of tumour involvement in these organs.

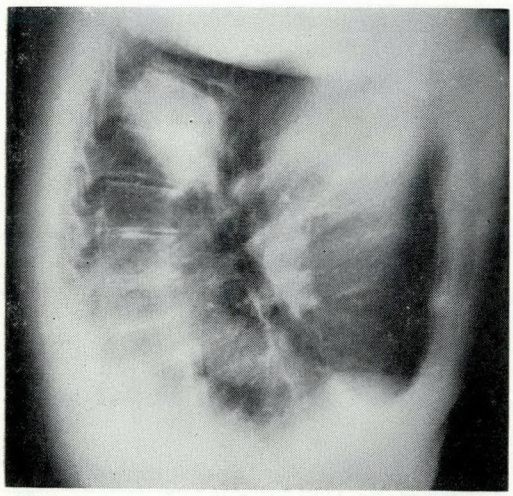

**Fig. 2.**—Lateral projection of the chest confirming the size and location of the tumour.

The electrocardiogram was normal and the electroencephalogram showed only a mild grade I dysrhythmia with no focal abnormalities. Pulmonary function studies showed a total lung capacity of 4.84 l, a vital capacity of 3.26 l, and a residual volume of 33%. The forced expiratory flow from 0 to 25% was 4.8 l or 87% of the estimated normal value, and alveolar $Pco_2$ was 34 mm Hg. Bronchoscopy revealed no evidence of endobronchial disease.

An operation was performed on May 15, 1972 when, through a fifth interspace posterolateral approach, the mass could be readily palpated in the central portion of the left lower lobe. A left lower lobectomy was performed. An immediate frozen section revealed that the tumour was a lymphosarcoma, with a uniform appearance of mature lymphocytes and no follicle formation (Figs. 3 and 4).

The patient's recovery was satisfactory and she was discharged on the eleventh postoperative day.

## Discussion

The first case of primary lymphosarcoma of the lung was reported by O'Donnell[1] in 1926, and a survey of subsequent literature shows that this remains a rare entity. This is in contrast to pulmonary involvement secondary to generalized lymphosarcoma which according to Robbins[2] occurs in approximately 7% of patients with malignant lymphoma. Ergin and Kemler[3] reported 27 cases of primary pulmonary lymphosarcoma in a literature search they conducted in 1960. In 1965 Papaioannou and Watson,[4] in an excellent appraisal of primary lymphoma of the lung, reported 77 cases in the literature to that date. In 1969 Gautam[5] reported an accumulative total of 80 cases of primary lymphosarcoma to that date. The additional reports since that time would give a total of fewer than 100 cases.

There remains some confusion in the literature in recording the true incidence of this condition. Some clinicians have reported patients with primary lymphosarcoma in the presence of mediastinal or distant lymph-node involvement. Furthermore, the nomenclature used to designate this tumour has varied. The classification most commonly used today is that of Jackson and Parker[6] put forward in 1947. In 1965 Papaioannou and Watson[4] of the Sloan Kettering Cancer

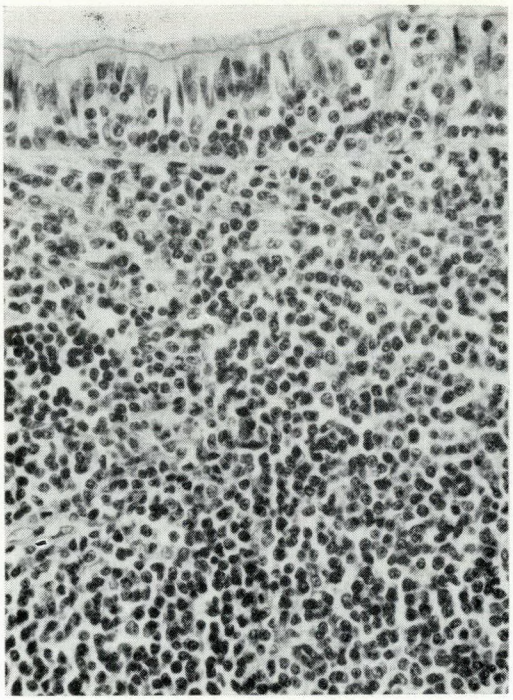

**Fig. 3.**—Microscopic section of the excised tumour mass showing uniform appearance of mature lymphocytes with no follicle formation (H & E x 100).

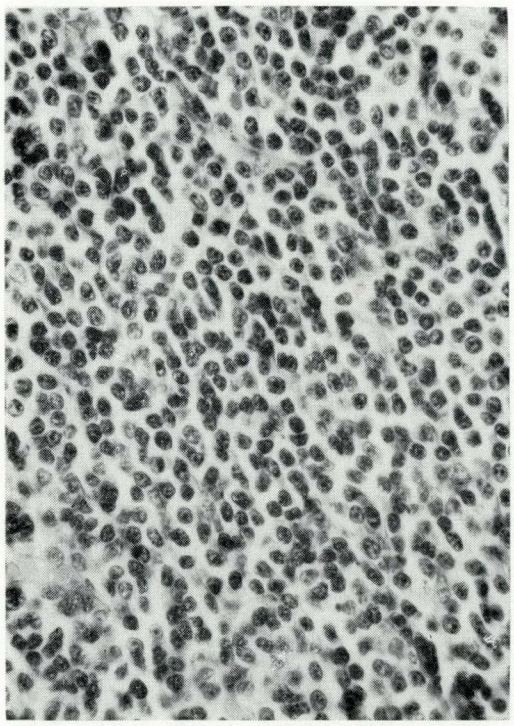

**Fig. 4.**—View showing a uniform appearance of mature lymphocytes (H & E x 160).

Center conducted a careful search of the literature from which they concluded that a total of 93 cases of primary lymphoma of the lung had been reported to that time (these included seven patients with primary lymphoma of the lung treated at Sloan Kettering). The total comprised 77 cases of primary lymphosarcoma and 16 cases of primary reticulum cell sarcoma.

The criterion for inclusion in their series was confinement of the lesion to one lung, with or without hilar involvement but without mediastinal disease. Patients suspected of having secondary lymphoma of the lung were excluded. Also excluded were reports from the literature in which insufficient information for adequate classification was present, and those cases which were found incidentally at autopsy. They found 149 cases reported as primary lymphoma of the lung but 55 cases failed to meet their criteria and were excluded.

In the 77 cases of primary lymphosarcoma reviewed, the average age of patients was 52.9 years compared with 42.6 years in the 16 cases with primary reticulum cell sarcoma.

In approximately half the patients respiratory symptoms preceded the discovery of the disease by months or years. The most common symptoms were cough, chest pains and recurrent respiratory infections. However, one-third of the patients were asymptomatic and the lesion was discovered in routine chest roentgenograms. Our patient, as noted, was without respiratory symptoms.

Primary lymphoma of the lung originates from lymphoid tissue present subpleurally in proximity to pulmonary veins and bronchi or in the lung parenchyma itself. Sternberg, Sidransky and Ochsner[7] point out that lymphoma cells do not spread by intra-alveolar extension but rather by spread within alveolar septa. Though it grows diffusely, the primary lymphoma usually does not infiltrate or obstruct the lumen of vessels or bronchi. The absence of infiltration or obstruction is undoubtedly the main reason why the diagnosis of primary lymphoma of the lung is difficult to make before operation.

Radiological findings in primary lymphoma are non-specific. The size of the lesion varies greatly, and it may be associated with

hilar densities characteristic of lymphadenopathy. It may appear as a single, poorly defined mass in the parenchyma, near the hilus or subpleurally. The most common radiological presentation of the lesion is diffuse lobar involvement with indistinct margins. As bronchi are seldom compromised by the tumour mass, patent bronchi may occasionally be seen coursing through the substance of the lesion. When the tumour is near the pleural surface it may produce a pleural reaction with adhesion or pleural fluid. The lesions have been observed to cross interlobar fissures with involvement of adjoining lobes.

The usual absence of bronchial involvement is probably responsible for the high incidence of negative bronchoscopic examinations. In more than 50% of the patients with primary lymphoma of the lung no abnormal findings were noted at bronchoscopy. However, in a number of cases bronchial erythema accompanied by some edema and stenosis was noted. Biopsy of these erythematous areas usually reveals characteristics of chronic inflammation only. Papaioannou and Watson[4] found only four cases where a diagnosis of malignancy, and one case where a diagnosis of lymphoma, was obtained from bronchial biopsy.

Because the bronchial mucosa is not involved, exfoliative cytology has been of little value in establishing a diagnosis.

The actual pathogenesis of lymphosarcoma has been the subject of some controversy. Baron and Whitehouse[8] express doubt that the lesion is malignant from the start, and consider that it may merely be a degeneration of a benign lymphoma. Saltzstein[9] believes that many lymphosarcomas represent benign inflammation of "pseudolymphomas", rather than truly malignant lymphomas.

Gautam[5] reported a slight preponderance of females with this disease, and observed that its occurrence bears no relation to environment, occupation or chronic lung disease.

Papaioannou and Watson[4] reported a five-year survival rate of 46.7% in primary lymphosarcoma of the lung. They compare this with the five-year survival rate of 54.5% in primary lymphosarcoma of the head and neck, and 24% in primary lymphosarcoma of the small intestine.

Treatment of this condition has included surgical excision (either lobectomy or pneumonectomy), radiotherapy or both. In the series of Papaioannou and Watson the five-year survival rate was 43.9% with operation. This compares favourably with the survival rate with radiotherapy, which was 41.6%. When radiotherapy was combined with surgery the survival rate was increased to 46.2%.

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# BOOK REVIEWS

**ATLAS DER GYNÄKOLOGISCHEN OPERATIONEN. Unter Berücksichtigung gynäkologische-urologischer Eingriffe. 3rd ed. O. Käser, F. A. Ilklé and H. A. Hirsch. 593 pp. Illust. Intercontinental Medical Book Corp., New York; Georg Thieme Verlag, Stuttgart, 1973. DM 248,00. $102.55 (approx.).**

This large and impressive volume has been produced with all the care one has come to associate with this eminent German publishing house. The selection of paper, the binding, the clarity of the print and the excellence of the illustrations attest to the publishers' intention to spare nothing to make this an outstanding and authoritative text. They and the authors deserve congratulations for their success.

The subject matter covers all the standard gynecological procedures and includes as well descriptions of such modern subjects as vacuum curettage and the use of hypertonic saline in abortion, laparoscopy, the Shirodkar cerclage and the Williams operation utilizing the labia majora in cases of congenital absence of the vagina. There is a detailed section on tuboplasty and reimplantation of the tubes in cases where tubal obstruction is responsible for infertility. It is gratifying to see included steps designed to overcome difficulties in awkward situations: hemisectomy of the uterus when its size causes trouble at vaginal hysterectomy, myomectomy as a preliminary to abdominal hysterectomy when the myomata are unduly large, and subtotal hysterectomy followed by excision of the cervix when the pelvic organs are unduly fixed.

There are clear accounts of repair of hernia, of breast surgery, of bowel resection and of urological operations which the gynecologist may be called upon to perform unexpectedly.

The illustrations make this a valuable reference work even for those with only a rudimentary knowledge of the German language, to be consulted with profit the evening before an operation thought likely to be complicated.

A. W. ANDISON

**INTERMEDIARY METABOLISM OF THE LIVER. Edited by Henry Brown and David F. Hardwick. 187 pp. Illust. McGraw-Hill Ryerson Limited, Toronto; Charles C Thomas, Publisher, Springfield, Ill., 1973. $12.75.**

This book was written following a conference on intermediary metabolism of the liver, sponsored by the Harvard Medical and Surgical Services, Boston City Hospital. The first three chapters deal with the role of the liver in specific aspects of protein, lipid and carbohydrate metabolism. In the chapter "Metabolic Studies Following Orthotopic Liver Transplantation", Dr. Starzl demonstrates that the two liver proteins studied retain the phenotype of the donor. This makes it possible to use these proteins as indicators of graft function and also opens new vistas of therapy for liver-based metabolic disorders. The role of hepatic adenosine triphosphate deficiency in various disease states is discussed. Experimental models of fructose- and methionine-induced hepatic ATP depletion are discussed with their implications for pathogenesis and treatment. There is a review of ammonium metabolism in liver disease and a discussion of the present status of therapy for this disorder. The final chapter deals with the clinical methods used in support of fulminant hepatic failure.

This is probably not a book that will be widely read by practising surgeons. Nevertheless it is well-referenced and will be of interest to those engaged in hepatic research and those whose primary interest is hepatology.

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**REHABILITATION OF THE FACIALLY DISABLED. Prevention of Irreversible Psychic Trauma by Early Reconstruction. J. J. Longacre. 124 pp. Illust. McGraw-Hill Ryerson Limited, Toronto; Charles C Thomas, Publisher, Springfield, Ill., 1973. $14.75.**

This monograph is a plea by an experienced surgeon for early reconstruction of facial deformity to prevent irreversible psychic trauma. Quite correctly he points out that though facial disfigurement is rarely physically disabling, the psychological and socioeconomic ramifications reach much further than those of the physically handicapped.

The book is very short and can be read in one evening. The first section deals with early reconstruction after trauma such as is seen in war wounds and motor vehicle accidents. The second discusses and emphasizes immediate reconstruction after ablative cancer surgery of the head and neck. Many examples are given showing the psychic damage to people by making them facial mutilees. Cure of the cancer without reconstruction may destroy the patient's entire ego. Technical details in these two sections are only briefly discussed but are based on the usual plastic surgery principles.

The next section deals with early correction of congenital facial deformities such as Crouzon's, Apert's and the first and second branchial arch deformities by repeated onlay grafts of ribs. The work of Tessier and others has now made most of these techniques invalid but the principle of early treatment before the child is fully grown to prevent irreversible psy-

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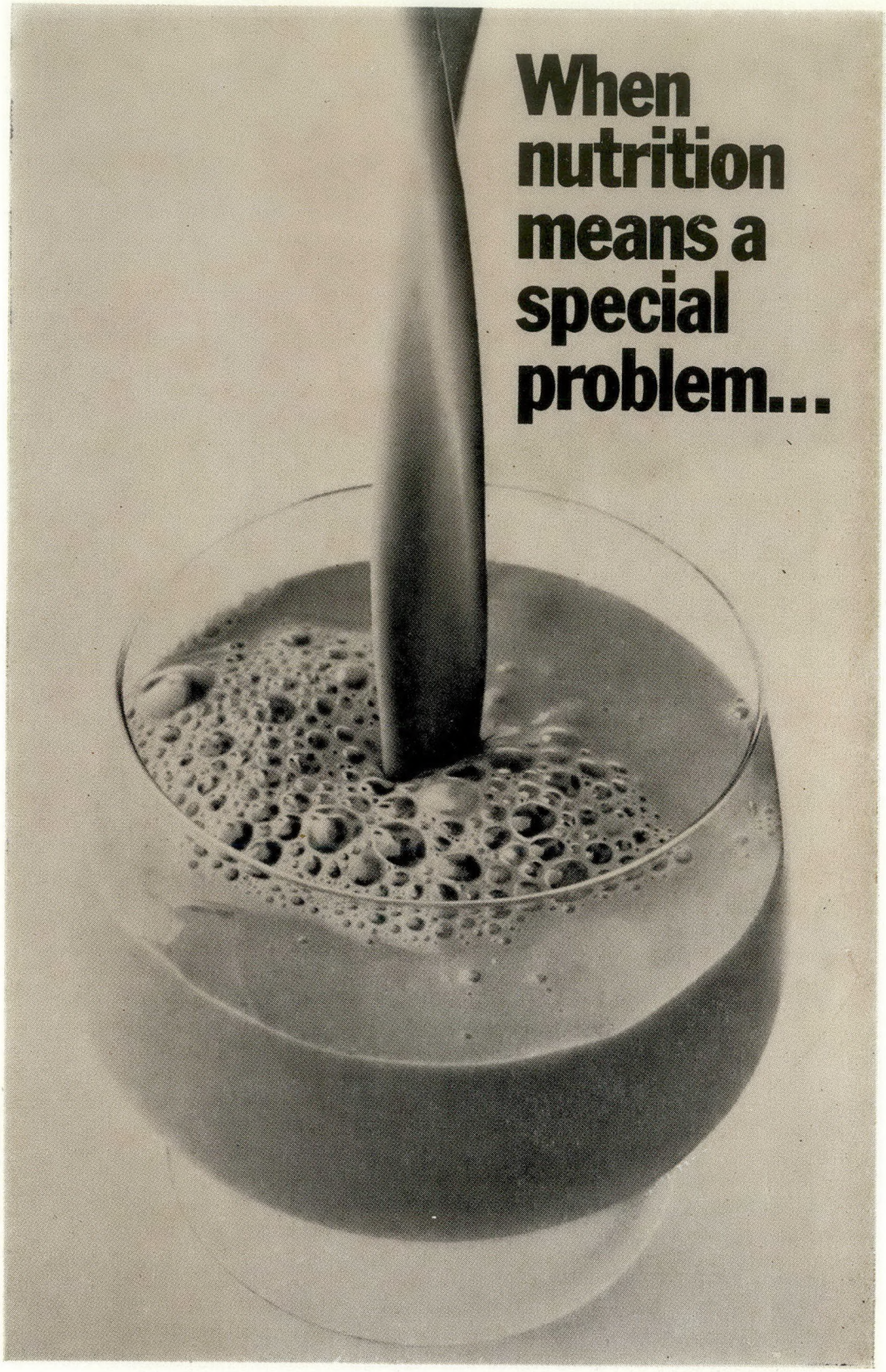
When
nutrition
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(Continued from page 121)

chic damage remains true. A short chapter on the behaviour of rib grafts has little basic scientific proof but the 20-year follow-up of many cases, including radiographic evidence, together with discussion by the author of experience with over 1,000 cases of rib onlay grafting demand the acceptance that free bone grafts do, in fact, fulfil the purpose of their design.

An unusual feature of this book is two chapters by Dr. Thelma Brown. She was a successful, attractive psychologist severely disfigured in a motor vehicle accident who describes the mental changes gone through before, during and after rehabilitation by facial reconstruction in a section "The Ego in Distress". Dr. Brown also gives a format for numerical evaluation of the ego functioning level related to the body image.

It would be too easy to adversely criticize this book. All the many photographs are black and white with little control of lighting or position. Thus, colour texture differences and many scars cannot be appreciated. Not all cases shown live up to the author's claim of complete restoration to normal. However, this book should be read by all who are called upon to deal with congenital, traumatic or iatrogenic facial deformity whether they believe in early reconstruction or not.

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**OUTPATIENT SURGERY. Edited by George J. Hill, II. 1079 pp. Illust. W. B. Saunders Company, Philadelphia; W. B. Saunders Company Canada Limited, Toronto, 1973. $28.85.**

It is a delight to see a surgical textbook that reverses the trend to greater and more costly surgical care by stressing that which can be done safely, reasonably and at much less cost of money, personnel and facilities on an outpatient basis. The book covers outpatient surgery in its widest sense including anesthesia, ophthalmology, otorhinolaryngology, podiatry, obstetrics and gynecology. Twenty-four of the 27 authors are from the Denver, Colorado area. They emphasize the diagnosis and management of outpatient problems as well as the preoperative and postoperative outpatient care of patients requiring hospitalization. There are very interesting chapters on: organization; design, function and operation of outpatient clinics and emergency rooms; outpatient surgery in developing countries; surgery and medicine in the field; the unconscious patient; and excruciating pain. The pictures and diagrams are excellent.

Although the text is at times wordy and at times supplies detail more appropriate to a

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# when shock threatens the lung

Abstract visualization of lung tissue

# Solu-Medrol

## helps reduce pulmonary damage and increase survival rates

- preserves lysosome and cell membranes, thereby preventing the release of destructive lysosomal enzymes[3]
- preserves platelets thereby reducing the risk of intravascular coagulation[1]
- preserves leukocyte integrity thereby helping to maintain the pulmonary architecture[1]

The recovery of patients in shock is often complicated by a pattern of deteriorating pulmonary function. This pulmonary insufficiency progresses despite restoration of hæmodynamic balance and apparent stabilization of the acute episode.

Under conditions of prolonged shock, lack of oxygen at the cellular level causes alterations in the oxygen-carbon dioxide exchange mechanism. These changes in cell metabolism lead ultimately to interstitial œdema and perivascular hæmorrhage.[1] Polymorphonuclear leukocytes aggregate in the pulmonary capillaries and obstruct the pulmonary vascular bed. As these trapped cells break down, they release lysosomes, tiny subcellular particles containing proteolytic enzymes.[1] These enzymes attack their host cell and go on to damage or destroy other cells.[2] The resulting tissue damage may not readily repair itself even if the shock patient survives.

When administered in conjunction with standard therapeutic measures, Solu-Medrol exerts a protective effect on the lung and improves the patient's chance of survival.

Prescribing information on page

**References:**
1. Wilson, J.W. (1972). Surg., Gynec. & Obstet., *134*:675.
2. Janoff, A. (1964). Shock, p. 93.
3. DeDuve, C. (1964). Injury, Inflammation and Immunity, p. 283.

*(Continued from page XXXII)*

complete textbook of medicine, it is recommended. It should be available in all emergency departments as a reference work. It should be of considerable value to students, interns and residents who work in an outpatient setting. Practising surgeons will find that the chapters on areas adjacent to their own, e.g. cancer chemotherapy, transplantation, anesthesia, provide refreshing current summaries.

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**PATHOLOGY ANNUAL. Volume 8, 1973. Edited by Sheldon C. Sommers. 479 pp. Illust. Appleton-Century-Crofts, Educational Division, Meredith Corporation, New York, 1973. $18.50.**

This volume of the "Pathology Annual" continues in the established tradition of presenting concise reviews of important current topics in clinical and experimental pathology. This volume covers 15 unrelated topics. The first paper by Dr. D. W. Penner of Winnipeg provides a lucid account of the difficult subject of quality evaluation techniques in surgical pathology, a timely article and very well done. Another excellent article deals with correlations between specimen mammograms and pathologic findings in breast disease. Other articles deal with endometrial and cervical cancer, anthracotic pneumoconiosis, the pathobiology of lymphocyte interactions, recent advances in pathologic aspects of neonatal respiratory disease, intestinal lymphoma and inflammatory diseases of the liver. The book is highly recommended for pathologists and portions could be useful to a range of surgical specialists.

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**REOPERATIVE GASTROINTESTINAL SURGERY. Thomas Taylor White and R. Cameron Harrison. 304 pp. Illust. Little, Brown and Company, Boston, 1973. $25.00.**

This monograph is an excellent addition to the surgical literature. It presents a concise review of the diagnostic and operative problems of reoperative gastrointestinal surgery and discusses these in considerable detail. This is the first book of its type in the English literature and, as such, is of particular importance, filling the gap admirably.

The text covers abdominal wall problems,

*(Continued on page XL)*

# Fight infection, help wounds heal with—

# Furacin*

- **Broad, stable antibacterial range.** More than 80,000,000 courses of topical therapy with Furacin have scarcely changed its wide antibacterial range.
- **Non-antibiotic Non-Systemic.** Furacin is used only topically. There is no development of cross-resistance or cross-sensitization with antibiotics or sulfonamides, hence no interference with any planned systemic therapy.
- **Effective in pus, serum and other wound fluids.** Unlike certain antibiotics, sulfonamides and other antibacterials, Furacin is not bound, inactivated or destroyed by body secretions or exudates.
- **Non-toxic to healing tissue.** Freedom from cytotoxicity facilitates tissue regeneration and take of skin grafts.
- **Non-macerating.** Water-solubility of the Furacin carrier, the unique, non-lipid Solubase*, ensure tissue and fluid compatibility.
- **Low incidence of sensitization.** Rarely seen in burns and surgical practice, the reported overall incidence of sensitization to Furacin is about 1.2%.
- **Limited development of resistance.** There has been no emergence of clinically significant resistant bacterial mutants in over 20 years of clinical use. Furacin continues to destroy pathogens that have long since grown resistant to some other antimicrobials.
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- **Ready to use.** No time or labor wasted in preparing impregnated dressings and in sterilization. Furacin impregnated rolls and pads are supplied sterile and ready for immediate use, as is the Furacin Stretch Gauze.
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- **Economical therapy.** Saves time and money in the hospital, in the office, and on prescription.

## The first family of ready-to-use antibacterial dressings.
## versatile/economical
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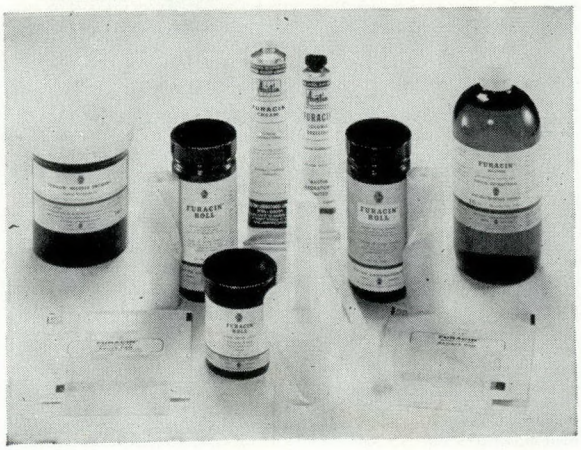
# Furacin* (nitrofurazone)




## Furacin Product Information

**FURACIN STERILE STRETCH GAUZE:**
A sterile prepacked bactericidal wet dressing that conforms and clings comfortably to body contours and hard to dress wounds. It is impregnated with a water-miscible 0.2% Furacin solution. If a continuously wet dressing is desired, it may be moistened as required with Furacin Solution diluted 1:1 with sterile water.

**FURACIN STERILE ROLLS:**
Rolls of sterile cotton gauze or sterile cotton batiste impregnated with Furacin Soluble Dressing containing 0.2% Furacin in water-soluble Solubase*.

**FURACIN STERILE PADS:**
Individual foil envelopes contain a sterile cotton gauze pad or sterile cotton batiste pad 3" x 3" (opens to 3" x 9"). Each pad is impregnated with Furacin Soluble Dressing containing 0.2% Furacin in water-soluble Solubase*.

*Also available:* Furacin Soluble Dressing, Furacin Soluble Powder, Furacin Solution, and Furacin Topical Cream.

**Additional information available on request**

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the esophagus, stomach and duodenum, biliary tract, pancreas and the small and large bowel. Each topic is well discussed and illustrated and numerous well-chosen references substantiate the authors' opinions.

The paragraphs on stomach and duodenum, biliary tract and pancreas are particularly informative and it is likely these cover areas of major interest to the authors. The same cannot be said of the section on the esophagus, for modern trends in the diagnosis and management of esophageal disease are omitted. This is an unfortunate deficiency in an otherwise admirable text.

This monograph will be of value to the practising surgeon and be of even greater value to the resident surgeon.

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**SURGERY OF THE HIP JOINT. Edited by Raymond G. Tronzo. 840 pp. Illust. Lea & Febiger, Philadelphia; The Macmillan Company of Canada Limited, Toronto, 1973. $49.54.**

Dr. Tronzo is to be congratulated on his masterful editing of this book. As he states in his preface, there are very few books devoted to hip problems and the need for a comprehensive text on hip surgery is undoubted.

Despite the use of multiple contributors, there is surprisingly little overlap of the material presented by the various authors and what little there is, is of value.

The book is specifically orientated towards treatment, as its title implies, and there is little emphasis on the theoretical or histopathological aspects of disease processes apart from an excellent and stimulating chapter by Victor Frankel on the biomechanics of the hip. Dr. Frankel's observations are of importance when considering surgical apporaches to hip problems but I feel that Raymond Tronzo was wise in not enlarging the content of his book with other chapters on basic pathology.

This is, in essence, a practical manual and therefore the book has been profusely and excellently illustrated with beautiful radiographs and very clear diagrams. It will be extremely valuable reading, not only for a surgeon whose practice includes a considerable amount of hip-joint surgery but also for orthopedic residents for whom it will provide a clear, lucid and authoritative account.

"Surgery of the Hip Joint" is an erudite, thorough and masterly survey of the subject.

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