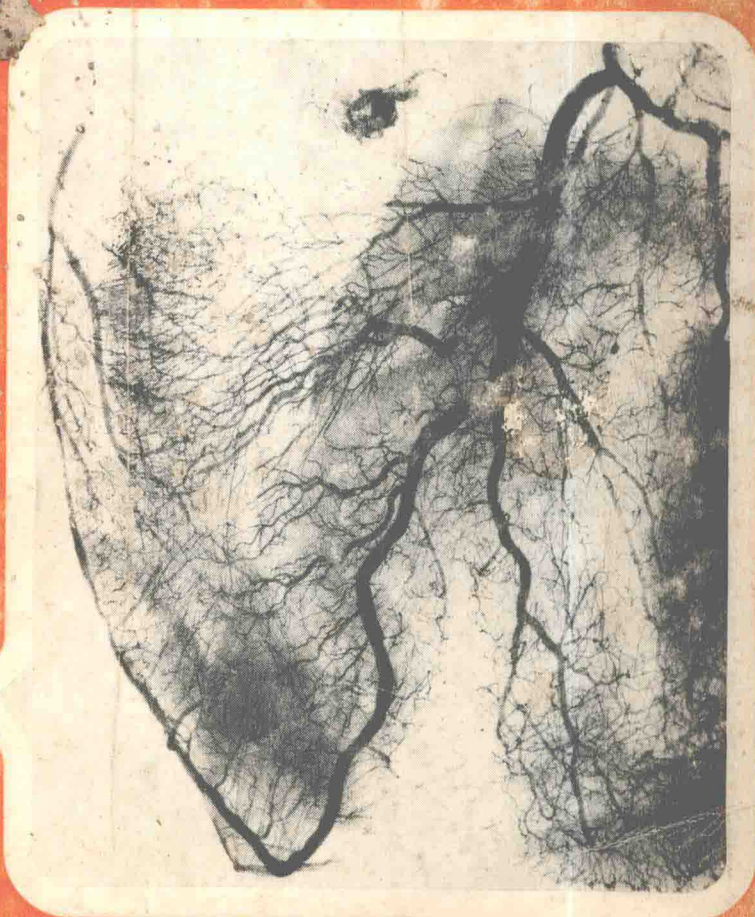


clinical studies
volume 1

d.a.k. black
editor

the collateral circulation of the heart

by
w. schaper



north-holland

THE COLLATERAL CIRCULATION OF THE HEART

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D. A. K. BLACK

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Editor's preface

The launching of a new series of medical books perhaps requires a word of explanation, at a time when there is no great apparent shortage of medical titles. We have, however, good reasons for doing so, which may be briefly outlined, as they also serve to indicate the scope of the series for the benefit of future authors.

We are naturally not uninfluenced by the prestige and success of the already established series 'Frontiers of Biology', edited by Professors A. Neuberger and E. L. Tatum. This displays the advantages of a coherent publishing policy and of critical choice of individual titles. In the main, the series consists of monographs, but occasionally conference reports on clearly defined topics have been included. Our own choice of material will be similar in character, but we hope to draw contributions from another area of scientific endeavour, that which is concerned less with fundamental biology, and more with problems arising in clinical medicine. Our publishers naturally gave thought to the possibility of expanding the already well-established series in this direction; but we were able to persuade them that the clinical sciences already formed a discipline, or group of disciplines, which justified a separate enterprise.

In taking this view, we are fully aware that modern medicine, with its tantalising combination of triumphs and difficulties, is firmly based on the fundamental sciences – particularly if these are extended to include those which deal with the behaviour of animals, of man, and of society. But we are equally conscious of the intensity and depth of the scientific work which is inspired by clinical problems, and often carried out in clinical departments. Much of this work consists of careful observation of nature's own experiments; but 'observation' now means something much more

sophisticated than it did in the days of Auenbrugger and Laennec. The older scientific techniques still have a central place in studying the natural history of disease; but tools from the laboratory have greatly extended the range of what can be observed. Partly because of this, and also because the fascination of clinical studies has always attracted keen minds, we believe that in the new series our problems will be those of selection rather than of any need to instigate contributions, once the series is well under way.

In this belief, we approach our task as editors with some trepidation, but also with a good deal of confidence in the future of the series.

D.A.K. BLACK

To

Susanne
Wolfgang Jr.
Martin-James
Martine
Wim
and Inge

Preface

'... there is a tendency when you really begin to learn something about a thing not to want to write about it but rather to keep on learning about it always and at no time, unless you are very egotistical, which of course, accounts for many books ...'

Ernest Hemingway
'Death in the Afternoon'

This book represents an attempt to study the collateral circulation from a multitude of different angles. Hemodynamics, gross and microscopic morphology, ultrastructure, cytochemistry, cell population kinetics, computer simulation and human morbid anatomy were fitted into a general view of collateral circulation. We hope that our integrated approach will stimulate research in this neglected but very important area. We are fully aware that this book contains not only experimental results and facts but also speculations, opinions, unfounded beliefs and partly baked ideas (PBI). We preferred to put these PBI's on paper rather than feed the reader with a lot of uninterpreted data. Few things are more stimulating in research than wholehearted disagreement. We hope that these PBI's are the only things on which to disagree but we do hope that our data may remain valid for a couple of years.

Some chapters which we initially planned have not been included in this book. The role of physical exercise in the development of the collateral circulation was not described because our data are so far inconclusive. From the point of view of experimental design and statistics it would have meant a delay of publication of at least one year. We decided not to take chances because the outcome of our efforts is at present not at all clear.

This book describes only our own studies, and only literature relating to our work was discussed. We did not plan to give an exhaustive and complete review of the entire existing literature.

This book would not have been made possible without the help of friends who are not mentioned as co-authors. Dr. Paul Janssen, Director of Research, Janssen Pharmaceutica, encouraged and stimulated our studies. Without his deep scientific interest and support we could never have hoped

to even study the problem. We express our sincere gratitude to Paul Janssen for his creation of a scientific environment of unparalleled quality.

We are greatly indebted to Anton Jageneau and Raymond Xhonneux, the gifted surgeons who performed the implantation of constricting devices in hundreds of experimental animals. Marc De Brabander relieved us from the necessary evils of scientific writing. He ably classified the literature, prepared the references, reread the manuscript many times and tried to eliminate errors. Paul Van Even helped to develop our autoradiographic technique and prepared and stained thousands of tissue sections.

The senior author expresses his gratitude to Professor J. Schoenmackers (Department of Pathology, Technical University Aachen, Germany) for kindly furnishing laboratory space, materials and advice to study the pathology of human ischemic heart disease.

Wolfgang Schaper
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Introduction

All therapeutic measures aimed at the rehabilitation of the 'coronary' patient are based on the assumption of an improved collateral blood supply to ischemic myocardium. These therapeutic measures include cardiac surgery, i.e. implantation of arteries directly into the myocardial muscle, drug therapy and occupational therapy (i.e. physical training).

Although these rehabilitation-oriented forms of therapy rely completely on the existence or development of a collateral circulation, the actual role of collaterals and anastomoses is not fully understood. A number of secondary factors concerning the efficiency of the therapeutic measures has obscured the importance of the collateral circulation which has hardly been studied because its existence is so universally accepted. This has not always been so, in fact the history of the collateral circulation has had its ups and downs.

As early as 1669, Lower found that 'the vessels which carry blood to the heart ... come together again and here and there communicate by anastomoses'. A century after the great Albrecht von Haller (1757) had demonstrated the existence of anastomoses by direct preparation and dissection, several highly respected anatomists such as Hyrtl (1873), Henle (1876), Cohnheim and von Schulthess-Rechberg (1881) and Dragneff (1897), denied the existence of such vessels and declared the coronary arteries as anatomical end-arteries. However, at the beginning of this century Spalteholz' work (1907, 1924) left little doubt about the existence of vessels which were so clearly described by Lower. Improved injection and clearing techniques, in part invented by Spalteholz led to the often quoted book 'Die Arterien der Herzwand' which contained for the first time high-quality photographs providing unquestionable evidence for the existence of anastomoses. The newly invented technique of X-ray arteriography, which led to Jamin and Merkel's (1907) stereo-

scopic atlas of postmortem coronary arteriograms, added impact to Spalteholz' findings and led Gross (1921) to the statement that, at least in the dog heart, 'anastomoses in the heart are universal and abundant'.

Although this sounded like the final victory of the collaterals over their contestants the pendulum swung back when in the thirties and early forties Schlesinger (1938) and coworkers denied the existence of anastomoses in the normal heart although their techniques were much inferior to methods used earlier by Spalteholz (1907, 1924), Gross (1921), Jamin and Merkel (1907).

It took indeed 30 years before Fulton (1965) set the record straight again in his admirable book 'The coronary arteries'. Fulton described anastomoses in the normal and diseased human heart with such clarity and precision that it is indeed difficult to imagine that his findings could ever be questioned.

In fact Fulton's work is so perfectly and beautifully presented that one feels almost discouraged to engage in this type of research because the standards he has set are too rigorous. However, Fulton's work is one of the causes that have led to the universal acceptance of the existence and functional significance of collaterals which had been expressed by Grande and Taylor (1963): '... the weight of evidence supports the idea that inter-coronary anastomoses exist in the great majority of the normal human hearts.' Although it is good to see that a fact is finally acknowledged, the universal acceptance of this fact usually tends to kill the interest in the subject because there is apparently nothing left to disagree upon.

However, the existence of a collateral circulation in the heart is not a solution to all our therapeutic problems but rather a challenge. It is amazing to anyone familiar with the vascular anatomy of the heart to see how different in quantity and quality anastomoses appear when comparing normal hearts with those having a coronary artery occlusion. The increase in caliber of anastomoses suggests growth processes, which is somewhat in contrast to the often quoted (Winbury 1969) belief that anastomoses (in coronary artery disease) are greatly stretched arterioles lacking an arterial coat. But although the collateral bed can passively expand, this process obviously fails more often than it succeeds, because otherwise myocardial infarcts would be much less of a problem.

I was genuinely intrigued by the possibility that the very small pre-existent collateral vessels of a normal heart might grow into substantial arterial blood conductors and I got very much interested in the mechanics of such a growth process. As a result this study became an exercise in cell biology as well as in many other specialties and techniques of which I was completely ignorant at the beginning of the study.

The general strategy of the present study was as follows: since it is impossible to study the day-to-day changes in the growth and transformation of small vessels into larger ones after coronary artery occlusion in the human heart the necessary experiments were performed in animals. The results of these experiments were then compared with postmortem findings in the human heart. In particular I tried to compare the histology of human collaterals and anastomoses with those of dogs, pigs and sheep after experimental coronary artery occlusion. By comparing pictures and patterns it was possible to make inferences and to draw conclusions as to how the vascular transformation might progress in the human heart.

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