

Annual Conference Key Note Address

My 40-year journey in diabetes research: The power of collaboration

Viswanathan Mohan

Madras Diabetes Research Foundation and Dr. Mohan's Diabetes Specialities Centre, WHO Collaborating Centre for Noncommunicable Diseases Prevention and Control, IDF Centre of Excellence in Diabetes Care and Education & ICMR Centre for Advanced Research on Diabetes, Chennai, Tamil Nadu, India

Abstract

This article describes a 40 year journey in diabetes research of an Indian diabetologist, starting as an undergraduate medical student. The article describes how collaborations with multiple stake-holders is necessary if one is to advance one's research from the simple studies that one starts with and take it to higher and higher levels. It is also essential that the seeds for doing research are planted early in a medico's life even during undergraduate days, as only then will more doctors take up medical research as a career. Finally, the article demonstrates how it is possible to do good quality research in India if one has the passion and sustained interest in the field even if one is not in a university or academic setup.

Keywords: Diabetes, power of collaboration, research

Address for correspondence: Dr. Viswanathan Mohan, Madras Diabetes Research Foundation and Dr. Mohan's Diabetes Specialities Centre, WHO Collaborating Centre for Noncommunicable Diseases Prevention and Control, IDF Centre of Excellence in Diabetes Care and Education & ICMR Centre for Advanced Research on Diabetes, No 6, Conran Smith Road, Gopalapuram, Chennai, Tamil Nadu, India.
E-mail: drmohans@diabetes.ind.in

INTRODUCTION

It is often believed that it is difficult to do medical research outside of the university set up or academia. This is particularly true in developing countries like India where only a negligible number of doctors do serious research. This article demonstrates how if one starts early, develops sustained interest in a particular field and most importantly, is willing to collaborate, high quality research can be done even in developing countries like India.

THE MAKINGS OF A DOCTOR AND RESEARCHER: ROLE OF SERENDIPITY

My father, Prof. M. Viswanathan is often referred to as the "Father of Diabetology in India" as he set up the first Diabetes Clinic in India at the Government Stanley Medical College and

Hospital at Chennai in 1948. Till today, I am not sure what prompted him to set up a diabetes clinic or choose Diabetology as a speciality at that time, when diabetes as a disorder was virtually unknown in India. He continued working at the Stanley Medical College and Hospital but had to leave the government setup in 1970, well before his scheduled retirement age. I was just finishing school at the time, and I was very passionate about poetry and wanted to take-up English literature as my career and become a writer and a poet. However, my father persuaded me to give up my "literature" dream and instead take-up medicine as a career, so that I could help him setup the first private diabetes center in India. I am a great believer in serendipity and I am convinced that nothing in life happens just by chance, but that there is a divine will, which directs everything. Hence, to cut a long story short, I decided to take-up medicine as my career. As I was passionate about

Access this article online	
Quick Response Code:	Website: www.picronline.org
	DOI: 10.4103/picr.PICR_86_18

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Mohan V. My 40-year journey in diabetes research: The power of collaboration. *Perspect Clin Res* 2018;9:113-22.

writing, I started getting involved in research right from my MBBS days, although several of my teachers tried to dissuade me, saying it was a sheer waste of time. Luckily, I did not give up. Looking back, I am now convinced that unless we start inculcating the passion for research in medical students during their undergraduate days, it is very unlikely they will develop interest in research or take-up medical research as a career. The other lesson I have learned, all through my career as a researcher, is the power of collaboration. I often hear from my colleagues that they are scared to collaborate with someone in research as they feel that they will be “cheated” out of the glory due to them, or even worse, that their data will be stolen! My experience has taught me otherwise and has, in fact, convinced me about the need for collaboration with multiple stakeholders for conducting successful research and certainly to take it to the next level, as I shall explain in this article.

Two people were pillars of support for me during my medical student life and both encouraged me to do research. One, of course, was my father. He was an extraordinary clinician, a great teacher, a superb researcher, and a visionary par excellence who could see 30–40 years ahead of his time. Even during his days at Stanley Medical College, he had several notable publications and was among the top clinical researchers in medicine in India at that time. The other person who influenced me greatly was my teacher Prof. Lalitha Kameswaran, Professor of Pharmacology at Madras Medical College (MMC) who later became the first Vice-Chancellor of the Tamil Nadu Dr. MGR Medical University. She encouraged us to use the facilities in the Pharmacology Department of MMC during our summer holidays to carry out our research. Along with some of my classmates (all of them now leaders in their respective fields of specialization in medicine and surgery), we also revived the dilapidated animal house at MMC where we carried out animal experiments. That was the real start of my research career because until then I had been helping my father with clinical research by studying and analyzing a large number of patient case records. One such experiment that I did during my MBBS was later published in the Indian Journal of Pharmacology.^[1] We carried out subtotal pancreatectomy in dogs to produce an animal model to mimic what we now call as type 2 diabetes. We then treated the dogs with a sulfonylurea and biguanide and compared the effect with the use of either drug alone. We showed a synergistic effect if both drugs were used, leading to a reduction of the dose of the individual drugs. This study was one of the first of its kind at that time in India.

MY INITIAL YEARS OF RESEARCH WITH MY FATHER

I was also able to simultaneously do a similar clinical trial along with my father and confirm the findings of the

sulfonylurea/biguanide combination clinically also.^[2] I continued to do research all through my MBBS and MD studies at MMC, and by the time, I had finished my MD, I had about 30 publications which was a record of sorts, for a medical student in India. One must appreciate the fact that during those days, there were no proper facilities to do research. In 1972, when we started our first private diabetes hospital in India (the M. V. Hospital for Diabetes at Royapuram in North Chennai), we did not even have a proper laboratory. All we had was a dilapidated car shed with one colorimeter and a part-time technician and the only tests we could do were blood sugar and urine sugar estimations. However, we gradually built-up our laboratory with the help of a retired Professor of Biochemistry from JIPMER, Puducherry. However, we only had manual, paper-based, medical records. This meant that if one had to do a study, one had to go through hundreds of records manually to note down all the clinical and biochemical findings. We had no computers. There was no Google, no Pubmed, and no Science Citation Index. Indeed, we did not even have a library or access to journals. If I needed to get copies of a large number of articles, I would take a flight to Delhi, go to the National Medical Library there, search for all the articles I wanted, pay for them in advance and the library would then send me the photocopies of the articles, which could take up to a month to reach Chennai. Young researchers today complain that it is tough to do research. I can only smile inwardly when they say this when I compare today's facilities with what we had those days. However, the other side of the coin is that all these difficulties and challenges make one work very hard and one's passion for research increases. I do not regret the hours, days, and months I spent trying to do research under the most trying and difficult circumstances.

WORK AT THE M. V. HOSPITAL FOR DIABETES AND DIABETES RESEARCH CENTRE AT ROYAPURAM, CHENNAI

After completing my MD in 1981, I joined my father as a full-time Consultant Diabetologist, and this resulted in a much faster rate of growth of research. I spent a total of 20 years working with my father (first 10 years as a student and next 10 as a consultant). During the second 10 years, my late wife Dr. Rema Mohan who later became an internationally renowned ophthalmologist and specialist in diabetic retinopathy, also worked with me at my father's center. We both took a 2-year sabbatical between 1984 and 1986 spending a year at the Royal Postgraduate Medical Schools and Hammersmith Hospital, London, UK where we worked with the world famous expert on diabetic retinopathy Prof. Eva Kohner. The primary purpose of our visit to the UK was for Rema to get trained in diabetic

retinopathy by Prof. Eva Kohner. I worked as a Wellcome Research Fellow while Rema was supported by the British Society for Prevention of Blindness. During this period, I also worked with Prof. Hugh Mather at the Ealing Hospital, near Southall where a large number of Indian (mostly Punjabi Sikh) patients lived.

Our work at this time brought to light a very interesting fact about South Asians (Indians). We showed for the first time that Indians had higher plasma insulin levels compared to age, sex-, and weight-matched white Europeans.^[3] This suggested that Indians had higher insulin resistance which was later proved by doing euglycemic clamp studies along my colleague, Dr. Patrick Sharp.^[4] I also worked in the biochemistry laboratory at Hammersmith Hospital running insulin and C-peptide assays on my own. This was an excellent opportunity for me to learn about quality control of various laboratory assays. The year in the UK was remarkably productive and led to over a dozen papers in peer-reviewed journals and my first publications in highly rated international journals.^[3-6] My wife Rema also published some excellent papers with Dr. Eva Kohner on diabetic retinopathy during this time.^[7]

I then received the news that I was awarded the prestigious Alexander Von Humboldt Fellowship from Germany. This enabled me to spend a year working with the great legend in the field of diabetes, Prof. E. F. Pfeiffer, at the University of Ulm in Germany. Here, I learned how to work on the Artificial Pancreas (Biostator) and continuous glucose monitoring which was in its rudimentary stages at that time. Meanwhile, Rema continued her work on retinopathy with Dr. Margret Pfeiffer, wife of Prof. Pfeiffer, and an expert in retinopathy.

After we came back from our sabbatical, we again started to work at my father's center. I received two grants, one from the Wellcome Trust and the other from the Alexander Von Humboldt Foundation. These grants gave me the seed money needed to pursue my research. I focused on Maturity Onset Diabetes of the Young (MODY) which was at that time a purely clinical entity.^[8-10] I also worked on Fibrocalculous Pancreatic Diabetes (FCPD) and Tropical Chronic Pancreatitis^[11-17] and obtained my Ph.D. working under the guidance of Dr. Lalitha Kameswaran. My work on FCPD led to collaboration with Prof. C. S. Pitchumoni, the world-renowned expert in pancreatic disorders based at New York. Prof. Pitchumoni has the unique distinction of working with three generations of my family. He had earlier worked with my father Prof. Viswanathan and then continued over three decades of collaborative research with me. More recently, he has published papers with my

daughter Anjana and son-in-law Ranjit, thus completing collaboration with three generations of our family. To add to this, his granddaughter Shreya came to Chennai to do research at our centre and published a first author paper!

Another fruitful collaboration was with the legendary gastroenterologist and my teacher, Prof. N. Madanagopal and his brilliant young research associate Dr. Suresh Chari who later became a world-renowned pancreatologist at the famous Mayo Clinic in the US. I spent nearly 15 years of my life working on FCPD (which also led to a Doctor of Science D.Sc, degree) describing its national history and establishing the criteria for its diagnosis which later came to be known as Mohan's Criteria for FCPD.^[16,17]

ESTABLISHING THE MADRAS DIABETES RESEARCH FOUNDATION AND DR. MOHAN'S DIABETES SPECIALITIES CENTRE

In September 1991, Rema and I felt it was time for us to move on and start our own center as we felt there was scope to expand to South Chennai as the city was growing in that direction. We left empty handed with just a stethoscope and a near zero bank balance. In fact, my wife had taken a huge loan to set up a diabetic retinopathy unit at my father's hospital and so we actually were in huge debt. We set up the Dr. Mohan's Diabetes Specialities Centre (DMDSC) (then known as M. V. Diabetes Specialities Centre), initially in a small rented building at Royapettah. However, slowly, but steadily, we started to grow and in 1996, moved into our own building at Gopalapuram which remains the headquarters of our institutions even today. Luckily, we started using computers and electronic medical records right from day one, and today we have electronic records of over 430,000 diabetes patients which is the largest in the world.^[18] We also started establishing branches of our centre at different geographies and we now have 45 branches of DMDSC spread across 10 states of India.

RESEARCH CARRIED OUT AT MADRAS DIABETES RESEARCH FOUNDATION: THE POWER OF COLLABORATION

As we started seeing more and more patients, we also continued to do more research and publish more papers. In 1996, we set up the Madras Diabetes Research Foundation (MDRF), a 100% nonprofit organization. Around this time, I also decided to move on from FCPD which was a relatively rare condition and work on the much more common type 2 diabetes, as its prevalence was beginning to reach epidemic proportions. At first, we were limited to clinical papers from our centre and the data were mainly drawn from our own large clinical electronic

records of patients,^[19] many of whom were followed up for several decades.^[20,21] One disadvantage of such studies was that being clinic based, they were subject to “referral bias” and hence the data obtained was often not generalizable to the community at large.

Around 1998, we took a bold decision and decided to go out into the community to start population-based epidemiological studies. Initially, we tried to keep it simple and started off with “convenience sampling” and tried to study just a small part of Chennai city. At this stage, we had to collaborate with the owners of residential properties and other local authorities and carried out our first epidemiology study at Chennai – the Chennai Urban Population Study (CUPS) between the years 1998 and 2000.^[22] We studied a low-income group in T. Nagar (which was a slum) and a middle-income group in Thirumangalam, where we selected a typical housing colony where people lived in flats (condominium). The question we tried to answer was whether there was any “intraurban” difference in the prevalence of diabetes between a middle- and low-income colony.^[23] This study was our foundation in epidemiology and though CUPS was relatively small, we managed to publish a total of 21 papers from this study.^[24-28]

We soon realized that there were no epidemiological data on complications of diabetes from India or indeed, from other developing countries. We also knew that if we wanted to study the complications of diabetes such as nephropathy, neuropathy, and retinopathy, we needed a study with a much larger sample size, as otherwise, we would not have sufficient power to study these complications. We thus decided to carry out our next major epidemiological study, this time covering the whole of Chennai city – the Chennai Urban Rural Epidemiology Study (CURES).^[29] This study which covered a study population of 26,001 individuals totally representative of Chennai, was done in 5 phases (CURES 1 to 5) each phase answering different research questions that we posed. CURES has led to the publication of a record number of 150 papers in peer-reviewed journals till date.^[30-33] This is perhaps one of the largest numbers of papers from a single study in India.

“CURES” was the result of a collaboration between MDRF, the Chennai Willington Corporate Foundation (a nongovernmental organization [NGO], which funded the study), the Corporation of Chennai and multiple residential colonies and took our research collaboration to a different level. It is fair to state that it was through CURES that we became seasoned epidemiology researchers.

FROM CHENNAI TO THE WHOLE OF INDIA: THE ICMR-INDIAB STUDY

Around this time, my daughter, Dr. Anjana who had just finished her postgraduation in medicine, expressed her keen interest to take-up even more ambitious studies covering the whole of India. She first wrote a paper in the Indian Journal of Medical Research on the need to collect national data on diabetes.^[34] Thus was born the Indian Council of Medical Research-India Diabetes (ICMR-INDIAB) Study whose primary objective was to study the prevalence of diabetes and prediabetes in India by estimating the state-wise prevalence of the same.^[35] This landmark study was only possible due to the generous support of ICMR and the Department of Health Research, Government of India and due to our numerous collaborators who served as the Principal Investigators, in every state of India [Appendix 1]. The ICMR-INDIAB study in fact really taught us the power of collaboration and how we could take up a landmark national study to produce valuable data at a national and state level if we included collaborators from across the country. The ICMR-INDIAB study also meant working with the state governments and health departments in every state of India and the logistics of doing this, as can be imagined, was mind-boggling.

The ICMR-INDIAB study is one of the largest, longest, and most ambitious studies on diabetes undertaken by ICMR. At the time of writing this article, 20 whole states of India and 1 union territory have been completed and several more are ongoing. Nearly, a dozen world-class publications (including one in *Lancet Diabetes and Endocrinology*) have already been published from this study till date.^[36-41]

Indeed, ICMR has been pivotal in driving the research at MDRF and I am grateful to several Director Generals of ICMR and Dr. Bela Shah, Dr. Tanvir Kaur, Dr. R.S. Dhaliwal, Dr. D.K. Shukla, Dr. Chander Shekhar and Dr Prashant Mathur for their support. We are privileged to work with ICMR on the Young Diabetes Registry as a collaborating centre, as a Centre for Advanced Research (CAR) on Diabetes, on testing of various indigenous low-cost glucometers and several other projects including our recent projects on Yoga. We have also been generously supported by several grants from the Department of Science and Technology (DST) and Department of Biotechnology (DBT) and recently from the AYUSH Department.

AND ON TO INTERNATIONAL COLLABORATION...

We were now ready to take-up larger collaborations with different universities and research/organizations

around the world. Our current collaborations include the Emory University, Atlanta in the US; the University of Dundee in Scotland; Warwick University, University of Leicester and the Imperial College, London in the UK; the McMaster University in Hamilton, Canada; the University of Copenhagen, Denmark; and several others. One of our longest collaborations was with the University of Alabama at Birmingham with Prof. Dale Williams (and later with Florida International University, USA) and Prof. Cora Lewis and Prof. Myron Gross at the University of Minnesota, USA. This project was funded by the National Institutes of Health (NIH), Fogarty International Center, USA, for nearly 15 years and helped in capacity building for Prevention and Control of Noncommunicable Diseases in India and training of Community Medical Specialists from 350 Medical Colleges in India. Over 1471 community health specialists benefited from this program.^[42] This also indirectly led to our centre being recognized as the World Health Organization (WHO) Collaborating Centre for Noncommunicable Diseases Prevention and Control.

One of the role model and long-term, still ongoing, collaborations we developed was with my good friend Prof. K. M. Venkat Narayan (Venkat) and colleagues at the Emory University. We initially started off with no funding whatsoever. Based on our initial publications, Emory University,^[43] kindly provided an initial funding of 1 million US dollars with the understanding that we would then raise additional funding. This worked out very well for us. Venkat and I expanded the collaboration to include Prof. Mohammed (Mo) Ali and several junior colleagues from Emory, Prof. Nikhil Tandon of All India Institute of Medical Sciences, Prof. Dorairaj Prabhakaran of the Centre for Chronic Disease and Public Health Foundation of India at Delhi, and Prof. Masood Kadir at the Aga Khan University, Karachi, Pakistan. We managed to obtain grants from the International Diabetes Federation (IDF) for the “Diabetes Community Lifestyle Improvement Program (D-CLIP)”^[44] and the NIH, USA, for the Centre for Cardiometabolic Risk Reduction in South Asia surveillance study (CARRS).^[45] These led to further grants and collaborations with other universities in the US and then to studies on depression and diabetes, among others.^[46] This is an example of how collaborations in research can start small with virtually no funding but later, if the collaborators work together, can keep growing and expanding to solve pressing health problems and research questions relevant to the country.

Another highly successful collaboration of ours is with the McMaster University in Hamilton, Canada, where we collaborate with my good friend Dr. Salim Yusuf, the world-renowned cardiologist and one of the world’s

topmost medical researchers! This included among others, the Diabetes REduction Assessment with ramipril and rosiglitazone Medication (DREAM) Trial^[47] and The Indian Polycap Study^[48] led by Prof. Prem Pais and Prof. Denis Xavier at the St. John’s Medical College, Bengaluru. The most impressive collaboration was the Prospective Urban Rural Epidemiological (PURE) Study, which is one of the largest epidemiological studies ever conducted in the world. PURE is currently studying 250,000 participants in 25 countries, with over 15 years of follow-up already.^[49] PURE taught us the power of collaboration and demonstrated how, if top researchers come together, we can do studies of a kind which can never be done by a single individual or institution or even by any single country.

One of the points that one has to learn early in the life of a researcher is that we have a choice. Either we can have a very small cake, all to ourselves or have a small piece of a huge cake, that is, produce very high caliber research which can change the way medicine is practiced. There are “pros and cons” of each of these, and based on my 40 years of experience as a researcher, I feel that there is value in both. One should continue to do one’s own small studies which do have their own local relevance and impact. At the same time, one should also be collaborative and willing to share one’s data and experience, expertise and knowledge, and become part of a much larger group which can answer questions which are much bigger, which cannot be answered by just collecting local data. The whole idea of medical research is to change the way we think of diseases or improve our treatments/methods so that humanity at large can reap the benefits. There is no way that this can be achieved without collaboration.

I would also like to mention our collaboration in food and nutrition research. Prof. Walter Willett, Frank Hu, and Donna Spiegelman of the Harvard School of Public Health, Boston are our collaborators in our studies of brown rice.^[50,51] Recently, we have also worked with Cashew Export Promotion Council of India and Ministry of Commerce on a Cashew nut supplementation trial among adults with type 2 diabetes and currently also with Almond Board of California for supplementation trial with almonds among obese Asian Indians. Our collaboration with agriculture scientists helped us to produce a unique high fiber low glycemic index (GI) white rice.^[52] This high-fiber rice is being sold under the company name, Dr. Mohan’s Healthcare Products (DMHCP). DMHCP focuses on bringing out authentic health-care products and services to promote better health. DMHCP’s vision is to translate food and nutrition research findings into evidence-based health foods to benefit the society, especially the population with diabetes and those at risk for diabetes. Our collaboration the World

Diabetes Foundation (WDF), Denmark, and the Indian Space Research Organization (ISRO) led to the Chunampet Rural Diabetes Prevention Project (CRDPP) which has been recognized as model for rural diabetes health care.^[53,54]

I had a fascination for genetics of diabetes right from my medical college days, thanks to my interest in Maturity Onset Diabetes of the Young (MODY). This led to series of collaborations, starting with Dr. Bob Kirk at the University of Canberra, Australia, and later a very productive collaboration with Dr. Graham Hitman at the Royal London Hospital, London, with whom we had a large number of papers on genomics of diabetes. Around 1996, the Government of India introduced a ban on sending blood samples abroad and hence sending blood samples to foreign universities completely stopped. This, in a way, was good for us because it led to setting up of our own genomics department at our centre. Our initial focus was on the genomics of type 2 diabetes and we had several collaborators who worked with us on this. Later, we started focusing on monogenic diabetes.

We have been fortunate to collaborate with several national and international collaborations in our work on monogenic forms of diabetes such as MODY and Neonatal Diabetes. The ICMR generously funded MDRF, initially as an ICMR Advanced Centre for Genomics of Diabetes and recently recognized MDRF as an ICMR Centre for Advanced Research on Diabetes. Our initial international collaborators in our work on MODY included Prof. Oluf Pedersen and Dr. Torben Hansen at the University of Copenhagen, Denmark and Dr. Pal Njolstad, University of Bergen, Norway. More recently, we are fortunate to have a wonderful collaboration with scientists at MedGenome in India and Dr. Andrew Peterson and Dr. Somasekar Seshagiri at Genentech, California, which led to the discovery of a new MODY gene in India.^[55] Our most recent collaborators are Prof. Louis Philipson and his team from the Kovler Diabetes Center at the University of Chicago, USA.

Collaboration in the UK includes the Warwick University (Prof. Saravanan Ponnusamy) in our work on Gestational Diabetes Mellitus (GDM). Recently, our work with Prof. Colin Palmer and colleagues at the University of Dundee, Scotland, on Precision Diabetes and response to various antidiabetic drugs and with Prof. John Chambers and colleagues from the Imperial College, London, on surveillance and digital application of diabetes, offer great promise.

During the last few years, we have been very fortunate to forge a very useful and productive collaboration with the Deakin University at Melbourne, Australia. Through this collaboration, our students are able to work at MDRF

and obtain their Ph.D. from Deakin University with the help of their Primary Supervisors who work at Deakin University. Several students have completed their Ph.D. program through this mechanism and others are currently pursuing their Ph.D. We also established the first Diabetes Nurse Educator programme in collaboration with Deakin University and several such programs are being planned.

One of our major collaborations was the Indo-Danish Bilateral Research Project entitled “MicroDiab: Studies of interactions between the gut Microbiome and the human host biology to elucidate novel aspects of the pathophysiology and pathogenesis of type 2 Diabetes.” In this project, we collaborated with Prof. Oluf Pedersen, Prof. Torben Hansen, and Dr. Henrik Vestergaard of the University of Copenhagen, Denmark; Dr. G. Balakrish Nair and Dr. Bhabatosh Das at THSTI, Faridabad; and Dr. Sharmila Mande and colleagues at TCS, Pune, and this study is providing interesting results.

Our work on GDM started largely due to the support of the IDF through the BRIDGES grant and led to the now well known, Women in India with GDM Strategy (WINGS) Program. Thanks to this project, we were able to build up a network of obstetric and gynaecology collaborators in and around Chennai, led by Dr. Uma Ram of the Seethapathi Clinic and Hospital, Chennai. WINGS led to several excellent publications on the screening and diagnosis of diabetes, prevalence of GDM and the development and testing of model of low-cost model of care for GDM.^[56,57] This also led to our next project on GDM, the Stratification of Risk of Diabetes in Early Pregnancy project with our collaborators Dr. Saravanan Ponnusamy in the UK, Dr. Sonak Pastakia from Kenya, and with several obstetric colleagues in India led by Dr. Uma Ram.

More recently, the GDM collaboration further extended to the LIVING trial-A lifestyle intervention program for the prevention of type 2 diabetes mellitus among South Asian women with GDM with Dr. Nikhil Tandon of All India Institute of Medical Sciences and Dr. Uma Ram from Seethapathi Clinic and Hospital which is funded by the National Health and Medical Research Council of Australia Global Alliance for Chronic Diseases and ICMR.

There are also notable collaborations with Prof. Jeyakumar Henry, earlier at the Oxford Brookes University, Oxford (and later based at Singapore) which led to setting up of the Glycemic Index (GI) testing laboratory^[58] and many others. Our clinical trials department has been continuously taking up high-quality good clinical practice

trials. This department has successfully conducted over 130 major trials during the last 25 years. Here we have been collaborating with various pharmaceutical companies and Clinical Research Organizations with high retention rates of study participants. It is impossible to do justice to all our collaborators in one article, for example, there are Indo-German projects, Indo-French projects, etc., Moreover, as this article focuses only on research, I am not including our numerous collaborators in health-care activities including several NGOs in Diabetes Education (e.g. Public Health Foundation of India with whom we run numerous courses including the very popular Certificate Course in Evidence-Based Diabetes Management) or our charitable activities which are supported by several trusts and foundations.

WHAT ARE MY LEARNINGS AS A MEDICAL RESEARCHER WHO HAS BEEN INVOLVED IN RESEARCH FOR OVER FOUR DECADES?

1. “Catch them early.” We must inculcate the passion for research by providing opportunities for young medical students to do research even during their MBBS studies. Credits can be given for students who do research when measuring their overall output and impact as a medical student. This will encourage young medical students get the feel and “taste” of research and see whether this is something that they would like to pursue as a career option. This could definitely attract at least a few young medical doctors to taking up medical research as a career
2. Research must be made more attractive by providing better emoluments. Today, most doctors believe that the only way to make money is by building up a practice. If researchers are paid handsomely, many doctors would think of an alternative career as a researcher. This will also indirectly mean that many talented and smart young doctors would take up public health as a career. This could lead to improved healthcare of the country as a whole
3. The private sector has to be encouraged to take-up research. There is no denying the fact that today 80% of health care in India is with the private sector. Hence, it makes no sense whatsoever to ignore the private sector. The private sector has several advantages. Most private hospitals and clinics have access to sophisticated and state of the art equipment. There are also tertiary care referral centers which have large numbers of patients, electronic records, and staff who are already on permanent salaries. There is also less bureaucracy. If we are able to harness all the data which is available in the private sector and if we establish successful collaborations between private

sector hospitals, universities, and research centers, India can contribute significantly to medical research. As disease patterns are quite different in India, there are ample opportunities to contribute and thus put India on the world map of medical research.

FINAL THOUGHTS

How does one replicate what I have achieved in my own humble way in my career?

I believe that first one has to build a multidisciplinary team, who will interact with each other to develop new research questions. One must work with like-minded people, trust each other and not only begin to work together but also stay together. One should draw up long-term plans so that longitudinal research can be carried out over several decades with good outcome processes and measures. One can initiate small research projects and clinical studies, slowly develop the infrastructure facilities and build one’s team of collaborators, both within India and abroad. Later, if one has the interest and the ability, one can gradually progress toward answering more basic research questions by building the necessary research facilities. Unlike in the past, there are enough grants available from national and international funding agencies today. If one has the right research questions, finding the funds for research should not be too difficult (although it is never easy!).

Finally, one should not keep dreaming about things which one may never be able to do, but rather do whatever is possible with the available infrastructure. One may start small (as I did 40 years ago in a dilapidated car shed) but build up gradually until our big dreams ultimately become a reality. This would be my message to young researchers and this indeed is the very purpose of writing this article! The time to act is NOW!

Acknowledgments

I wish to thank my colleagues at the M. V. Hospital for Diabetes and Diabetes Research Centre, Royapuram, especially my late father Prof. M. Viswanathan, my beloved mother Mrs. Sarada Viswanathan, my brother-in-law, Dr. A. Ramachandran, my brothers Dr. Vijay Viswanathan, and Mr. Arun Viswanathan, my sisters Dr. R. Shobhana and Dr. Indira Padmalayam, Dr. C. Snehalatha for all their support. My staff at DMDSC and MDRF are far too many for me to thank individually. But for you guys, there would have been no article for me to write! I also wish to thank my innumerable collaborators in India and abroad, all of whom could not be acknowledged by name due to limitations of space and my apologies if I omitted any of your names. I included only those with whom I have published original articles and not

review articles. I would like to thank the various funding agencies, ICMR, DBT and DST, ISRO, WDF, IDF, the NIH (through its various institutions), The WHO, Wellcome Trust, the NIH Research, UK, the Alexander von Humboldt Foundation, the Canadian Institutes of Health Research, the Chennai Willington Foundation, and several pharmaceutical companies. Finally, I wish to thank my family, particularly my late wife Dr. Rema Mohan, my daughter Dr. R. M. Anjana, my son-in-law Dr. Ranjit Unnikrishnan and grandson Pranav for their continuous support all through my career. Finally, I thank my spiritual Guru and Master Bhagawan Sri Sathya Sai Baba but for whose blessings, my life would have been meaningless.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Mohan V, Nazimuddin SK, Viswanathan M, Kameswaran L. Hypoglycemic effect of combination of glybenclamide and phenformin – An experi. *Indian J Pharmacol* 1978;10:239-41.
- Viswanathan M, Ramachandran A, Mohan V. Low dosage combination therapy of glybenclamide and phenformin in maturity onset diabetes. *J Diabet Assoc India* 1975;15:145-9.
- Mohan V, Sharp PS, Cloke HR, Burrin JM, Schumer B, Kohner EM, *et al*. Serum immunoreactive insulin responses to a glucose load in Asian Indian and European type 2 (non-insulin-dependent) diabetic patients and control subjects. *Diabetologia* 1986;29:235-7.
- Sharp PS, Mohan V, Levy JC, Mather HM, Kohner EM. Insulin resistance in patients of Asian Indian and European origin with non-insulin dependent diabetes. *Horm Metab Res* 1987;19:84-5.
- Sharp PS, Mohan V, Maneschi F, Vitelli F, Cloke HR, Burrin JM, *et al*. Changes in plasma growth hormone in diabetic and nondiabetic subjects during the glucose clamp. *Metabolism* 1987;36:71-5.
- Sharp PS, Mohan V, Vitelli F, Maneschi F, Kohner EM. Changes in insulin resistance with long-term insulin therapy. *Diabetes Care* 1987;10:56-61.
- Mohan R, Kohner EM, Aldington SJ, Nijhar I, Mohan V, Mather HM, *et al*. Evaluation of a non-mydriatic camera in Indian and European diabetic patients. *Br J Ophthalmol* 1988;72:841-5.
- Mohan V, Ramachandran A, Snehalatha C, Mohan R, Bharani G, Viswanathan M, *et al*. High prevalence of maturity-onset diabetes of the young (MODY) among Indians. *Diabetes Care* 1985;8:371-4.
- Mohan V, Snehalatha C, Ramachandran A, Viswanathan M. Abnormalities in insulin secretion in healthy offspring of Indian patients with maturity-onset diabetes of the young. *Diabetes Care* 1986;9:53-6.
- Mohan V, Snehalatha C, Ramachandran A, Jayashree R, Viswanathan M. C-peptide responses to glucose load in maturity-onset diabetes of the young (MODY). *Diabetes Care* 1985;8:69-72.
- Mohan V, Mohan R, Susheela L, Snehalatha C, Bharani G, Mahajan VK, *et al*. Tropical pancreatic diabetes in South India: Heterogeneity in clinical and biochemical profile. *Diabetologia* 1985;28:229-32.
- Mohan V, Snehalatha C, Ramachandran A, Jayashree R, Viswanathan M. Pancreatic beta-cell function in tropical pancreatic diabetes. *Metabolism* 1983;32:1091-2.
- Mohan V, Ramachandran A, Vijay Kumar G, Snehalatha C, Viswanathan M. Insulin resistance in fibrocalculous (tropical) pancreatic diabetes. *Horm Metab Res* 1988;20:746-8.
- Mohan V, Snehalatha C, Ahmed MR, Madanagopalan N, Chari S, Jayanthi V, *et al*. Exocrine pancreatic function in tropical fibrocalculous pancreatic diabetes. *Diabetes Care* 1989;12:145-7.
- Mohan V, Chari ST, Hitman GA, Suresh S, Madanagopalan N, Ramachandran A, *et al*. Familial aggregation in tropical fibrocalculous pancreatic diabetes. *Pancreas* 1989;4:690-3.
- Mohan V, Snehalatha C, Chari ST, Bhattacharyya PK, Madanagopalan N, Viswanathan M, *et al*. Clinical and biochemical studies in the prediabetic phase of tropical calcific pancreatitis. *Pancreas* 1992;7:109-13.
- Mohan V, Premalatha G, Padma A, Chari ST, Pitchumoni CS. Fibrocalculous pancreatic diabetes. Long-term survival analysis. *Diabetes Care* 1996;19:1274-8.
- Pradeepa R, Prabu AV, Jebarani S, Subhashini S, Mohan V. Use of a large diabetes electronic medical record system in India: Clinical and research applications. *J Diabetes Sci Technol* 2011;5:543-52.
- Mohan V, Vijayaprabha R, Rema M. Vascular complications in long-term South Indian NIDDM of over 25 years' duration. *Diabetes Res Clin Pract* 1996;31:133-40.
- Mohan V, Shanthi Rani CS, Amutha A, Dhulipala S, Anjana RM, Parathasarathy B, *et al*. Clinical profile of long-term survivors and nonsurvivors with type 2 diabetes. *Diabetes Care* 2013;36:2190-7.
- Anjana RM, Shanthirani CS, Unnikrishnan R, Mugilan P, Amutha A, Nair HD, *et al*. Regularity of follow-up, glycemic burden, and risk of microvascular complications in patients with type 2 diabetes: A 9-year follow-up study. *Acta Diabetol* 2015;52:601-9.
- Shanthi Rani CS, Rema M, Deepa R, Deepa R, Premalatha G, Ravikumar R, *et al*. The Chennai urban population study (CUPS) – Methodological details – (CUPS Paper No. 1). *Int J Diabetes Dev Ctries* 1999;19:149-57.
- Mohan V, Shanthirani S, Deepa R, Premalatha G, Sastry NG, Saroja R, *et al*. Intra-urban differences in the prevalence of the metabolic syndrome in southern India – The Chennai urban population study (CUPS no 4). *Diabet Med* 2001;18:280-7.
- Mohan V, Shanthirani CS, Deepa M, Datta M, Williams OD, Deepa R, *et al*. Community empowerment – A successful model for prevention of non-communicable diseases in India – The Chennai urban population study (CUPS-17). *J Assoc Physicians India* 2006;54:858-62.
- Mohan V, Gokulakrishnan K, Deepa R, Shanthirani CS, Datta M. Association of physical inactivity with components of metabolic syndrome and coronary artery disease – the Chennai urban population study (CUPS no 15). *Diabet Med* 2005;22:1206-11.
- Ravikumar R, Deepa R, Shanthirani C, Mohan V. Comparison of carotid intima-media thickness, arterial stiffness, and brachial artery flow mediated dilatation in diabetic and nondiabetic subjects (The Chennai urban population study [CUPS-9]). *Am J Cardiol* 2002;90:702-7.
- Mohan V, Deepa R, Rani SS, Premalatha G; Chennai Urban Population Study (CUPS No. 5). Prevalence of coronary artery disease and its relationship to lipids in a selected population in South India: The Chennai urban population study (CUPS no 5). *J Am Coll Cardiol* 2001;38:682-7.
- Mohan V, Ravikumar R, Shanthi Rani S, Deepa R. Intimal medial thickness of the carotid artery in South Indian diabetic and non-diabetic subjects: The Chennai urban population study (CUPS). *Diabetologia* 2000;43:494-9.
- Deepa M, Pradeepa R, Rema M, Anjana Mohan, Deepa R, Shanthirani S, *et al*. The Chennai urban rural epidemiology study (CURES) – Study design and methodology (Urban Component) (CURES 1). *J Assoc Physicians India* 2003;51:862-70.
- Mohan V, Deepa M, Deepa R, Shanthirani CS, Farooq S, Ganesan A, *et al*. Secular trends in the prevalence of diabetes and impaired glucose tolerance in urban South India – The Chennai urban rural epidemiology study (CURES-17). *Diabetologia* 2006;49:1175-8.
- Rema M, Premkumar S, Anitha B, Deepa R, Pradeepa R, Mohan V, *et al*. Prevalence of diabetic retinopathy in urban India: The Chennai urban rural epidemiology study (CURES) eye study, I. *Invest Ophthalmol Vis Sci* 2005;46:2328-33.
- Unnikrishnan RI, Rema M, Pradeepa R, Deepa M, Shanthirani CS,

Mohan: My 40 year diabetes research journey

- Deepa R, *et al*. Prevalence and risk factors of diabetic nephropathy in an urban South Indian population: The Chennai urban rural epidemiology study (CURES 45). *Diabetes Care* 2007;30:2019-24.
33. Pradeepa R, Rema M, Vignesh J, Deepa M, Deepa R, Mohan V, *et al*. Prevalence and risk factors for diabetic neuropathy in an urban South Indian population: The Chennai urban rural epidemiology study (CURES-55). *Diabet Med* 2008;25:407-12.
 34. Anjana RM, Ali MK, Pradeepa R, Deepa M, Datta M, Unnikrishnan R, *et al*. The need for obtaining accurate nationwide estimates of diabetes prevalence in India – Rationale for a national study on diabetes. *Indian J Med Res* 2011;133:369-80.
 35. Anjana RM, Pradeepa R, Deepa M, Datta M, Sudha V, Unnikrishnan R, *et al*. The Indian council of medical research-India diabetes (ICMR-INDIAB) study: Methodological details. *J Diabetes Sci Technol* 2011;5:906-14.
 36. Anjana RM, Deepa M, Pradeepa R, Mahanta J, Narain K, Das HK, *et al*. Prevalence of diabetes and prediabetes in 15 states of India: Results from the ICMR-INDIAB population-based cross-sectional study. *Lancet Diabetes Endocrinol* 2017;5:585-96.
 37. Anjana RM, Pradeepa R, Deepa M, Datta M, Sudha V, Unnikrishnan R, *et al*. Prevalence of diabetes and prediabetes (impaired fasting glucose and/or impaired glucose tolerance) in urban and rural India: Phase I results of the Indian council of medical research-INDIA DIABetes (ICMR-INDIAB) study. *Diabetologia* 2011;54:3022-7.
 38. Anjana RM, Pradeepa R, Das AK, Deepa M, Bhansali A, Joshi SR, *et al*. Physical activity and inactivity patterns in India – Results from the ICMR-INDIAB study (Phase-1) [ICMR-INDIAB-5]. *Int J Behav Nutr Phys Act* 2014;11:26.
 39. Bhansali A, Dhandania VK, Deepa M, Anjana RM, Joshi SR, Joshi PP, *et al*. Prevalence of and risk factors for hypertension in urban and rural India: The ICMR-INDIAB study. *J Hum Hypertens* 2015;29:204-9.
 40. Joshi SR, Anjana RM, Deepa M, Pradeepa R, Bhansali A, Dhandania VK, *et al*. Prevalence of dyslipidemia in urban and rural India: The ICMR-INDIAB study. *PLoS One* 2014;9:e96808.
 41. Unnikrishnan R, Anjana RM, Deepa M, Pradeepa R, Joshi SR, Bhansali A, *et al*. Glycemic control among individuals with self-reported diabetes in India – The ICMR-INDIAB study. *Diabetes Technol Ther* 2014;16:596-603.
 42. Mohan V, Williams OD, Chella S, Unnikrishnan R, Anjana RM, Vidyasagar S, *et al*. Clinical research training and capacity building for prevention and control of non communicable diseases: A programme in India. *Natl Med J India* 2018.[In Press].
 43. Ali MK, Narayan KM, Mohan V. Innovative research for equitable diabetes care in India. *Diabetes Res Clin Pract* 2009;86:155-67.
 44. Weber MB, Ranjani H, Staimetz LR, Anjana RM, Ali MK, Narayan KM, *et al*. The stepwise approach to diabetes prevention: Results from the D-CLIP randomized controlled trial. *Diabetes Care* 2016;39:1760-7.
 45. Nair M, Ali MK, Ajay VS, Shivashankar R, Mohan V, Pradeepa R, *et al*. CARRS surveillance study: Design and methods to assess burdens from multiple perspectives. *BMC Public Health* 2012;12:701.
 46. Kowalski AJ, Poongothai S, Chwastiak L, Hutcheson M, Tandon N, Khadgawat R, *et al*. The INtegrating DEPrEssioN and diabetes treatmENT (INDEPENDENT) study: Design and methods to address mental healthcare gaps in India. *Contemp Clin Trials* 2017;60:113-24.
 47. DREAM Trial Investigators, Bosch J, Yusuf S, Gerstein HC, Pogue J, Sheridan P, *et al*. Effect of ramipril on the incidence of diabetes. *N Engl J Med* 2006;355:1551-62.
 48. Indian Polycap Study (TIPS), Yusuf S, Pais P, Afzal R, Xavier D, Teo K, *et al*. Effects of a polypill (Polycap) on risk factors in middle-aged individuals without cardiovascular disease (TIPS): A phase II, double-blind, randomised trial. *Lancet* 2009;373:1341-51.
 49. Dehghan M, Mentz A, Zhang X, Swaminathan S, Li W, Mohan V, *et al*. Associations of fats and carbohydrate intake with cardiovascular disease and mortality in 18 countries from five continents (PURE): A prospective cohort study. *Lancet* 2017;390:2050-62.
 50. Kumar S, Mohanraj R, Sudha V, Wedick NM, Malik V, Hu FB, *et al*. Perceptions about varieties of brown rice: A qualitative study from Southern India. *J Am Diet Assoc* 2011;111:1517-22.
 51. Wedick NM, Sudha V, Spiegelman D, Bai MR, Malik VS, Venkatachalam SS, *et al*. Study design and methods for a randomized crossover trial substituting brown rice for white rice on diabetes risk factors in India. *Int J Food Sci Nutr* 2015;66:797-804.
 52. Mohan V, Anjana RM, Gayathri R, Ramya Bai M, Lakshmi Priya N, Ruchi V, *et al*. Glycemic index of a novel high-fiber white rice variety developed in India – A randomized control trial study. *Diabetes Technol Ther* 2016;18:164-70.
 53. Mohan V, Deepa M, Pradeepa R, Prathiba V, Datta M, Sethuraman R, *et al*. Prevention of diabetes in rural India with a telemedicine intervention. *J Diabetes Sci Technol* 2012;6:1355-64.
 54. Patel V, Chatterji S, Chisholm D, Ebrahim S, Gopalakrishna G, Mathers C, *et al*. Chronic diseases and injuries in India. *Lancet* 2011;377:413-28.
 55. Mohan V, Radha V, Nguyen TT, Stawiski EW, Pahuja KB, Goldstein LD, *et al*. Comprehensive genomic analysis identifies pathogenic variants in maturity-onset diabetes of the young (MODY) patients in South India. *BMC Med Genet* 2018;19:22.
 56. Bhavadharini B, Anjana RM, Mahalakshmi MM, Maheswari K, Kayal A, Unnikrishnan R, *et al*. Glucose tolerance status of Asian Indian women with gestational diabetes at 6 weeks to 1 year postpartum (WINGS-7). *Diabetes Res Clin Pract* 2016;117:22-7.
 57. Uma R, Bhavadharini B, Ranjani H, Mahalakshmi MM, Anjana RM, Unnikrishnan R, *et al*. Pregnancy outcome of gestational diabetes mellitus using a structured model of care: WINGS project (WINGS-10). *J Obstet Gynaecol Res* 2017;43:468-75.
 58. Henry CJ, Lightowler HJ, Newens K, Sudha V, Radhika G, Sathya RM, *et al*. Glycaemic index of common foods tested in the UK and India. *Br J Nutr* 2008;99:840-5.

APPENDIX

Appendix 1: Indian Council of Medical Research – India Diabetes [ICMR-INDIAB] study

Expert group

1. Dr. L. M. Nath, Consultant in Community Medicine, New Delhi
2. Dr. R. C. Mahajan, Postgraduate Institute Medical Research, Chandigarh
3. Dr. Ashok Kumar Das, Pondicherry Institute of Medical Sciences, Puducherry
4. Dr. R. S. Dhaliwal, Dr. Tanvir Kaur, Dr. Soumya Swaminathan, Indian Council of Medical Research, New Delhi
5. Dr. J. Mahanta, Dr. Kanwar Narain, Regional Medical Research Centre, Dibrugarh, Assam
6. Dr. S. V. Madhu, University College of Medical Sciences and GTB Hospital, New Delhi
7. Dr. P. V. Rao, Diabetes Research Society, Hyderabad, Andhra Pradesh
8. Dr. Arvind. Pandey, National Institute of Medical Statistics, New Delhi
9. Prof. K. Ramachandran, All India Institute of Medical Sciences, New Delhi
10. Dr. M. D. Gupte, National Institute of Epidemiology, Chennai
11. Dr. R Lakshmy, All India Institute of Medical Sciences, New Delhi.

State principal investigators – Indian Council of Medical Research – India Diabetes study (In alphabetical order of states)

Completed states:

1. Dr. P.V. Rao, Diabetes Research Society, Hyderabad, Andhra Pradesh
2. Dr. L. Jampa, Directorate of Health Services, Naharlagun, Arunachal Pradesh
3. Dr. H.K. Das, Regional Medical Research Centre, Dibrugarh, Assam
4. Dr. Ajay Kumar, Diabetes Care and Research Centre, Patna, Bihar
5. Dr. Banshi Saboo, Dia Care—Diabetes Care and Hormone Clinic, Ahmedabad, Gujarat
6. Dr. V.K. Dhandhanian, Diabetes Care, Centre, Ranchi, Jharkhand
7. Dr. Prabha Adhikari, Kasturba Medical College, Mangalore, Karnataka
8. Dr. Sunil M Jain, Totall Diabetes Hormone Institute, Indore, Madhya Pradesh
9. Dr. Shashank R Joshi, Lilavathi Hospital, Mumbai, Maharashtra
10. Dr. Prashant P. Joshi, Indira Gandhi Government Medical College, Nagpur Maharashtra
11. Dr. C.S. Yajnik, King Edward Memorial Hospital & Research Centre, Pune, Maharashtra
12. Dr. Somorjit Ningombam, Directorate of Health Services, Imphal, Manipur
13. Dr. R.O. Budnah, Directorate of Health Services, Shillong, Meghalaya
14. Dr. Rosangluaia, Civil Hospital, Aizawl, Mizoram
15. Dr. Vizolie Suokhrie, Directorate of Health Services, Govt. of Nagaland, Nagaland
16. Dr. Nikhil Tandon, All India Institute of Medical Sciences, New Delhi
17. Dr. Anil Bhansali, Postgraduate Institute of Medical Education and Research, Punjab & Chandigarh
18. Dr. Arvind Gupta, Jaipur Diabetes Research Centre, Jaipur, Rajasthan
19. Dr. Jigme Karma Tobgay, Health Services, Govt. of Sikkim, Sikkim
20. Dr. Tarana Reang, Agartala Government Medical College, Agartala, Tripur
21. Dr. Sarita Bajaj, MLN Medical College, Allahabad, Uttar Pradesh

Currently ongoing states:

1. Dr. Ankush Desai, Goa Medical College, Goa
2. Dr. P. K. Jabbar, Government Medical College, Trivandrum, Kerala
3. Dr. Anil Purty, Pondicherry Institute of Medical Sciences, Puducherry

States to be completed:

1. Chhattisgarh
2. Haryana
3. Himachal Pradesh
4. Jammu and Kashmir
5. Odisha
6. Uttarakhand
7. West Bengal.