TCF7L2 and diabetes – A transcription gene with prescription hope?

M. Balasubramanyam

There is a growing feeling in the biomedical community that the efforts of geneticists to identify the specific genetic variants underlying polygenic diseases such as type-2 diabetes have been less successful than had been promised. Genetic susceptibility to the common form of type-2 diabetes involves a number of variants, each with a modest effect on the risk of disease in an individual person. The genetic web of type-2 diabetes is particularly tangled. Despite important advances in understanding the genetic determinants of the relatively rare monogenic forms of diabetes, the pace of definitive identification of genes that increase the risk of common type-2 diabetes has been slow.

However, slow does not mean an end to the efforts. This was reflected in the recent identification of a common allele in the transcription factor 7-like 2 (TCF7L2) gene that increases the risk of type-2 diabetes. The risk of diabetes among carriers of a single copy of the risk allele is increased by a factor of 1.45, and among carriers of two risk alleles, by an impressive factor of 2.41. This is the largest odds ratio that we are aware of for a gene associated with susceptibility to type-2 diabetes. Florez et al. studied participants in the Diabetes Prevention Program (DPP) and examined whether the TCF7L2 genotype (variants rs12255372 and rs7901146) influences the risk of progression from impaired glucose tolerance to diabetes over a three-year period. They found that participants who were homozygous for the high-risk allele had 55% greater rate of conversion from impaired glucose tolerance to diabetes over a three-year period than those who were homozygous for the low-risk alleles. Wang et al. also observed that variants of the TCF7L2 gene predicted conversion to type-2 diabetes in the Finnish Diabetes Prevention Study.

TCF7L2, also known as TCF-4, is a nuclear receptor for β-catenin, which in turn mediates the canonical WNT (Wingless-type MMTV integration site family) signalling pathway (Figure 1). The WNT signalling pathway is critical for normal embryogenesis, cell proliferation and motility, as well as cell fate determination. While a role of WNT signalling in myogenesis and adipogenesis is also known, a tightly regulated WNT signalling is required for normal development of the pancreas and islets during embryonic growth. Little is known about the physiological implication of TCF7L2 in glucose homeostasis. It has been suggested that intestinal proglucagon gene expression may be regulated by the WNT/TCF7L2 pathway in enterendocrine cells. Thus, TCF7L2 variants may modify type-2 diabetes susceptibility through alterations in glucagon-like peptide-1 (GLP-1) that is linked to physiological insulin secretion. A putative role for TCF7L2 in β-cell differentiation was also suggested by the strong correlation between neurogenin-3 (NGN-3, an upstream marker of differentiation) and TCF7L2 expression during the early stages of rat pancreas development. In this regard, attenuated WNT signalling is expected to restrict pancreatic growth.

Although TCF7L2 seems to be a diabetes-associated gene in which common polymorphisms primarily affect the β-cell, it might have a role in insulin resistance. Interestingly, TCF7L2 is highly expressed in most human tissues, including pancreatic β-cells and adipocytes, with the exception of low mRNA expression in skeletal muscle. This suggests that the common polymorphisms of TCF7L2 might influence skeletal muscle insulin sensitivity via indirect pathways. Since TCF7L2 is highly expressed in adipose tissue, the relationship between polymorphisms of TCF7L2 and insulin resistance could be mediated through altered endocrine function of adipocytes, which needs to be addressed in tissue-specific investigations. In subcutaneous and omental fat from obese, type-2 diabetic subjects, TCF7L2 expression was significantly decreased compared with obese normoglycaemic individuals. One intriguing observation reported across several studies is that in cases (but not controls), the type-2 diabetes susceptibility variants in TCF7L2 were associated with reduced body mass index (BMI). As suggested by Zeggini and McCarthy, this may reflect an ascertainment effect, i.e. reduction in β-cell function is so pronounced that carriers tend to develop type-2 diabetes at a lower BMI than otherwise. If it is true that TCF7L2 polymorphism carriers develop diabetes at lower levels of BMI, the functional consequences of TCF7L2 variants may have a potential impact on Asian Indians who are thin (low BMI) but have higher adiposity (percentage body fat), and are more centrally obese. It is plausible that a potentially increased WNT signalling in carriers of the TCF7L2 risk variants could be expected to influence adipose tissue growth and development, and thus BMI. While studying the elderly population, Mezger et al. have observed that patients with diabetes carrying TCF7L2 variants are less likely to have metabolic syndrome features, but may be at a higher risk from more microvascular complications, including renal impairment and (vascular) dementia. Thus, TCF7L2 studies continue to pose problems in its physiological and pathological roles.

Since the initial report in early 2006, we have now more than 20 robustly reproducible studies to indicate that TCF7L2 might be a strong candidate for conferring susceptibility to type-2 diabetes across different ethnicities. The speed of confirmation and reproducibility of the findings with TCF7L2 has certainly been unprecedented. Unlike TCF7L2, the other two type-2 diabetes susceptibility variants, notably the PPARγ and E23K in KCNJ11, have only modest effects on disease risk (odds ratios ~1.2), far too small to offer (either individually or in combination) clinically useful predictive testing. Since these variants lie within genes whose products are already known to be therapeutic targets, genetic studies with PPARγ and KCNJ11 have also had limited capacity to deliver novel pathophysiological insights. The paradoxical link of TCF7L2 with diabetes suggests that many more type-2 diabetes susceptibility variants with large effect sizes do exist and can be revealed by genome-wide association mapping. TCF7L2 may not be the most attractive of drug targets, since it is closely involved in fundamental developmental processes. There is also skepticism in that the main effect of the high-risk single-nucleotide
polymorphisms in relation to diabetes may be developmental and may not be amenable to therapeutic manipulation in adult patients. Nevertheless, the pharmaceutical industry will be looking carefully at agents that modulate the signalling pathways of WNT/TCF7L2. Moreover, the critical role of TCF7L2 in glucose homeostasis points out the need for improved understanding of the role played by WNT signalling in metabolic processes, and exploration of the possibilities for novel therapeutic modalities.

How might current findings on TCF7L2 benefit patients? The good news from the study of Florez et al. is that you can overcome your genetic risk, at least when it comes to this particular gene. People with two copies of the variation who lost weight and exercised (moderately for 30 min a day at least five times a week) reduced their increased risk of type-2 diabetes to 15%, compared to 80% for those on a placebo. This finding emphasizes that people at risk of diabetes, whether they are overweight, have elevated blood glucose levels, or have this particular genetic variant, can benefit greatly by implementing a healthy lifestyle. Here, it is worth noting that current public health recommendations for physical activity are for 30 min of moderate-intensity activity/day, which provides substantial benefits across a broad range of health outcomes for sedentary adults. Therefore, TCF7L2 might qualify to be called as a ‘lifestyle-friendly’ gene.

Will this transcription gene imply a prescription hope? Together with deCODE diagnostics, DNA Direct is now offering deCODE T2, a genetic test that examines the presence of the ‘T’ allele of SNP rs7903146, located within the TCF7L2 gene. deCODE T2 is the first of several DNA-based predisposition tests that are being developed for common diseases. According to deCODE, it is believed that as individuals, doctors and healthcare providers begin to integrate these tests as a part of healthcare, these tests may provide major benefit to public health. Given that type-2 diabetes is a multifactorial disease caused by many different genetic and lifestyle factors, having one genetic test done on one specific gene variant may not tell much about one’s risk for the disease. If the test is positive, one’s risk of developing type-2 diabetes is twice as high as someone who does not have two copies of the TCF7L2 gene variant. However, the cumulative risk still depends on other risk factors such as weight, lifestyle habits, diet and other genetic variants. In other words, one should not be deduced into thinking to be free of risk if the test is negative.
Genetic testing to pre-determine disease risk and the design of preventative therapeutic regimens, will have a place in future medical care. Although TCF7L2 variants do have predictive value beyond other measurements that can also foretell diabetes, further studies are needed to determine whether a routine genetic test would drastically improve the results that are achieved using current treatments, or if developing and administering such a test would be cost-effective. The indication that the deCODE T2 genetic test will cost several hundreds US dollars, is certainly a profound limitation. Nevertheless, future predictive testing might include testing a battery of common genetic variants, followed by computational joint assessment of traditional, environmental and lifestyle risk factors, which may assist physicians and patients in choosing a preventive strategy. Recent theoretical studies have emphasized that as few as 20 susceptibility variants on the scale of those in TCF7L2, PPARγ and KCNJ11 may suffice to explain as much as 50% of the burden of the disease.13,14 If personalized medicine is to be realized in the future for complex diseases, such models will be required. However, the question still remains - what will it cost and whether 'gene-prescription' knowledge of the possibility of developing a particular disease be enough to motivate some patients to modify that risk? More than genetic testing, for developing countries like India, TCF7L2 studies send a clear message - 'lifestyle modifications to prevent diabetes' - the same philosophical teachings of our ancient saints, now with a flavour of molecular evidence in the post-genomic era.


M. Balasubramanyam is in the Madras Diabetes Research Foundation, 4 Conran Smith Road, Gopalaparam, Chennai 600 086, India.
E-mail: drbalu@mdrc.org

---

**MEETINGS/SYMMOSIA/SEMINARS**

**National Seminar on Recent Advances in Thin Film Technology**

Date: 26–27 October 2007  
Place: Gwalior

Topics include: Various types and kinds of thin films: Opto-electronic thin films, Magnetic thin films, Smart thin films, Transparent conducting coatings, Carbon-related thin films and nanostructured thin films; Growth of thin films: Chemical methods, vacuum deposition, spluttering, laser ablation, ion implantations; Thin film characterization techniques: Surface, elemental, structural and electrical; Application on thin films in devices solar cells, detectors, sensors, VLSI, nanoscale devices (quantum dots, carbon nanotubes).

Contact: Dr Y. C. Goswami  
Coordinator, National Seminar  
Institute of Technology & Management  
ITM Campus, Opp. Sithouli Railway Station  
NH 75, Jhansi Road, Sithouli  
Gwalior 474 001  
Phone: 0751-2432977-216, 244005  
Fax: 0751-2432988  
Mobile: 94251 21044  
E-mail: itmpysics@yahoo.co.in  
Website: www.itmuniverse.org

---

**First Annual Meeting of The Cytometry Society**

17–19 December 2007

**8th Indo-US Cytometry Workshop: Clinical Applications of Flow Cytometry**

19–22 December 2007

The workshop will teach the fundamentals of flow cytometry for beginners and give special emphasis for its use in diagnosis and management of various clinical conditions like leukemias, lymphomas, idiopathic thrombocytopenic purpura, pre-transplant cross match, analysis of fluids in solid tumors, apoptosis, etc.

Contact: Workshop/Conference Secretariat  
Department of Immunology  
Sanjay Gandhi Postgraduate Institute of Medical Sciences  
Raebareli Road  
Lucknow 226 014  
Phone: 91-522-2668700/800/900 Ext 2284  
E-mail: cytometry2007@sgpgi.ac.in  
Website: www.cytometry2007.com

---

**CURRENT SCIENCE, VOL. 93, NO. 5, 10 SEPTEMBER 2007**