Ana Johnson
and
Thérèse Stukel
Medical Practice Variations
Health Services Research
10.1007/978-1-4899-7573-7_85-1

# Medical Practice Variations in Diabetes Mellitus

John-Michael Gamble[1] and Sonia Butalia[2]
(1)School of Pharmacy, Memorial University of Newfoundland, 300 Prince Philip Drive, A1B 3V6 St. John's, NL, Canada

(2)Division of Endocrinology, University of Calgary, Alberta Health Services – Calgary Zone, T2N 1N4 Calgary, AB, Canada

**John-Michael Gamble (Corresponding author)**
**Email:** jgamble@mun.ca

**Sonia Butalia**
**Email:** sbutalia@ucalgary.ca

## Abstract

Diabetes mellitus is a serious chronic health condition that has a global impact on both individuals and healthcare systems. In 2013, approximately 382 million people worldwide were living with diabetes, and it is expected that over 590 million people (~10 % of the world's population) will be living with diabetes by 2035. Most recently, an estimated US$548 billion were spent globally on diabetes care. Beyond the enormous financial burden of diabetes, individuals living with diabetes are prone to numerous health risks and complications. Diabetes not only reduces an individual's life expectancy but also increases the risk of heart disease, kidney disease, eye disease, limb amputations, and other complications. There are cost-effective treatment approaches to help reduce the risk of these devastating complications; however, the uptake of these evidence-based treatments is not consistent across geographic regions. In this chapter, medical practice variation is reviewed within the context of access to and provision of high-quality diabetes care. This chapter briefly reviews the therapeutics of diabetes, including the epidemiology, diagnosis, pathogenesis, and management of diabetes. The bulk of the chapter then focuses on describing the current state of medical practice variation research in diabetes, and the systematic interventions have been put in place to increase the quality of care and potentially reduce unwarranted practice variation.

## Introduction

Despite the availability of several evidence-based interventions, where you live still matters, especially concerning access to and provision of high-quality diabetes care. This geographical disparity in diabetes care has been described in the literature since the 1970s and continues to be documented today. Stemming from the poor prognosis of individuals with diabetes compared to those

without and the care gaps between best practice and actual practice, organizations started developing quality indicators throughout the 1990s to measure the level of diabetes care being provided. Although the use of these indicators is highly variable across geographic regions, today many regions do use these indicators or performance measures. Furthermore, the increasing accessibility of electronic health records is allowing for more sophisticated performance measures to be developed. Studies assessing medical practice variation in diabetes have primarily used these quality indicators or performance measures to map out geographical differences in quality of care.

This chapter aims to summarize the current state of the evidence surrounding medical practice variation in diabetes care and describe interventions that have been trialed to improve care and reduce variation. In order to study medical practice variation in the diabetes care milieu, it is necessary to first provide some background on diabetes itself and its therapeutic management.

# An Overview of Diabetes Mellitus

Diabetes mellitus (or diabetes) is a chronic metabolic disorder of hyperglycemia due to defective insulin action, defective insulin secretion, or both (Holleman *2013*; International Diabetes Federation *2014*). Diabetes as a condition is increasingly placing an enormous burden on both individuals and health systems across the world. In 1980, there were approximately 153 million people with diabetes worldwide, which consisted of approximately 77 million men (age-standardized prevalence 8.3 %) and 76 million women (age-standardized prevalence 7.5 %) (Danaei et al. *2011*). Almost three decades later, in 2008, there were approximately 347 million people with diabetes, which consisted of an estimated 173 million men (age-standardized prevalence 9.5 %) and 173 million women (age-standardized prevalence 9.2 %) (Danaei et al. *2011*). More recent estimates by the International Diabetes Federation suggest that approximately 382 million people had diabetes in 2013 and by 2035 over 550 million people will be living with diabetes (International Diabetes Federation *2013*). Although the number of people with diabetes is increasing in every country, the majority of this growth is from low- and middle-income countries. Even more concerning is that up to 50 % of those with diabetes are undiagnosed, representing about 175 million people globally (International Diabetes Federation *2013*).

Diabetes, irrespective of its etiology, is characterized by chronic high blood glucose or hyperglycemia. As a consequence of being exposed to prolonged periods of hyperglycemia, people with diabetes are susceptible to numerous complications. In fact, in economically developed countries, diabetes is the leading cause of kidney failure, adult blindness, and lower limb amputation (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*). Moreover, diabetes is also a major risk factor for cardiovascular disease with up to 80 % of people with diabetes dying from heart disease (Canadian Diabetes Association *2009*; Yusuf et al. *2004*). Consequently, diabetes increases the risk of disability, hospitalizations, and premature death (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*; Ohinmaa et al. *2004*). Furthermore, the financial costs of diabetes to individuals, the healthcare system, and society are enormous, with the total costs attributable to diabetes recently estimated at over US$548 billion (International Diabetes Federation *2013*). Others estimate that total costs will reach US$490 billion by 2030 (Zhang et al. *2010*). While many complications from diabetes can be prevented with optimal care, without question, the personal and societal costs of diabetes are best managed by preventing diabetes altogether.

As mentioned, diabetes itself is characterized by hyperglycemia, either stemming from an insulin deficiency or resistance to insulin action. A diagnosis of diabetes is based on measuring blood glucose and can be made using two of the following confirmatory laboratory tests on separate days: (1)

random plasma glucose ≥ 11.1 mmol/L and symptoms of diabetes, (2) fasting plasma glucose ≥ 7.0 mmol/L, (3) 2 h plasma glucose in a 75-g oral glucose tolerance test ≥ 11.1 mmol/L, and/or (4) glycosylated hemoglobin (HbA1c) ≥ 6.5 % (American Diabetes Association *2013*; Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*; Goldenberg et al. *2011*). Unless the diagnosis is clear on clinical grounds (e.g., a patient with a hyperglycemic crisis or classic symptoms of hyperglycemia and a random plasma glucose ≥ 11.1 mmol/L), a repeat diagnostic test is necessary (American Diabetes Association *2013*; Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*; Goldenberg et al. *2011*). The HbA1c test indirectly measures the average amount of blood glucose over an approximately 3-month time span. The above diagnostic cut points are based off of thresholds that are correlated with microvascular disease, primarily retinopathy (American Diabetes Association *2009*). Although hyperglycemia is diagnostic and a common characteristic among people with diabetes, the condition may be categorized based on its etiology. In general, diabetes may be categorized as type 1 diabetes, type 2 diabetes, gestational diabetes mellitus, or others.

## Type 1 Diabetes

Type 1 diabetes is caused by autoimmune destruction of the insulin-producing beta cells of the pancreas resulting in insulin deficiency (Borchers et al. *2010*; Rother *2007*). Type 1 diabetes was formerly known as “juvenile diabetes mellitus” because the majority of patients acquired the disease as children or adolescents (American Diabetes Association *2013*; Haller et al. *2005*). However, this terminology is no longer accurate as onset can occur at any age with approximately 25 % of persons with type 1 diabetes being diagnosed as adults (Haller et al. *2005*). In addition, although the majority of onset of type 1 diabetes occurs in children and adolescents, people of all ages are susceptible to the complications associated with type 1 diabetes. Once diagnosed, people with type 1 diabetes are dependent on insulin for their survival. It is estimated that up to 10 % of people with diabetes have type 1 diabetes (American Diabetes Association *2013*; Centers for Disease Control and Prevention *1997*).

The incidence of type 1 diabetes peaks in a bimodal distribution. The first peak is in early childhood between the ages of 4 and 6 years and the second is in puberty between the ages of 10 and 14 years (Felner et al. *2005*; The Diamond Project Group *2006*). The overall age-adjusted incidence is greatest in Finland at 40 per 100,000 per year and lowest in China and Venezuela at 0.1 per 100,000 per year (The Diamond Project Group *2006*). Rates in the USA and Canada are considered to be high with the age-adjusted incidence to be estimated between 17 and 25 per 100,000 per year in children and adolescents (The Diamond Project Group *2006*). Since the 1960s, it has been observed that the incidence of type 1 diabetes has been rising by 3–5 % per year (Borchers et al. *2010*; EURODIAB ACE Study Group *2000*; Forlenza and Rewers *2011*; Jarosz-Chobot et al. *2011*; Onkamo et al. *1999*; Patterson et al. *2009*; The Diamond Project Group *2006*). To date there is no known effective prevention strategy for type 1 diabetes (Skyler *2013*).

## Type 2 Diabetes

Type 2 diabetes primarily results from insulin resistance where the body cannot effectively use the insulin it produces (International Diabetes Federation *2005*; Rother *2007*). Type 2 diabetes has several known risk factors including age, family history, sedentary lifestyle, and being a member of high-risk population including people of the South Pacific Islands, Arab countries of the Middle East, and

aboriginal, Hispanic, South Asian, Asian, or African descent (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*; International Diabetes Federation *2013*). Type 2 diabetes may be managed by a combination of diet, lifestyle, oral medications, and/or insulin (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*). There are multiple known modifiable risk factors and preventive strategies that decrease the onset of type 2 diabetes (e.g., diet, exercise, weight loss, and medications) (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*; Knowler et al. *2002*).

Type 2 diabetes has in the past been thought to be a disease of adults, but more and more patients are being diagnosed at a younger age including children and adolescents (Amed et al. *2010*). Type 2 diabetes represents approximately 90 % of the diabetic population and therefore is the most common form of diabetes.

## Gestational Diabetes Mellitus and Other Types

Gestational diabetes mellitus (GDM) refers to the onset or recognition of glucose intolerance during pregnancy (Metzer *1991*). The prevalence of GDM varies in a given population or ethnic group and is estimated to range between 1.7 % and 11.6 % (Schneider et al. *2012*; Public Health Agency of Canada *2009*). GDM is often managed by diet and lifestyle; however, sometimes insulin and oral medications are required. GDM is on the rise with the prevalence of GDM increasing by 50 % over the last decade (Kaul et al. *2011*). It is important to note that GDM may represent undiagnosed or evolving type 1 diabetes or type 2 diabetes with onset or recognition during pregnancy. Furthermore, GDM is a known risk factor for diabetes whereby the cumulative risk of diabetes postpartum is up to 70 % (Kim et al. *2002*). Ultimately, the magnitude of risk depends on the population of study, diagnostic test used, and length of follow-up.

There are a wide variety of other relatively uncommon forms of diabetes. These forms of diabetes are specific genetic forms or associated with other diseases or medication use (American Diabetes Association *2013*).

## Consequences of Diabetes

As previously mentioned, the prolonged hyperglycemic state in individuals with diabetes is associated with an increased risk of morbidity and mortality. Diabetes-related complications are often described as either acute or chronic.

## Acute Complications

The “acute” or “short-term” metabolic complications of diabetes include diabetic ketoacidosis (DKA), hyperglycemic hyperosmolar state (HHS), and hypoglycemia. They are termed such as they develop quickly from a significant imbalance between blood glucose and hormone levels (Masharani and German *2007*). DKA, HHS, and hypoglycemia are medical emergencies that require prompt recognition and treatment. DKA is often the initial presentation of type 1 diabetes occurring in up to 70 % of incident cases (Fishbein and Palumbo *1995*; Usher-Smith et al. *2011*). DKA may also occur in patients with type 2 diabetes particularly of African American or Hispanic descent (Newton and Raskin *2004*; Nyenwe et al. *2007*).

The incidence of DKA is between 4.6 and 8 per 1,000 person-years among those with diabetes, whereas HHS is much less common with an estimated incidence of less than 1 per 1,000 person-years (Fishbein and Palumbo *1995*). Case fatality rates are between 1 % and 12 % for DKA and between 10 % and 50 % for HHS, with the highest rates observed in the extremes of age and those with concomitant illnesses (Chen et al. *2010*; Chiasson et al. *2003*; Efstathiou et al. *2002*; Fishbein and Palumbo *1995*; Hamblin et al. *1989*; Kitabchi et al. *2006*; Ko et al. *2005*; Lin et al. *2005*; Snorgaard et al. *1989*).

Hypoglycemia, or low blood sugar, is not a direct complication of diabetes; rather it is the result of a relative excess of insulin from either oral medications or insulin. Thus, hypoglycemia is a consequence of treatment. Hypoglycemia is a clinical syndrome characterized by signs and symptoms of low blood glucose, a low plasma glucose (often defined by a blood glucose of less than 4.0 mmol/L), and the relief of symptoms when plasma glucose is normalized (American Diabetes Association Workgroup on Hypoglycemia *2005*). Although there is not a universally accepted classification scheme for hypoglycemia, its severity is often characterized as severe when an individual's ability to self-treat their low blood glucose is compromised and they require assistance from another person (American Diabetes Association Workgroup on Hypoglycemia *2005*; Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*). The morbidity and mortality of hypoglycemia in patients with diabetes are considerable. Mortality as a potential consequence of hypoglycemia may occur in up to 10 % of deaths in people with type 1 diabetes (Feltbower et al. *2008*; Skrivarhaug et al. *2006*). The frequency of hypoglycemia varies by the definition used, study design, treatment, and modality of testing (Donnelly et al. *2005*; The Diabetes Control and Complications Trial Research Group *1993*).

## Chronic Complications

Diabetes affects many of the major organs of the body including the heart, blood vessels, eyes, nerves, and kidneys (American Diabetes Association *2013*). Complications to these organs are collectively known as the "chronic" or "long-term" complications of diabetes as they are the result of vascular injury which develops over many years (American Diabetes Association *2013*). Chronic complications include both microvascular disease (retinopathy, nephropathy, and neuropathy) and macrovascular disease (atherosclerosis). Diabetes is also a leading cause of nontraumatic amputation. Several randomized controlled trials have demonstrated the importance of glycemic control in the prevention and progression of chronic complications in diabetes (Lewis et al. *2001*; Parving et al. *2001*; The Diabetes Control and Complications Trial Research Group *1993*; UKPDS Study Group *1998a*, *b*). The landmark DCCT study examined the effect of glycemic control on microvascular chronic complications in patients with type 1 diabetes (The Diabetes Control and Complications Trial Research Group *1993*). At trial initiation with the mean hemoglobin A1c in the 8.8–9.0 % range, patients were randomized to receive either conventional insulin therapy (one to two insulin injections per day) or intensive insulin therapy (≥ three injections per day or the insulin pump). After mean follow-up of 6.5 years, the mean hemoglobin A1c in the intensive group was 7.2 % compared to 9.1 % in the conventional therapy group. In the intensive group, there was a relative risk reduction (RRR) of new onset retinopathy of 76 % (95 % confidence interval [CI], 62–85 %) and a 54 % RRR in the progression of retinopathy (95 % CI, 39–66 %) in those with previous eye disease. In addition, microalbuminuria, albuminuria, and clinical neuropathy were also reduced in the intensive insulin group. Unfortunately, the main adverse event associated with intensive therapy was a two- to threefold increase in severe hypoglycemia (The Diabetes Control and Complications Trial Research

Group *1993*). A follow-up study to the DCCT, the Epidemiology of Diabetes Interventions and Complications (EDIC) study, found that intensive insulin therapy also decreased the risk of any cardiovascular disease by 42 % (The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications (DCCT/EDIC) Study Research Group *2005*).
Another landmark trial of people with newly diagnosed type 2 diabetes, the UKPDS study, examined the effect of glycemic control on chronic complications. In the UKPDS-33, participants were randomized to conventional therapy (diet) or intensive therapy (sulfonylurea or insulin) (UKPDS Study Group *1998b*). After median follow-up of 10 years, there was a 25 % RRR in microvascular endpoints ( $p = 0.0099$) in the intensive therapy group compared to conventional therapy group. Patients in the intensive therapy group experienced more weight gain and hypoglycemia (UKPDS Study Group *1998b*). Despite convincing evidence from the UKPDS for intensive glucose lowering for microvascular complications, more recent trials have had mixed results, particularly when assessing macrovascular complications (Duckworth et al. *2009*; Gerstein et al. *2008*; Patel et al. *2008*). In fact, one trial showed an increased risk of mortality among patients with type 2 diabetes randomized to intensive glucose (Gerstein et al. *2008*), and others have not shown significant clinical benefit for macrovascular disease with intensive glycemic control versus less intensive glycemic control (Duckworth et al. *2009*; Patel et al. *2008*). Interestingly, a post-randomization follow-up analysis of the UKPDS study (UKPDS-80) reported statistically significant reductions in microvascular disease (relative risk reduction [RRR] 24 %; $p$-value = 0.001), myocardial infarction (RRR 15 %; $p$-value = 0.01), and all-cause mortality (RRR 13 %; $p = 0.0007$) in the intensive therapy group (Holman et al. *2008*). However, glycemic control is not the only factor that reduces complications in people with diabetes. As demonstrated in the Steno-2 study, targeting multiple risk factors in patients with diabetes significantly lowers cardiovascular disease and mortality (Gaede et al. *2003*, *2008*). Patients receiving intensified, multifactorial therapy (e.g., blood pressure, cholesterol, glycemic control) compared to conventional therapy had a 61 % lower risk of cardiovascular disease (hazard ratio [HR], 0.39; 95 % CI, 0.24–0.73). Intensive therapy was also associated with a lower risk of death from cardiovascular causes (HR, 0.43; 95 % CI 0.19–0.94) (Gaede et al. *2008*).

## Management of Diabetes

In general, the risk of complications associated with diabetes may be reduced through strategies aimed to achieve normal or near normal blood glucose and minimize individual modifiable cardiovascular risk factors such as hypertension, hyperlipidemia, obesity, and smoking. Non-pharmacologic and pharmacologic interventions are aimed to control these risk factors and ultimately reduce the incidence of diabetes-related complications. Several evidence-based guidelines are regularly updated to reflect the most current therapeutic knowledge (American Diabetes Association *2013*; Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*; Colagiuri et al. *2009*; Garber et al. *2013*; Guzman et al. *2010*; International Diabetes Federation *2005*; The Task Force on Cardiology et al. *2013*). An overview of the key components of diabetes management is provided below.

## Non-pharmacologic Management

Self-management education and support are essential for long-term treatment of diabetes. As diabetes is a chronic health condition that is largely managed by the individual living with diabetes, it is key that self-management techniques are taught early and reassessed on a regular basis. Upon diagnosis of

diabetes, a comprehensive self-management education program is essential for patients to understand the disease process and start to gain the skills necessary to look after themselves. Self-management education should be individualized based on a person's age, motivation, cognitive ability, and support system and include basic teaching on diabetes, how and how often to self-monitor bold glucose, how to recognize and treat episodes of low blood sugar (hypoglycemia), how to manage sick days, and how to monitor for complications (e.g., daily foot check). Certain motivated individuals may be taught to adjust their medication based on changes in diet and activity. Further, diabetes self-management education should include teaching on problem-solving and goal setting.

Nutritional and physical activity modifications are two essential components of a diabetes care plan and have both been shown to improve glycemic control (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*). All individuals with diabetes should work with a registered dietician to understand healthy eating choices and, most importantly, the connection to glycemic control. This is particularly important for those with type 1 diabetes as carbohydrate intake needs to correspond with the amount of insulin being used. Current guidelines recommend a diet that is individualized according to patient preferences and that consists of a balanced consumption of carbohydrates (no less than 45 % of daily caloric intake), protein (~15–20 % of daily caloric intake), and fats (no more than 35 % of daily caloric intake). Several, more specific, recommendations exist and are described elsewhere in detail (American Diabetes Association *2013*; Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*).

In addition to nutritional modifications, regular physical activity is an important aspect of diabetes management. Increased physical activity will help most individuals with diabetes by improving glucose control, improving cardiovascular risk factors, increasing quality of life, and reducing mortality by 30–70 % over a 15–20-year period (Chudyk and Petrella *2011*; Kodama et al. *2013*). North American guidelines specifically recommend, in the presence of no contraindications, at least 150 min per week of aerobic exercise done at 50–70 % of an individual's maximum heart rate and at least 2 days of resistance training using all major muscle groups (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*; Colberg et al. *2010*).

## Pharmacologic Management

Although nutritional and physical activity modifications are effective approaches to mitigating hyperglycemia, pharmacotherapy remains the primary modality of diabetes management. Drugs used in the management of diabetes include both injectable agents such as insulin and incretin mimetics and oral agents such as metformin, sulfonylureas, meglitinides, glitazones, and dipeptidyl peptidase-4 inhibitors, among others. The pharmacologic regimen is dependent on the type of diabetes, whether marked symptoms are present at diagnosis, and other patient and drug characteristics. Details regarding the current pharmacotherapeutic approaches for type 1 and type 2 diabetes are available elsewhere (American Diabetes Association *2013*; Brahm et al. *2011*; Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*).

Historically, diabetes management has focused on treating hyperglycemia. This "glucocentric" model is slowly being replaced by a multifactorial approach that focuses on controlling not only blood glucose but also other risk factors for diabetes-related complications such as hypertension and hyperlipidemia. Evidence for a multifactorial treatment approach is largely derived from randomized clinical trials that have demonstrated that treating cardiovascular risk factors such as high blood pressure and abnormal cholesterol reduces the risk of chronic diabetes-related complications (Gaede et al. *2003*, *2008*). Specific treatment recommendations for hypertension and hyperlipidemia in

patients with diabetes are available in contemporary clinical practice guidelines (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*).

Monitoring for treatment effectiveness and acute and chronic complications of diabetes is an essential component of a diabetes management plan. Ongoing assessment for the presence of chronic complications of cardiovascular risk factors (e.g., blood pressure, lipids, smoking status) and adherence to diet, lifestyle, and medications is an important of diabetes management. Current clinical practice guidelines have suggested specific targets for glucose level, blood pressure, cholesterol, and weight reduction, based on evidence generated from randomized clinical trials.

In summary, diabetes management involves participation of the individual with diabetes, the individual′s family, and healthcare professionals. Due to the potential life-threatening complications of diabetes that affect the heart, kidneys, nerves, skin, eyes, and extremities, it is crucial that a comprehensive management plan is in place. Diabetes management plans should be individualized and modified based on a person′s age, dietary and physical activity habits, social and cultural norms, school or work schedule, comorbidities, and the presence of diabetes-related complications. Coordinated care among multiple healthcare professionals, such as a family physician, nurse, pharmacist, social worker, dietician, podiatrist, have been shown to lead to better glucose control (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*). Furthermore, health system factors such as having adequate electronic medical record support and a structured reminder system for assessing treatment and complications may also enhance the quality of diabetes management.

# Describing Variation in Diabetes Care

Medical practice variation in diabetes is primarily concerned with the notion of where people live being a major determinant in their access to and quality of diabetes care. Much of the variation in care is unwarranted, meaning that such variations “cannot be explained by type or severity of illness or by patient preferences” (Wennberg *2002*, p. 964). Wennberg ( *2002*) classifies unwarranted variation into three types of care: (1) effective or evidence-based care, (2) preference-sensitive care, and (3) supply-sensitive care. This taxonomy is a useful framework when considering unwarranted variation because the categories differ according to their cause, consequence, and solution. Unwarranted variation in diabetes care primarily consists of effective or evidence-based care, meaning that the medical care or service provided is based upon robust scientific evidence. Indeed, in the field of diabetes, there are several landmark clinical studies such as the UKPDS trials (Holman et al. *2008*; UKPDS Study Group *1998a*, *b*), DCCT/EDIC studies (The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications (DCCT/EDIC) Study Research Group *2005*), and Steno trial (Gaede et al. *2003*, *2008*) on which clinicians base their decisions to provide many elements of diabetes care.

Despite this accumulation of evidence over the past several decades, there continues to be significant gaps between the type of comprehensive care supported by this evidence and actual care received in clinical practice (Ali et al. *2013*; Braga et al. *2010*; Radley and Schoen *2012*). Furthermore, regional variation in the uptake of evidence-based quality diabetes care has been well documented (Leese et al. *2011*; Otiniano and Wood *2012*). Although it is not always the case for all types of unwarranted variation, for evidence-based care the goal is to maximize the number of people receiving care. In other words, regional variation should be minimized and evidence-based care maximized. If follows that emulating best practice among those that demonstrate high levels of quality care should be encouraged.

In the remainder of this chapter, the current body of literature describing and analyzing medical practice variation is reviewed within the context of access to quality diabetes care. This discussion starts with reviewing quality indicators or performance measures that quantitatively describe what is generally accepted as quality diabetes care.

## Measuring Quality and Access to Diabetes Care

The Institute of Medicine (IOM) defines healthcare quality as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge" (Institute of Medicine *1990*), whereas the IOM defines access as "the timely use of personal health services to achieve the best possible health outcomes" (Institute of Medicine *1993*). Both access and quality are concerned with achieving optimal health outcomes and are complex constructs with multiple dimensions (Gulliford et al. *2002*). For example, access to care includes the provision of healthcare services such as screening for diabetes and diabetes-related complications, performing adequate monitoring using laboratory tests, ability to see a specialist if required, and adequate follow-up care in the community. Quality measures also include many of these elements, and thus, the constructs of "quality of care" and "access to care" are inherently linked. Quality and access to care are generally measured using several performance metrics or quality indicators. These quality indicators are usually categorized into either process or outcome measures, which follow Donabedian's taxonomy for classifying quality of care into three domains: structure, process, and outcome (Donabedian *2005*). Measuring the performance or quality of diabetes care began to expand beyond single organizations to include a concerted national effort in the 1990s whereby the Diabetes Quality Improvement Project (DQIP) in the USA was one of the first large-scale efforts put forth to define quality indicators to measure high-quality diabetes care (Fleming et al. *2001*). DQIP identified eight quality indicators based on predefined criteria that required each indicator to have sufficient scientific evidence, to be reproducible and feasible for implementation and measurement across health settings, and for variation to exist at a population level. Details in the development process of the DQIP quality indicators are available elsewhere (Fleming et al. *2001*). Most of the key organizations involved in many aspects of diabetes care (e.g., delivery, management, guideline development) had input into the development of the DQIP quality indicators; consequently, they have been adopted by many of the major healthcare organizations in the USA including the Centers for Medicare and Medicaid Services, the Veterans Health Administration, the National Committee for Quality Assurance (NCQA), and others. The first international-scale effort to develop quality indicators to be able to compare healthcare quality across countries was the Organization for Economic Co-operation and Development's (OECD) Health Care Quality Indicator (HCQI) Project in January 2003 (Mattke et al. *2006*).

Today there are several quality indicator sets that have been developed at the local, national, and international levels specifically to measure the quality of diabetes care being delivered. Most of the current quality indicator sets measure very similar processes and outcomes of care, as shown in Table 1. Differences among indicator sets often include slightly different thresholds for intermediate outcomes such as blood glucose (HbA1c) or blood pressure control. Some organizations such as the UK's National Institute for Health and Clinical Excellence also have a structural domain built into their quality standards framework (National Institute for Health and Clinical Excellence *2011*). All quality indicators stem from the body of evidence, which shows a reduction in diabetes complications when blood glucose, blood pressure, and low-density lipoprotein (LDL) cholesterol are well controlled. An important distinction between targets for quality indicators and those for clinical

practice is that the former is concerned with measuring the level of care across the population and the latter is concerned with measuring the level of care for an individual patient. This distinction is subtle but important, as quality indicators will not always match clinical guidelines. Ultimately, quality or performance indicators are reflective of the “quality” and “access” to care at a system or population level and are useful for measuring medical practice variation.**Table 1**

Common diabetes care quality indicators used to measure the performance of diabetes care

| **Processes of care** | **Intermediate (proximal) outcome measures** | **Distal or clinical outcome measures** |
|---|---|---|
| HbA1c testing | HbA1c control | Lower extremity amputations |
| LDL cholesterol testing | LDL cholesterol control | Kidney disease |
| Nephropathy screening | Blood pressure control | Cardiovascular mortality |
| Eye examination | | |
| Foot examination | | |
| Blood pressure measurement | | |
| Body mass index measurement | | |
| Smoking status recording | | |
| Influenza immunization | | |

Abbreviations: *HbA1c* hemoglobin A1c, *LDL* low-density lipoprotein

There are several inherent limitations with the current quality indicators. First, quality indicators are based on a process-outcome link, and if this link is weak, or in other words, if processes of care are not strongly correlated with outcomes of care, then the value of the quality indicator is questionable. Second, the current sets of quality indicators do not contain the level of detail that is often necessary to assess quality improvement interventions. There have been several quality indicators of diabetes care used in quality improvement studies. Bowker and colleagues identified 46 quality improvement studies that used various indicators to measure improvement in diabetes care (Bowker et al. *2005*). Overall, they found the majority of quality improvement studies reported indicators focusing on glycemic control, there was a lack of reporting of macrovascular and patient-reported outcomes (e.g., health-related quality of life), and there were many differences in the definitions of the same indicators. Following this work, Canadian researchers developed and validated a set of quality indicators using a consensus panel approach (Majumdar et al. *2005*). Beyond measuring quality of diabetes care using standardized metrics that would allow comparisons across regions, the panel also

aimed to define indicators that would track clinically meaningful changes over time and to define population-level benchmarks for each quality indicator. A third limitation is the use of dichotomous threshold-based design. There have been several proposed novel indicators which require more complex electronic medical record systems than are readily available across regions (O'Connor et al. *2011*).

Despite these limitations, studies exploring medical practice variation often use one or more of these diabetes quality indicators to measure variation. The current state of the evidence surrounding medical practice variation with respect to access to and quality of diabetes care is summarized in the following sections: (1) access and utilization of healthcare services, (2) process and intermediate (nonclinical) outcome measures, (3) treatment, (4) complications, and (5) mortality.

## Review of the Evidence: Access and Utilization of Healthcare Services

As mentioned above, the concept of access to care does not solely involve the availability of healthcare services but also includes the use of those services and any subsequent outcomes associated with those services. However, the purposes of summarizing the current evidence studies focusing on utilization of healthcare services will be discussed in this section and those relating to outcomes will be discussed under subsequent sections. Table 2 lists various medical practice variation studies that have analyzed access to care issues for individuals with diabetes.**Table 2**
Studies measuring variation in access to and utilization of healthcare services for patients with diabetes

| Source | Population studied | Geographical unit analyzed | Outcomes measured | Main results |
|---|---|---|---|---|
| Driskell et al. *2012* | 115,730 patients with HbA1c test requests in a university hospital, UK, 2001–2011 | Practice to practice variability among GP practices | Prevalence of over- and under-requesting of HbA1c testing | Prevalence of inappropriate requests varied ~six fold between general practices. The proportion of tests requested too soon (over-requesting) ranged from 6 % to 32 %. The proportion of tests requested too late (under-requesting) ranged from 9 % to 54 % |
| Zgibor et al. *2011* | 33,369 patients with type 2 diabetes who received education at seven diabetes centers in the USA, 2005– | Driving distance from home to diabetes center | Association between driving distance and glucose control | Residing more than 10 miles (16 km) from a diabetes center was associated with poor glucose control (A1C > 7 %): adjusted odds ratio = 1.91, $p <$ 0.0001. |

| | | | | |
|---|---|---|---|---|
| | 2007 | | | |
| Cook et al. *2010* | Surveys of hospitals, the USA | 269 hospitals in the USA | Presence of inpatient diabetes quality improvement program, protocol for glycemic conditions | Substantive variations in glucose targets, biochemical definitions of hypoglycemia, methods to track glucose among hospitals |
| Berkowitz et al. *2009* | US Medicare beneficiaries aged 65 years or older with diagnosis of CHF, COPD, and diabetes discharged from hospital, 2004 | Regions of the USA | Follow-up visit within four weeks of hospital discharge | There was little regional variation in follow-up visits, with ~90 % of patients seeing a clinician within 6 months after discharge |
| Strauss et al. *2006* | 973 patients with diabetes who attended primary care practices in the USA, 2003–2005 | Driving distance from home to site of primary care | Association between driving distance and glucose control | Longer driving distances were associated with poorer glucose control. For every 10 km, there was a 0.07 % change in A1C control (95 % CI 0.03–0.11) |
| Aro et al. *1996* | Patients with diabetes, 15–64 years old, Finland | 21 hospital districts of Finland | Hospital admissions, inpatient days, and mean length of stay due to diabetes | Large variations between hospital districts were observed in discharge rates due to diabetes and mean length of stay. Prevalence of diabetes and overall supply of hospital beds in the district were not related to hospital use. Access to a private practitioner and early onset of diabetes were associated with lower hospital use |
| Brown and Barnett *1992* | Patients with diabetes hospitalized in New Zealand, 1979–1986 | 27 hospital boards in New Zealand | Hospitalization rates per 10,000 | An area's bed supply (# of surgical, medical, and pediatric beds per 10,000) and level of tertiary |

| | | | | |
|---|---|---|---|---|
| | | | | education were the most important determinants of diabetes-related hospitalization |
| Connell et al. *1984* | US Medicaid and Medicare patients admitted to hospital in Washington, 1978–1979 | 106 hospitals | Hospitalization admission rates for diabetes | Substantial variation in admission rates for diabetes was explained by severity of initial illness. High-rate hospitals admitted more patients who were mildly ill versus low-rate hospitals. Low-rate hospitals admitted more severely ill patients versus high-rate hospitals. Coding errors or difference in sociodemographics among hospitals did not explain the variation in admission rates |

Abbreviations: *HbA1c* hemoglobin A1c, *UK* United Kingdom, *GP* general practitioner, *USA* United States of America, *CI* confidence interval

In general, people with diabetes compared to those without diabetes have been known to have higher healthcare utilization (Chan and Harju *2003*; Johnson et al. *2011*). In Alberta, Canada, people with diabetes visit their general practitioner twice as often and specialists three times as often as people without diabetes (Johnson et al. *2011*). In addition, each year adults with diabetes spent three times more days in hospital, and children and adolescents with diabetes spend greater than eight times more days in hospital than those without diabetes (Johnson et al. *2011*). In Alberta, despite a universal payer system, healthcare utilization varied among the five health region zones. This variation was observed for general practitioner visits, specialist visits, emergency department visits, and length of stay (Johnson et al. *2011*). In general, more populated urban zones had lower rates of general practitioner visits and emergency department encounters with higher rates of specialist visits, while less populated zones had lower specialist visits (Johnson et al. *2011*). This may be an example of supply-sensitive care, whereby urban areas have more supply of specialists. Other studies also suggest that variation in the utilization of specialist such as internal medicine and endocrinologist are related to supply (Fig. 1). Moreover, there is data from the 1980s in New Zealand that variation in diabetes-related hospitalizations is related to an area's bed supply and level of tertiary education (Brown and Barnett *1992*).

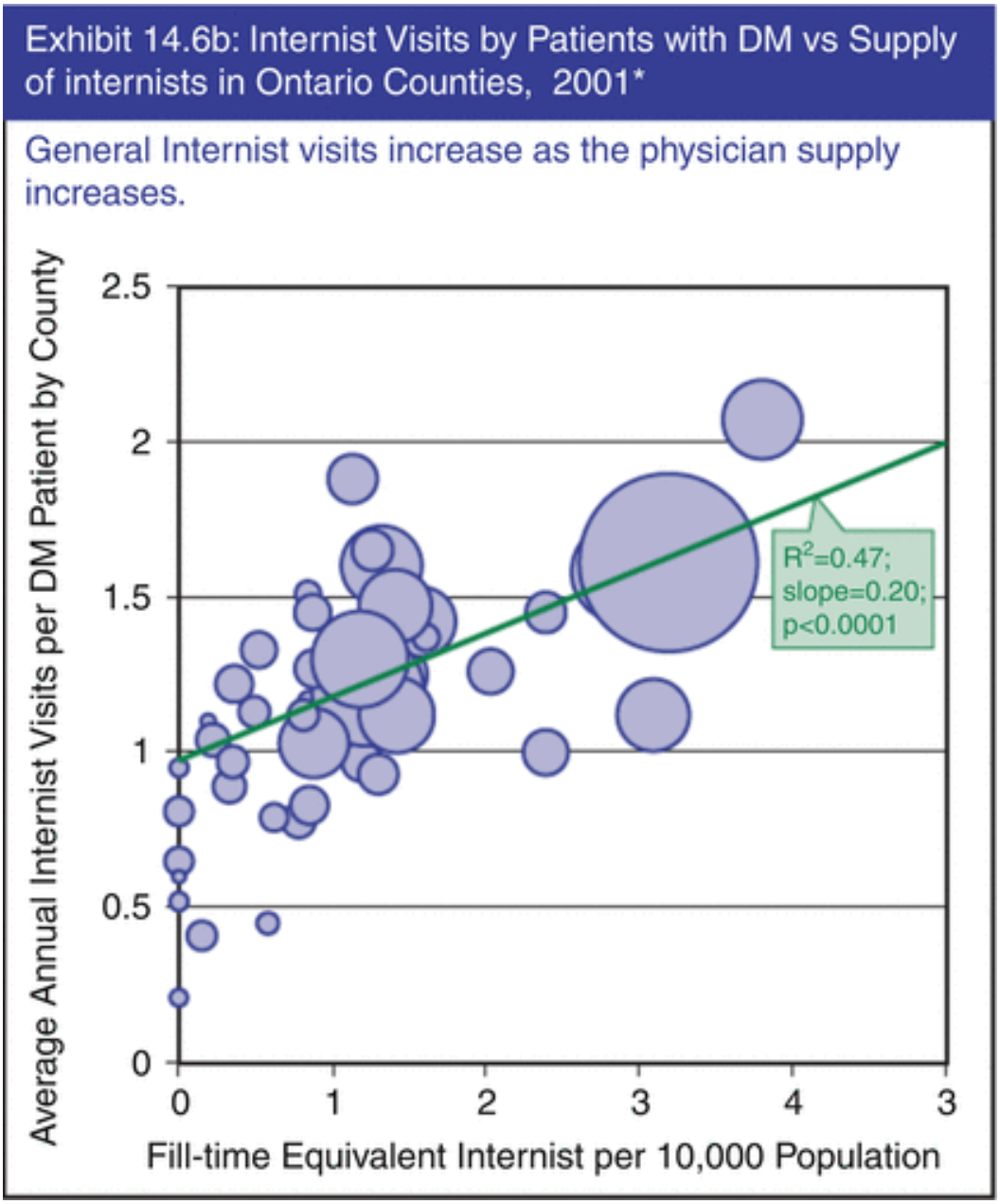


**Fig. 1**
Relationship between physician supply and number of patient care visits in patients with diabetes, Ontario, Canada, 2001 [ICES Diabetes Atlas, exhibit 14.6b]

Other indicators of inequities in access to care include variation in services and ease of travel to an individual's primary care site. Berkowitz and colleagues ( *2009*) examined 30-day follow-up visit frequencies following hospital discharge across hospital referral regions for US Medicare beneficiaries with diabetes, CHF, and COPD. They found that about 90 % of these patients had a follow-up visit within 30 days of hospital discharge and that about 90 % of patients were seen by a clinician every 6 months, with minimal variation between hospital referral regions (Berkowitz et al. *2009*). Multiple studies have found that those who drive further to obtain diabetes care have poorer glucose control as measured by HbA1c (Strauss et al. *2006*; Zgibor et al. *2011*). Strauss and colleagues ( *2006*) studied close to 1,000 outpatients with diabetes in Vermont, USA, and found that HbA1c was 0.07 % higher for every 10 km an individual lived from their primary care site. A stronger

association was observed in those using insulin (0.22 % change in HbA1c per 10 km). Similarly, Zgibor and colleagues ( *2011*) studied over 3,000 patients with type 2 diabetes and found that living more than 10 miles from a diabetes management center was associated with a poorer HbA1c, defined as >7 % (odd ratio 1.91, 95 % CI 1.59–2.30). These studies emphasize the importance of travel burden and poorer access for individuals living in a rural environment; however, travel burden may also impact those living in an urban environment. Researchers identified neighborhoods in Toronto, Canada, that potentially had barriers to accessing health resources by calculating a "health resource index" (Glazier et al. *2007*). This index was intended to measure access to health resources such as walking and cycling paths, parks and recreation centers, grocery stores with fresh vegetables and fruits, and family doctors. Poor access to health resources (lower health resource index) was associated with higher rates of diabetes.

## Review of the Evidence: Practice Variation in Processes and Intermediate Outcomes of Care

As previously mentioned, variation in quality of diabetes care is often measured using a number of common processes of care and outcome measures. Common processes of care measures include the percentage of individuals living with diabetes in a given geographic region with a record of having an HbA1c test, an LDL cholesterol test, a nephropathy screen, and an eye examination within the previous year. Common intermediate or nonclinical outcome measures include the percentage of individuals with diabetes that achieve certain HbA1c, blood pressure, and cholesterol thresholds. Table 3 summarizes a comprehensive list of studies that have evaluated practice variation in diabetes for both process of care and intermediate outcomes of care. There is a substantial amount of heterogeneity among studies in regard to the population studied, geographical unit analyzed, and outcomes measured. The majority of studies were based in the USA and measured variation between urban and rural residents or among large geographic regions across the USA. The most frequently studied outcomes included annual testing of HbA1c, cholesterol, and eye exams. HbA1c control was the most common intermediate outcome studied.**Table 3**

Studies measuring variation in processes and intermediate (nonclinical) outcomes of care for patients with diabetes

| Source | Population studied | Geographical unit analyzed | Outcomes measured | Main results |
|---|---|---|---|---|
| Egede et al. *2011* | 690,968 US veterans, 2002–2007 | Intra-country comparison (US regions, urban/rural) | A1c control, A1c >= 8.0 % | Rural residence was associated with uncontrolled diabetes (OR 1.02, 95 % CI 1.02–1.03). Small differences were observed among regions |
| Si et al. *2010* | Utilized publically available | Intercountry comparison (five OECD countries: | Six OECD indicators: HbA1c testing, | There are substantial gaps in diabetes care |

| | | | | |
|---|---|---|---|---|
| | national-level data of patients with diabetes | Australia, Canada, New Zealand, the USA, the UK) | lipid testing, renal function screening, eye exam, HbA1c control, lipid control | across the five countries examined. There were several limitations in data quality and consistency to compare quality indicators across countries |
| Berkowitz et al. *2009* | US Medicare beneficiaries aged 65 years or older with diagnosis of CHF, COPD, and diabetes discharged from hospital, 2004 | Regions of the USA | Follow-up visit within four weeks of hospital discharge | Marked variation was present for percentage of patients receiving HbA1c tests, eye exams, cholesterol tests, and kidney function tests |
| Lyon et al. *2009* | 542,504 HbA1c test results from Alberta, Canada, 2002–2007 | Four regions within the province of Alberta, Canada | HbA1c testing | Regional variation was observed in the proportion of HbA1c tests ordered for those without diabetes (18–34 %). The time interval between repeat HbA1c tests also varied among regions |
| Kirkbride and Wallace *2009* | 6,267 Oregon Medicaid beneficiaries, 18–64, 2002–2003 | Rural versus urban | Proportion of patients receiving: HbA1c, lipid profile, eye exam | Rural areas had lower rates of all three tests. Rural areas with a rural health clinic had higher rates of all three tests versus those without a rural health clinic |
| Weingarten et al. *2006* | Medicare beneficiaries with diabetes, 1999–2001 | Urban, semirural, and rural | Composite of three diabetes care quality indicators (QIs): HbA1c, biennial lipid profile, and biennial eye exam | Urban–rural differences were different for northern and southern states. In northern and eastern states, QIs were higher for rural |

| | | | | |
|---|---|---|---|---|
| | | | | residents. In the southern states, QIs were higher for urban residents |
| McGinn and Davis *2006* | ~17,000 diabetes patients in the Kansas City area, USA, 2004 | Intra-country comparison (five Kansas City counties) | HEDIS indicators: HbA1c tested, HbA1c poorly controlled (>9 %), LDL tested, LDL controlled (<130 mg/dL), eye exam, nephropathy screening | HEDIS measures varied significantly among counties. Physician-level predictors of QI metrics: number of patients with diabetes per physician, geography, physician age, group practice, non-primary care subspecialty |
| Andrus et al. *2004* | 187 patients with diabetes in two Alabama clinics, USA, dates | Intra-country comparison (urban vs. rural) | Numerous QIs based on ADA guidelines | Rural patients were less likely to achieve A1C (33.3 % vs. 48.6 %), LDL (11.5 % vs. 36.7 %), and blood pressure (7.7 % vs. 22.0 %) targets. A1c testing (79.5 % vs. 83.5 %), LDL testing (50 % vs. 74 %), eye exams (6.4 % vs. 18.4 %), kidney screening (3.9 % vs. 32.1 %), and other preventative services were less common in rural patients versus urban |
| Alberti et al. *2004* | Random sample of 235 patients with diabetes from four primary care clinics in Tunis, Tunisia | Intra-country comparison (four primary care clinics in Tunisia) | Processes of care: records of weight, blood pressure, fasting glucose, cholesterol, creatinine, HbA1c, fundoscopy, ECG, foot exam, | Significant variation among clinics was found for all processes of care. Systolic blood pressure varied among clinics; all other outcomes of care |

| | | | | |
|---|---|---|---|---|
| | | | and cardiovascular exam. Outcomes of care: results of BMI, blood pressure, fasting glucose, cholesterol, and creatinine | were similar |
| McBean et al. *2003* | 76,273 US Medicare beneficiaries, 1999 | Intra-country comparison (US census regions) | Poor diabetes control, A1c > 9.5 % | 32.7 % met definition of poor control. ORs (95 % CIs): Midwest 1.0 (0.99–1.12), Northwest 1.86 (1.77–1.95), South 1.33 (1.26–1.40), West (referent group) |
| Rith-Najarian et al. *2002* | Random sample of 10,889 patients with diabetes included in the 1998 Indian Health Service Diabetes Care and Outcomes Audit (the USA) | Intra-country comparison (regions within the USA: Pacific, Great Plains, Great Lakes, Colorado Plateau, Southwest, Southern Plains, Alaska) | Selected measures of cardiovascular risk stratified by age (<45 years/>= 45 years): (1) HbA1c, (2) tobacco use, (3) proteinuria, (4) cholesterol, (5) blood pressure, (6) BMI | There was significant variation across regions in all outcomes studied |
| Booth et al. *2002* | 2,849 patients with type 1 diabetes in the DCCT trial, the USA and Canada, 1983–1989 | Intercountry comparison (the USA vs. Canada) | A1c control | Despite differences in health systems, A1c control was similar between the USA and Canada (8.9 % vs. 9.0 %, $p = 0.4$ at baseline) |
| Arday et al. *2002* | 1,941,517 US Medicare beneficiaries, 1997–1999 | Intra-country comparison (US states) | Annual A1c testing, biennial eye exam, biennial lipid profile testing | A1c test overall rate 67.8 %, biennial eye exam rate 68.3 %, and biennial lipid profile 56.8 %. Lower rates in disabled and ESRD |

| | | | | |
|---|---|---|---|---|
| | | | | subgroups. Significant variation by state and within state |
| Krein et al. *2002* | 12,110 patients with diabetes in Veterans Affairs medical centers, USA, 1997–1998 | 252 primary care providers, 42 provider groups, and 13 facilities | Process measures (HbA1c testing, LDL testing), intermediate outcomes (HbA1c control, LDL control), and resource use (cost of medications, cost of home glucose monitoring) | Substantive practice variation was observed across all levels of care. The largest amount of variance was at the facility level |
| Kristensen et al. *2001* | 4,438 patients with type 2 diabetes, Denmark, 1997 | 106 medical practices | Annual HbA1c testing and HbA1c control | Annual HbA1c testing ranged from 32 % to 100 % (adjusted 69–80 %) of patients with diabetes among practices. The proportion of patients with a poor HbA1c ranged from 22 % to 100 % (adjusted 51–76 %) among practices |

As mentioned, one of the most common comparisons in the literature is between rural and urban settings (Andrus et al. *2004*; Kirkbride and Wallace *2009*; Weingarten et al. *2006*). In general, patients living in a rural environment appear to receive fewer annual tests for managing diabetes; have poorer control of their blood glucose, cholesterol, and blood pressure; and less frequently self-monitor blood glucose compared to their urban counterparts. For example, Andrus and colleagues ( *2004*) found that patients attending a rural family practice clinic were less likely to receive numerous processes of care including annual HbA1c testing (94.9 % rural vs. 97.3 % urban), LDL testing (50.0 % rural vs. 74.3 %), eye examinations (6.4 % rural vs. 18.4 % urban), foot exam (9.0 % rural vs. 25.7 % urban), microalbuminuria screening (3.9 % rural vs. 32.1 % urban), vaccinations (12 % rural vs. 40 % urban received the influenza vaccine), and serum creatinine measurements (37.2 rural vs. 97.2 % urban). Furthermore, the rural clinic had fewer patients achieving an HbA1c <7 % (33.3 % rural vs. 48.6 % urban), an LDL <100 mg/dL (11.5 % rural vs. 36.7 % urban), and a blood pressure <130/80 mmHg (7.7 % rural vs. 22.0 % urban) compared to the urban clinic.

Others have also observed lower rates of diabetes processes of care including HbA1c testing, lipid testing, and eye exams among rural versus urban residents (Kirkbride and Wallace *2009*; Weingarten et al. *2006*). However, the pattern of living in a rural setting being associated with poorer access to care and outcomes of care does not always appear to hold across all geographic regions. For example, Weingarten and colleagues ( *2006*) observed higher proportions of patients receiving HbA1c tests,

lipid tests, and eye exams among rural residence in northern and eastern USA compared to urban residents; however, in the southern USA rural residents had lower proportions of these processes of care compared to urban residents. Although not focused on geographic variation, others have tested for urban–rural differences in outcomes among patients with diabetes (Lipscombe et al. *2010*; Rose et al. *2008*; Shah et al. *2005*).

In addition to these observed urban–rural differences in processes and outcomes of diabetes care, others have observed significant variation within smaller and larger geographic regions across the USA (Arday et al. *2002*; Egede et al. *2011*; McBean et al. *2003*; McGinn and Davis *2006*; Rith-Najarian et al. *2002*). For example, Arday and colleagues ( *2002*) studied almost two million Medicare beneficiaries in the USA and found wide variations among states in the proportion of patients with diabetes who received annual HbA1c tests (range 51.5–83.2 %), biennial lipid tests (38.9–71 %), and biennial eye exams (56.3–78.2 %). Following adjustment for population characteristics that differed between states, the variation was reduced by 30 % for annual HbA1c testing, 27 % for biennial lipid testing, and 23 % for biennial eye exams. Berkowitz and colleagues ( *2009*) found an approximately twofold variation between the 90th and 10th hospital referral region percentiles for the percentage of patients receiving cholesterol, flu, eye, HbA1c, and kidney function tests. Lyon and colleagues ( *2009*) found significant variation in the frequency of HbA1c testing among regions within the province of Alberta, Canada.

In addition to the peer-reviewed journal literature, many countries and local health regions have examined geographic variation in processes and outcomes of diabetes care in the form of atlases (Table 4). For example, in the UK the National Health Service Atlas of Variation in Healthcare for People with Diabetes reported that individuals with diabetes were up to ten times more or less likely to have received all nine essential care processes depending on where they lived. Essential care processes included annual HbA1c measurement, cholesterol measurement, microalbuminuria measurement, blood pressure measurement, body mass index measurement, smoking status recording, eye examination, and foot examination. Specifically, the percent of patients with type 1 diabetes who received all nine care processes ranged from 5 % to 48 %. Similarly for patients with type 2 diabetes, there was a tenfold variation (ranged from 7 % to 71 %) in the percent of patients receiving all nine care processes. These findings are a call to action that more work is required to improve the standard of care for people with diabetes.

**Table 4**

Selection of diabetes atlases

| **Atlas title (country)** | **Internet address** |
|---|---|
| Alberta Diabetes Atlas (Canada) | http://www.albertadiabetes.com |
| Australian Diabetes Map (Australia) | http://www.ndss.com.au/en/Australian-Diabetes-Map/ |
| Centers for Disease Control and Prevention Diabetes Interactive Atlases | http://www.cdc.gov/diabetes/atlas/ |

| | |
|---|---|
| (USA) | |
| Diabetes in Ontario (Canada) | http://www.ices.on.ca/webpage.cfm?site_id=1%26org_id=31%26morg_id=0%26gsec_id=0%26item_id=1312 |
| International Diabetes Federation Diabetes Atlas (International) | http://www.idf.org/diabetesatlas/ |
| Minnesota Health Atlas (USA) | http://www.mnhealthatlas.org |
| The D-ATLAS (USA) | http://www.z-atlas.com/content.php?sec=diabetes |
| The National Health Service Atlas of Variation in Healthcare for People with Diabetes (UK) | http://www.rightcare.nhs.uk/index.php/atlas/diabetes/ |
| Toronto Diabetes Atlas (Canada) | http://www.stmichaelshospital.com/crich/reports/toronto-diabetes-atlas/ |

In addition to diabetes atlases, healthcare agencies often publish reports on healthcare quality that contain information on the achievement of several key diabetes-specific quality indicators, including information on variation. An example is the National Healthcare Quality Report (NHQR) published annually by the Agency for Healthcare Research and Quality in the USA (Agency for Healthcare Research and Quality *2013*). The intention of these annual reports is to improve the quality of care through measurement and reporting of the current status of healthcare quality and changes over time and identification of where the greatest need for improvement in healthcare is required.
International comparisons of diabetes processes and outcomes of care have also been published (Booth et al. *2002*; Si et al. *2010*). Si and colleagues ( *2010*) summarized data on six diabetes indicators (annual HbA1c testing, lipid testing, renal function screening, eye examination, HbA1c, and lipid control) available in the public domain from five OECD countries (Australia, Canada, New Zealand, the USA, and the UK). Comparisons across countries were difficult given different data collection methods and time periods. In fact, the authors identified 13 data sources that were relevant to the six diabetes indicators of interest. These data sources included administrative data, medical record data, and survey data and were of variable quality (62 % were appraised as good quality). When comparing annual HbA1c testing, lipid testing, kidney function examination, and eye examination rates (the four process of diabetes care indicators), only Australia, New Zealand, the USA, and the UK had comparable data (i.e., similar data sources and timeline). The USA and UK had higher rates across all four process of care indicators compared to Australia and New Zealand. For example, among adults treated in a primary care setting, annual HbA1c and lipid testing was reported for approximately 70–80 % of patients in the USA and UK and 50–60 % of patients in Australia and

New Zealand. Comparisons of intermediate outcome of care were more difficult due to different data sources and definitions of HbA1c (cut points ranged from <6.5 % to <8.0 %) and lipid control. For lipid control the criteria were extremely variable across countries due to different cut points and different lipid parameters (e.g., total cholesterol <4 mmol/L, total cholesterol <5.2 mmol/L, LDL < 2.6 mmol/L, etc.). Irrespective of these limitations, substantial variation was observed between countries in the proportion of patients achieving HbA1c and lipid control among OECD countries.
Another study by Booth and colleagues ( *2002*) analyzed data from the landmark Diabetes Control and Complications Trial (DCCT) and compared glucose control between patients living in the USA and those living in Canada. They found similar HbA1c control among American (9.1 %) and Canadian (9.2 %) patients even though the populations differed in demographics and healthcare delivery. Canadians enrolled in the DCCT were younger, less likely to have a college education, and more likely to receive care in an outpatient setting and from a family physician.
Although many studies have solely described the variation across geography, others have explored the potential reasons for such variation. Indeed, a key question stemming from all of the evidence summarized above is what are the drivers of such variation in diabetes care? Studies have identified several patient, clinician, and health system factors that are associated with variation among the geographical units analyzed (O'Connor et al. *2008*). O'Connor and colleagues ( *2008*) studied factors that explained variance in HbA1c values among 2,589 adults with diabetes. They studied patient-, physician-, and clinic-level factors using multivariate hierarchical models to partition the variance observed in HbA1c values. Over 95 % of the variance in HbA1c values was explained by patient-level factors. The most influential patient-level factors were intensification of pharmacotherapy (e.g., addition of second or third agent) and age. Others have reported clinician-level factors are associated with processes and intermediate outcomes of care. For example, McGinn and Davis ( *2006*) found independent of location, physician age was inversely associated with HbA1c control, physicians working in a group practice were associated with higher nephropathy screening rates, and non-primary care physicians were associated with higher HbA1c testing and better lipid control. Furthermore, one of the most significant predictors of a higher HbA1c and lipid testing rates, and better HbA1c and lipid control, was the number of patients with diabetes a physician cares for (McGinn and Davis *2006*). Another complicating factor is that the drivers may differ for specific types of healthcare services such as preventive services compared to services tied to monitoring disease progression or treatment effectiveness. Others have found that process measures and outcome measures vary depending on the continuity of care provided and if care was provided by a physician with a specialty in diabetes (De Berardis et al. *2004*).
Variation in key processes and outcomes of care is widespread and of significant magnitude that numerous quality improvement programs have been integrated into the health systems of many countries (see section on Reducing Practice Variation in Diabetes Care). For example, numerous jurisdictions have published or have real-time access to diabetes atlases that display key process and outcome indicators over geographic regions of importance for their respective health jurisdictions. Given the evidence-based nature of the key diabetes process and outcome indicators, it is crucial that researchers continue to document medical practice variation and explore the barriers to implementing all processes of care which in turn impact outcomes. Indeed it is through understanding the mechanisms responsible for these variations in the patterns of care that will help improve health policies at the individual patient, clinician, and health system level to improve the care for patients with diabetes.

## Review of the Evidence: Practice Variation in Treatment

There have been surprisingly few population-based studies evaluating regional variation in antihyperglycemic prescribing. Several studies were published prior to the completion of the DCCT or UKPDS results and were thus essential in a period of preference-based care (Bergman et al. *1975*; Griffiths et al. *1985*, *1986*). More recent studies have continued to describe regional variation in prescribing of antihyperglycemic agents. Sargen and colleagues ( *2012*) found marked regional differences across the USA in the percentage of diabetic Medicare beneficiaries that received metformin, a sulfonylurea, a thiazolidinedione, and insulin throughout 2007. They estimated the effect of various nonclinical factors on regional variation and found that lower household income and being of African American descent were correlated with variation in prescription rates; however, sex and Hispanic ethnicity were not associated with variation in prescription rates. A study by Shah and colleagues ( *2010*) analyzed state-level variation in rosiglitazone prescribing rates before and after the 2007 US Food and Drug Administration's black box warning. As documented by several other studies, prescribing of thiazolidinediones in general and particularly rosiglitazone substantially decreased following the black box warning. Interestingly, following the black box warning, there was an increase in the variation of rosiglitazone prescribing among states. In 2005, Wyoming had the highest use of rosiglitazone at 16.5 % of all antihyperglycemic medications and North Dakota had the lowest at 7.8 %. However by 2009, the highest rosiglitazone prescribing state was Oklahoma at 5.6 % and the lowest was North Dakota at 1.9 %. In fact the state-level variation increased from twofold in 2005 to threefold in 2009. Furthermore, in the province of Manitoba, Canada, rural–urban differences in the use of antihyperglycemic agents and test strips have been reported. Rural residents had a 15–57 % higher prevalent use and up to 82 % higher incident use compared to urban residents after adjustment for age, socioeconomic status, region, and sex (Raymond et al. *2010*).

Other elements of diabetes management such as prescribing of cardioprotective agents, adherence to antihyperglycemic agents, and spending on antihyperglycemic agents are also associated with significant medical practice variation. For example, Usher and colleagues ( *2004*) found up to twofold differences among health regions in Ireland in statin use in the diabetic population. Similarly, Gulliford and colleagues ( *2005*) found striking differences among primary care practices in England in the proportion of patients with type 2 diabetes prescribed thiazide diuretics (range 0–52 %), beta-blockers (5–60 %), ACE inhibitors (15–81 %), and statins (0–50 %).

Not only are there wide variations in the prescribing of cardioprotective and antihyperglycemic agents, other elements of medication use such as adherence and costs may differ by geography as well. Asghari and colleagues ( *2009*) found medication adherence to antihyperglycemic agents was better among rural residents compared to urban residents in the province of Quebec, Canada (adjusted odds ratio 1.26, 95 % CI 1.22–1.30 for regular users [≥80 % adherent] versus irregular users [<80 % adherent]). Costs of medications also differ by geographical locale. In Canada, significant interprovincial variation in the average annual spending on oral antihyperglycemic agents per person ranged from $43.20 to $73.30 for people 65 years and older in 2007 (Morgan et al. *2008*). The extent of variation was greater for those aged 45–64 years (range $17.80 to $36.80). Likewise, per capita spending varied across Canadian provinces for insulin in 2007, whereby spending for persons aged 19 and younger ranged from $1.80 to $5.80 and spending for people aged 65 years and older ranged from $7.80 to $28.20. Differences in provincial formularies may explain some of the variation; however, significant variation was still present after adjusting for therapeutic choice effects which would be expected to be impacted by provincial formularies. In fact, in populations with a uniform formulary, such variation in spending still exists. For example, Gellad and colleagues ( *2010*) analyzed annual spending in 2008 for antihyperglycemic and lipid-lowering agents across 135 Veterans Affairs medical centers. These centers have a standard formulary, and prices are generally consistent due to national-level negotiations. Despite this uniformity, the median cost per patient across 135 Veterans

Affairs centers varied for both antihyperglycemic agents ($123.34 [lowest quartile] to $198.31 [highest quartile]) and lipid-lowering agents ($39.68 [lowest quartile] to $69.57 [highest quartile]). Centers spending higher amounts on antihyperglycemic agents also tended to spend high amounts on lipid-lowering agents, whereby almost half (47 %) of the centers were in the highest quartile for both categories ( $r = 0.41$, $p < 0.001$). One reason for higher spending in some centers was through the use of brand name drugs, which were prescribed at twice the rate in the centers in the highest spending quartile compared to centers in the lowest quartile ( $p < 0.001$). Variation in drug spending was not related to quality indicators such as HbA1c or cholesterol control. Variation in drug costs ultimately impacts patients. For example, high drug costs are associated with poor adherence to medications. A recent study suggested that approximately 10 % of Canadians were nonadherent to their medications because they could not afford them (Law et al. *2012*).

Although the studies discussed above and listed in Table 5 have documented variation in the use of treatments for diabetes across different time periods and populations, the reasons for variation are not well understood. In general, variation in the prescribing of antihyperglycemic, antihypertensive, and antihyperlipidemic agents may reflect differences in the prevalence of diabetes (especially if the denominator of rates is of the general population), prevalence of comorbidities (e.g., chronic kidney disease, heart failure, etc.), or subgroups of individuals, local lifestyle of the population, changes in medical practice and local policy initiatives, influence of pharmaceutical representatives, physician prescribing preferences, drug coverage policies, proximity to university teaching hospitals, and patient sociodemographics (e.g., age, sex, economic status). The extent to which these factors independently contribute to variation in use is unclear. The detail of adjustment in many studies is likely inadequate to account for many of these factors. Ultimately, understanding the factors responsible for prescribing variation and their relative contributions is an important public health issue that will help inform policy.**Table 5**

Studies measuring variation in treatments for patients with diabetes

| Source | Population studied | Geographical unit analyzed | Outcomes measured | Main results |
|---|---|---|---|---|
| Sargen et al. *2012* | Entire US population with diabetes enrolled in Medicare Parts A, B, and D for 12 months, 2006–2009 (~8.8 million) | 306 hospital referral regions in the USA | Types of treatment: metformin, sulfonylureas, thiazolidinediones, and insulin | Twofold variation among hospital referral regions in prescription rates. Income and ethnicity were associated with variation in prescription rates |
| Shah et al. *2010* | US nationally representative monthly prescription volume for antihyperglycemic drugs using data from IMS Health, 2007–2009 | Quartiles based on state-level variation | Proportion of all antihyperglycemic prescriptions for rosiglitazone and all thiazolidinediones | Variation among states in rosiglitazone prescribing was twofold prior to FDA warning 2007 and increased to nearly threefold in 2009 |

| | | | | |
|---|---|---|---|---|
| Gellad et al. *2010* | 981,031 patients dispensed antihyperglycemic drugs in the Veterans Affairs (VA) system, USA, 2008 | 135 VA medical centers | Prescription use, drug costs per patient, proportion of patients on brand-name drugs, Healthcare Effectiveness Data and Information Set (HEDIS) scores | Median cost/patient varied from $123.34 to $198.31 between the least and most expensive quartile ( $p < 0.001$). No correlation was found between HEDIS scores and spending for diabetes agents ( $r = -.10$) |
| Asghari et al. *2009* | 155,646 patient with diabetes in Quebec, Canada | Urban versus rural residence | Adherence (measured using medication possession ratio[MPR]) to antihyperglycemic drugs | Regular users of antihyperglycemics (MPR ≥ 80 %) were more likely to live in a rural area (OR 1.26, 95 % CI 1.22–1.30) versus an urban area. Nonusers were also more likely to live in a rural area (OR 1.10, 95 % CI 1.06–1.12) |
| Henriksen et al. *2007* | Survey of 59 hospital internal medicine departments, Denmark | Interhospital variation | Treatment protocols for the management of diabetic ketoacidosis (DKA) | Substantial variation was observed in DKA management protocols among sites of care in Denmark: 24 different insulin treatment regimens among 53 departments were identified; 21 different fluid regimens among 43 protocols were identified |
| Usher et al. *2005* | 42,486 patients who received a prescription for an antihyperglycemic drug, Ireland, 2002 | Eight health board regions in Ireland | Standardized prescribing ratios (SPRs) for antihyperglycemic drugs, aspirin, beta-blockers, statins, ACE inhibitors, angiotensin receptor (AT2) blockers, and fibrates | Documented regional prescribing variation in diabetes medications (1.5-fold) and secondary preventive medications: aspirin (1.4- to 1.7-fold), beta-blockers (1.3- to 1.8-fold), statins (1.5- to 1.8-fold), ACEi (1.3- to 1.5- |

| | | | | |
|---|---|---|---|---|
| | | | | fold), AT2 blockers (1.7- to 2.0-fold) |
| Alberti et al. *2004* | Random sample of 235 patients with diabetes from four primary care clinics in Tunis, Tunisia | Four primary care clinics in Tunisia | Types of treatment: diet alone, oral monotherapy, oral dual therapy, or insulin | Significant variation among clinics was found in the proportion of patients using diet alone (range, 0–15 %) or dual therapy (range, 30–65 %) |
| Gulliford et al. *2005* | 4,519 patients with diabetes and hypertension in the UK, 1993–2001 | 105 general practices | Proportion prescribed thiazides, ACE inhibitors, angiotensin receptor blockers, statins | Large variation in prescriptions for cardioprotective drugs across primary care practices: thiazides (0–52 %), beta-blockers (5–60 %), ACE inhibitors (15–81 %), and statins (0–50 %). Age, sex, prevalence of coronary heart disease, or study year did not account for differences among practices |
| Hogan et al. *2003* | 137 patients with diabetes who completed the Canadian Community Health Survey | Five regions within Canada | Proportion that reported taking insulin, oral antihyperglycemics, ACE inhibitors, aspirin, lipid-lowering agent | No differences observed between provinces; however, numbers of patients are very small, limiting the power of the analysis |
| Griffiths et al. *1986* | Survey of 400 physicians in Northern Ireland, Norway, and Sweden | Intercountry comparisons (Northern Ireland, Norway, Sweden) | Physician opinions on choice of drug therapy based on three cases | Case 1, uncomplicated asymptomatic newly diagnosed diabetic: Swedish (65 %), Irish (51 %), and Norwegian (52 %) doctors recommended diet alone. Case 2, symptomatic with retinopathy: Sulfonylurea was the most popular drug among doctors of all countries. |

| | | | | |
|---|---|---|---|---|
| | | | | Biguanides were more popular in Northern Ireland. Case 3, treatment failure: Norwegian (71 %), Irish (44 %), and Swedish (49 %) recommend insulin |
| Griffiths et al. *1985* | National drug sales in Northern Ireland, Norway, and Sweden | Intercountry comparisons (Northern Ireland, Norway, Sweden) | Defined daily doses of antihypertensive and antihyperglycemic medications | Two- to threefold variation in use of antihypertensive (DDDs in Northern Ireland and Norway were 38 % and 25 % lower than in Sweden) and antihyperglycemic (Sweden had a 52 % higher DDD rate than Northern Ireland) medications |
| Bergman et al. *1975* | National drug sales in Northern Ireland, Norway, and Sweden | Intercountry comparisons (Northern Ireland, Norway, Sweden) | Agreed daily doses of antihypertensive and antihyperglycemic medications | Insulin use was twofold higher in Sweden versus Norway and Northern Ireland. Oral antihyperglycemic drugs were used more in Sweden compared to Norway and Northern Ireland. There was a high degree of intra-country variation in the choice of oral antihyperglycemic drugs |

## Review of Evidence: Practice Variation in Diabetes-Related Complications

Predictors of acute complications have been assessed in several population-based cohorts (Table 6). In one cohort of adults with diabetes, the relationship between geographic residence and acute complications was evaluated in Ontario, Canada (Booth et al. *2005*). The cohort was identified using physician and hospital claims data. The primary outcome was hospitalizations and emergency department visits for either hyperglycemic or hypoglycemic emergencies. After adjusting for several

sociodemographic and care factors, individuals with diabetes living in rural areas or aboriginal communities were more likely to have an emergency department visit or have a hospital admission (for rural, adjusted OR, 1.51; 95 % CI, 1.51–1.57; for aboriginal communities, adjusted OR, 1.84; 95 % CI, 1.65–2.05) (Booth et al. *2005*). In a similar cohort, the relationship between socioeconomic status and acute complications was evaluated (Booth and Hux *2003*). After adjusting for age, sex, comorbidity, type of residential area (urban versus rural), geographic location, and ambulatory care used, there was a clear inverse gradient between income level and event rate (lowest income quintile compared to highest OR, 1.20; 95 % CI, 1.4–1.26 for hospitalization) (Booth and Hux *2003*). These studies were not able to differentiate between patients with type 1 and type 2 diabetes due to limitations of the administrative databases used (Booth and Hux *2003*; Booth et al. *2005*). Curtis and colleagues ( *2002*) assessed trends of DKA and non-DKA admissions in children and adolescents with diabetes. Over approximately a 10-year period, variation across geographic areas remained stable for DKA admissions with an average of a 3.7-fold difference between the lowest and highest regions (Curtis et al. *2002*). In general, urban areas had lower rates of admissions compared to more remote, less populated areas. This may be due to differences in ambulatory care services and resources.**Table 6**

Studies measuring variation in diabetes-related complications

| Source | Population studied | Geographical unit analyzed | Outcomes measured | Main results |
|---|---|---|---|---|
| Schuyler Jones et al. *2012* | 2,730,742 patients 65 years and older with lower extremity peripheral artery disease (37 % had diabetes), US Centers for Medicare and Medicaid, 2000–2008 | US geographic regions | Rate of lower extremity amputation | There was a significant amount of variation in lower extremity amputations across regions of the USA. Diabetes mellitus was an independent predictor of a lower extremity amputation (adjusted OR 2.40, 95 % CI 2.38–2.43) |
| Margolis et al. *2011* | ~5 million US Medicare beneficiaries with diabetes, 2006–2008 | US hospital referral regions | Annual incidence of a lower extremity amputation | Lower extremity amputation (LEA) rates varied substantially across hospital referral regions. High rates of LEA were found in regional clusters. Factors independently associated with LEA rates included socioeconomic |

| | | | | |
|---|---|---|---|---|
| | | | | status, age, prevalence of diabetes, prevalence of African Americans, and mortality rate |
| Tseng et al. *2007* | 331,806 US Veterans Health Administration (VHA) patients with diabetes, 1998–2000 | 22 regional VHA networks | Total, major, and minor amputations | Patterns of variation differed for major and minor amputations |
| Walsh et al. *2006* | 2,657 patients with type 1 diabetes across 17 countries (DiaComp study [substudy of the DiaMond study]) | Intercountry comparisons | Retinopathy, laser treatment, neuropathy, renal disease, hyperlipidemia, hypertension, myocardial infarction, stroke, peripheral vascular disease, amputation, and angina | There was substantial between country variation for nearly all complications: retinopathy (eightfold), laser treatment (14-fold), neuropathy (20-fold), hypertension (fourfold), and macrovascular complications (tenfold) |
| Booth et al. *2005* | 577, 659 adults with diabetes in Ontario, Canada, 1994–1999 | Small area variation within the province of Ontario, Canada | Hospitalizations and emergency department visits for acute complications (hyper- and hypoglycemia) | Rural residence was associated with a twofold increase and those in remote areas a threefold increase in acute complications |
| Morbach et al. *2004* | 613 patients with diabetic foot lesions within three different centers between June 1998 and December 1999 | Germany, Tasmania, and India | Incident foot lesions, neuropathy, and peripheral vascular disease | Incident foot lesions were more common in the Indian Center (79 %) compared to the German (40 %) or Tanzanian Center (59 %). However, time to the initial foot lesion from diagnosis was significantly |

| | | | | |
|---|---|---|---|---|
| | | | | shorter in the Tasmanian Center (mean 5 years) versus the German (mean 14 years) and Indian (mean 12 years) centers |
| Curtis et al. *2002* | 15,782 children <19 years, Ontario, Canada, 1991–1999 with a diabetes-related hospital admission | Small area variation within the province of Ontario, Canada | DKA and non-DKA admissions | 3.7-fold difference between the highest and lowest regions. Kendall's correlation 0.64; $p = 0.017$ |
| Wrobel et al. *2001* | US Medicare beneficiaries, 65–69 years of age, 1996–1997 | US hospital referral regions | Lower extremity major amputations | Rates of lower extremity amputations varied substantially among individuals with and without diabetes. There was a 8.6-fold variation across hospital referral regions for those with diabetes and 6.7-fold variation for those without diabetes |
| Payne and Scott *1998* | Patients hospitalized for diabetes or its complications, New Zealand, 1980–1993 | Small area variation in New Zealand | Number of discharges for diabetic foot disease, length of hospital stay for diabetic foot disease, readmissions for diabetic foot problems | There was an 11-fold variation in the total bed days per 1,000 people among area health boards in New Zealand in 1993 |
| Van Houtum and Lavery *1996* | Patients hospitalized for a lower extremity amputations in the Netherlands, 1991–1992 | Small area variation in the Netherlands | Incidence of diabetes-related lower extremity amputations | The age-adjusted incidence per 10,000 of lower extremity amputations ranged from 10 to 45 (fourfold variation) among 27 health regions in the Netherlands among patients |

| | | | | |
|---|---|---|---|---|
| | | | | with diabetes. In those without diabetes, the age-adjusted incidence per 10,000 low lower extremity amputations ranged from 0.77 to 1.77 (twofold variation) |

Geographic variation of chronic complications has been observed among countries (Table 6). The DiaComp multinational cross-sectional study assessed geographic variation among complications in people with type 1 diabetes among 17 countries (Walsh et al. *2004*, *2006*). Complications were assessed by self-report of physician-diagnosed complications. A wide variation of complications was observed in retinopathy, neuropathy, renal disease/proteinuria, and hypertension (Fig. 2) (Walsh et al. *2004*, *2006*). For example, central European centers had high rates of retinopathy and laser treatment in those with diabetes of less than 15 years′ duration (Walsh et al. *2006*). Variation appeared to be more moderate among those with diabetes of longer duration (Walsh et al. *2004*, *2006*). Hypertension and duration of diabetes were predictors of all complications, and women were noted to have higher prevalence of retinopathy, laser treatment, and renal disease. Diabetes care activities of self-monitoring of blood glucose and intensive insulin therapy were not strongly associated with prevalence of complications (Walsh et al. *2006*).

**Table 3. Prevalence of reported complications in the DiaCom (Level 1) population by duration of diabetes and centre**

| Region/Centre | Retinopathy* % | Laser Tx* % | Neuropathy* % | MNSI* % | Hyperlipidaemia* % | Hypertension* % | MACRO* % | Renal Dx* % |
|---|---|---|---|---|---|---|---|---|
| **Short duration** | | | | | | | | |
| Asia | | | | | | | | |
| China (multiple) | 7.3 (3.7–12.7) | 1.3 (0.2–4.6) | 2.5 (0.7–6.3) | 1.9 (0.4–5.3) | 1.3 (0.2–4.5) | 1.9 (0.4–5.5) | 6.8 (3.3–12.2) | 6.4 (3.1–11.5) |
| Japan (Osaka) | 10.3 (6.1–16) | 3.6 (1.3–7.6) | 0.6 (0.02–3.4) | 0 | 6.5 (3.3–11.3) | 1.2 (0.1–4.4) | 1.9 (0.4–5.3) | 0.6 (0.02–3.3) |
| Australia | | | | | | | | |
| Tasmania | 7.5 (3–14.7) | 5 (1.6–11.2) | 0 | 1 (0.02–5.3) | 3 (0.6–8.4) | 4.9 (1.6–11.1) | 0 | 9.9 (4.9–17.5) |
| Caribbean | | | | | | | | |
| Cuba (Havana) | 9.4 (5.2–15.3) | 0.7 (0.02–3.7) | 15.4 (10–22) | 4.7 (1.9–9.4) | 11.4 (6.8–17.6) | 14.8 (9.5-21.5) | 8.1 (4.3-13.7) | 12.1 (7.3-18) |
| Puerto Rico | 3 (0.8–7.6) | 0.8 (0.02–4.2) | N/A | 7.4 (3.5–13) | 22.8 (16–30.8) | 10.5 (5.9–17) | 13 (7.7–20) | 6.6 (3.1–12.2) |
| Europe | | | | | | | | |
| Lithuania | 41.6 (34.4–49.1) | 25.4 (19.3–32.3) | 29.9 (23.4–37.1) | 8.7 (5–13.7) | 2.2 (0.6–5.4) | 15.7 (10.8–21.7) | 0.5 (0.1–3) | 7.6 (4.2–12.4) |
| Romania | 24.2 (16–34.1) | 2.1 (0.3–7.4) | 12.4 (6.5–21) | 4.1 (1.1–10) | 10.3 (5.1–18.1) | 2.1 (0.3–7.3) | 0 | 2.1 (0.3–7.3) |
| Slovakia (Martin) | 4.9 (1.1–13.7) | 0 | 1.5 (0.04–8.3) | 0 | 16.9 (8.8–28.3) | 4.6 (1–12.9) | 6.4 (1.8–15.5) | 4.7 (1–13.1) |
| UK (Oxford) | 2.1 (1–7.4) | 0 | 1.1 (0.03–6.2) | 0 | 0 | 2.1 (0.3–7.3) | 1.0 (0.03–5.7) | 0 |
| Mediterranean | | | | | | | | |
| Italy (Ancona) | 3 (0.1–15.8) | 0 | 0 | 0 | 9.1 (1.9–24.3) | 3 (0.1–15.7) | 0 | 3.1 (0.1–16.2) |
| Italy (Chieti) | 1.6 (0.4–8.5) | 0 | 1.6 (0.04–8.5) | 0 | 14.3 (6.7–25.4) | 9.5 (3.6–19.6) | 3.2 (0.4–11) | 0 |
| N America | | | | | | | | |
| Chicago | 3.0 (1–8.6) | 1.0 (0.03–5.4) | 6.2 (2.3–13) | 4.0 (1.1–10) | 8.1 (3.5–15.3) | 15.2 (8.7–23.8) | 15.1 (8.7–24) | 2.0 (0.2–7.1) |
| S America | | | | | | | | |
| Brazil (Rio de Janeiro) | 9.5 (2.7–22.6) | 4.7 (1–15.8) | 0 | 7 (1.5–19.1) | 41.9 (27–57.8) | 4.7 (1–15.8) | 11.9 (4–25.6) | 9.3 (2.6–22.1) |
| Brazil (Sao Paulo) | 3 (1.0–6.8) | 1.2 (0.1–4.3) | 0.6 (0.01–3.2) | 4.1 (1.7–8.3) | 9.9 (5.9–15.4) | 5.3 (2.4–9.8) | 3.9 (1.4–8.2) | 4.1 (1.7–8.3) |
| Argentina (Buenos Aires) | 3.1 (1.3–6.4) | 2.7 (1–5.8) | 8.5 (5.2–12.9) | 0.9 (0.1–3.2) | 28.4 (22.6–34.8) | 5.8 (3.1-9.6) | 0 | 2.2 (0.7-5.1) |
| Chile (nationwide) | 2.7 (0.1–14.2) | 2.7 (0.1–14) | 3.1 (0.08–16) | 0 | 2.8 (0.1–14.5) | 0 | 0 | 0 |
| **Long duration** | | | | | | | | |
| Asia | | | | | | | | |
| Japan (nationwide) | 58 (46.5–68.9) | 36 (26–47.4) | 12.4 (6–21.5) | 7.2 (2.7–15.1) | 22.9 (14.4–33.4) | 32.5 (22.6–43.7) | 10.5 (4.7–20) | 33.7 (23.7–45) |
| Japan (Osaka) | 25.7 (12.5–43.3) | 16.2 (6.2–32) | 0 | 0 | 16.2 (6.2–32) | 13.5 (4.5–28.8) | 8.6 (1.8–32.1) | 11.1 (3–26.1) |
| Australia | | | | | | | | |
| Tasmania | 62.7 (51.3–73) | 55.3 (45–66) | 12.1 (6.2–21) | 7.5 (3.1–14.7) | 22.3 (14.4–32.1) | 30.9 (21.7–41.2) | 6.5 (2.4–13.7) | 42.6 (32.4–53) |
| Caribbean | | | | | | | | |
| Cuba (Havana) | 49.4 (37.8–61) | 35 (24.5–47) | 19.5 (11.3–30) | 18.2 (10.3–29) | 20.8 (12.4–31.5) | 28.6 (18.8–40) | 26.3 (17–37.7) | 32.5 (22.2–44) |
| Mediterranean | | | | | | | | |
| Libya | 65 (48.3–79.4) | 39 (24–55.5) | 19.5 (8.8–35) | 12.2 (4.1–26.2) | 4.9 (0.6–16.5) | 14.6 (5.6–29.2) | 15 (5.7–29.8) | 25 (12.7–41.2) |
| Israel | 38.9 (30.7–47.5) | 34.5 (27–43) | 11.5 (6.7–18) | 6.5 (3–11.9) | 26.6 (19.5–34.8) | 17.3 (11.4–24.6) | 13 (7.9–19.8) | 27.5 (20.3–36) |
| N America | | | | | | | | |
| Pittsburgh | 35.7 (28.5–43.3) | 25.6 (19–33) | 15.9 (10.8–22.1) | 3.4 (1.3–7.3) | 9.7 (5.7–15) | 18.8 (13.3–25.3) | 9.3 (5.3–14.8) | 9.7 (5.8–15.1) |
| S America | | | | | | | | |
| Brazil (Rio de Janeiro) | 62.5 (40.6–81.2) | 33.3 (15.6–55.3) | 9.1 (1.1–29.2) | 12.5 (2.7–32.4) | 41.7 (22.1–63.4) | 50 (29.1–70.9) | 20.8 (7.1–42.2) | 34.8 (16.4–57.3) |
| Argentina (Rosario) | 35.3 (22.4–49.9) | 9.6 (3.2–21) | 17.3 (8–30.3) | 3.9 (0.5–13.2) | 8.2 (2.3–19.6) | 19.2 (9.5–32.5) | 1.9 (0.05–10) | 29.4 (17.5–44) |
| Europe | | | | | | | | |
| Sweden (County Skaraborg) | 37.5 (27.4–38.5) | 28.7 (20–38.6) | 5 (1.6–11.3) | 4 (1.1–9.8) | 5 (1.6–11.3) | 26.3 (17.9–36.1) | 3.3 (0.7–9.3) | 12.9 (7–21) |

**Key:** *Prevalence, by self-report, of retinopathy, laser therapy, neuropathy, hyperlipidaemia (high cholesterol or high triglycerides), hypertension, any macrovascular disease, and any renal disease; MNSI indicates prevalence of neuropathy by the Michigan Neuropathy Screening Instrument questionnaire.

**Fig. 2**
A multinational assessment of complications in type 1 diabetes: the DiaMond substudy of complications (DiaComp) level 1 (Reprinted by Permissions of SAGE. Original source: Walsh MG, Zgibor J, Vorch-Johnen K, Orchard TJ. Diabetes Vasc Dis Res 2006;3:84–92, Table 3, pg. 88)

In addition, regional variation in diabetic foot lesions and amputations has been observed within and among countries (Margolis et al. *2011*; Morbach et al. *2004*; van Houtum and Lavery *1996*; Wrobel et al. *2001*). In the Netherlands, a wide variation in the incidence of lower extremity amputations was observed among their 27 health regions (van Houtum and Lavery *1996*). Among men, the incidence ranged from 12.8 to 53.4 per 10,000, and among women, the incidence ranged from 5.7 to 59.2 per 10,000 among health regions (van Houtum and Lavery *1996*). In nearly all health regions, the incidence rates of lower extremity amputation were higher for men than for women. This is possibly due to differences in risk factor burden between men and women. Morbach and colleagues assessed

differences in clinical presentation and risk factors among 613 patients with diabetes from Germany, Tanzania, and India (Morbach et al. *2004*). Similarly, to the Netherlands, there was a predominance of men with diabetic foot lesions in all three centers. However, there were differences in age, diabetes duration, and peripheral vascular disease, and the precipitating factors contributing to injury were observed (Morbach et al. *2004*). In a cross-sectional population-based study of Medicare recipients in the USA, rates of major amputations were assessed among hospital referral regions (Wrobel et al. *2001*). Rates of major amputations were tenfold higher among people with diabetes compared to those without diabetes. Geographic variation was observed in both those with and without diabetes, and the patterns were distinct between the populations. In addition, geographic variation among people with diabetes was 8.6-fold compared to 6.7-fold in those without diabetes across hospital referral regions for major amputations (Wrobel et al. *2001*).

## Review of the Evidence: Practice Variation in Mortality

Table 7 describes studies measuring geographic variation in mortality among people with type 1 and type 2 diabetes (Diabetes Epidemiology Research International Mortality Study Group *1991*; Lozano et al. *2012*; Matsushima et al. *1997*; Sargen et al. *2013*). In people with type 1 diabetes, marked variation in mortality has been noted among countries (Diabetes Epidemiology Research International Mortality Study Group *1991*; Matsushima et al. *1997*). In the WHO DiaMond project, more than a tenfold difference in mortality was observed between developed countries and Eastern Europe populations in people with type 1 diabetes (Matsushima et al. *1997*). Areas with higher incidences have been observed to have lower mortality. There may be several patient, care provider, and health system factors contributing to this variation. For example, this may reflect greater expertise among healthcare providers caring for children and adolescents with type 1 diabetes (Matsushima et al. *1997*). More recently the Global Burden of Diseases, Injuries, and Risk Factors Study 2010 estimated global mortality in a number of conditions and diseases (Lozano et al. *2012*). Diabetes deaths almost doubled between 1980 and 2010, with diabetes now ranking in the top ten causes of death globally. Years of life lost (YLL) varied markedly regionally, being the second highest cause of years of life lost in Oceania to the 33rd in Eastern Europe (Lozano et al. *2012*).**Table 7**
Studies measuring variation in mortality in patients with diabetes

| Source | Population studied | Geographical unit analyzed | Outcomes measured | Main results |
|---|---|---|---|---|
| Sargen et al. *2013* | US Medicare beneficiaries with diabetic foot ulcers ( *n* = 682,887) and lower extremity amputations ( *n* = 151,752), 2007 | US geographic regions | Mortality rates | Geographic variation in Medicare spending and mortality rates for diabetic patients with foot ulcers and amputations is associated with regional differences in the utilization of inpatient services and the |

| | | | | |
|---|---|---|---|---|
| | | | | prevalence of macrovascular complications |
| Lozano et al. *2012* | Global assessment of cause of death trends across 187 countries, 1980–2010 | Global regions, time | Annual cause-specific mortality | Number of deaths due to diabetes has doubled from 1990 (~665,000 deaths) to 2010 (~1.3 million deaths). Diabetes was the 15th leading cause of death in 1990 and the 9th in 2010. In 2010, the regional ranking for years of life lost due to diabetes ranged from 2 to 33 among the leading cause of deaths |
| Matsushima et al. *1997* | Data from the WHO DiaMond project. Patients with a diagnosis of type 1 diabetes, aged 0–24 in 1989 or 1990 | Intercountry comparisons | Incidence rates and case fatality rates | Tenfold variation in mortality across countries. Japan (mortality rate ratio [MRR] 4.77), Russia (MRR 5.72), Rumania (MRR 9.86), and Bulgaria (9.92) had the highest case fatality rates (Norway was the reference country) |
| Patrick et al. *1992* | 2,380 patients with type 1 diabetes, <18 years of age, 1965–1979 | Japan versus Allegheny County, PA, USA | Renal disease mortality | Tenfold increased risk of renal disease mortality in Japan versus the USA (age-adjusted renal disease mortality rate was 267.7/100,00 person-years for Japan versus 22.8/100,000 person-years for |

| | | | | |
|---|---|---|---|---|
| | | | | the USA) |
| Diabetes Epidemiology Research International Study *1991* | 8,138 patients with type 1 diabetes, <18 years of age, 1965–1985 | Allegheny County, PA, USA, Finland, Israel, Japan | Overall mortality | 20-year duration results: 5.5 % mortality rate Allegheny County, 3.1 % Finland, 4.6 % Israel. The age-adjusted mortality rate (n/100,000 person-years) in Japan (681) and the USA (230) were higher than Finland (171) and Israel (131) |

# Reducing Practice Variation in Diabetes Care

Unwarranted variation in the provision of effective diabetes care is a serious and ubiquitous problem as demonstrated in the vast literature summarized above. The significant care gaps and variation in care have not gone unrecognized by the healthcare community, and as such, several strategies have been tested in an effort to improve diabetes care. Evidence-based diabetes care guidelines recommend the organization of diabetes care be patient centric and be delivered using a chronic care model (American Diabetes Association *2013*; Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*). Over 40 randomized clinical trials have been conducted evaluating the effect of disease management programs on glycemic control that have shown a small improvement in HbA1c (absolute mean difference of 0.51 %) (Pimouguet et al. *2011*).

Quality improvement strategies target the patient, healthcare provider, healthcare system, or combinations of each. Others have described 11 different types of quality improvement strategies including case management, team changes, electronic patient registry, facilitated relay of information to clinicians, continuous quality improvement, audit and feedback, clinician education, clinician reminders, financial incentives, education of patients, promotion of self-management, and reminder systems (Shojania et al. *2006*; Tricco et al. *2012*). See Tricco and colleagues ( *2012*) for comprehensive definitions of each quality improvement strategy. Briefly, *case management* involves a person or multidisciplinary team that helped with coordination of care including diagnoses, treatments, and navigating the health system (e.g., arranging referrals); *team changes* usually involve the addition of another health professional to the team or reorganization to a multidisciplinary team; *electronic patient registries* allow for tracking patients with a particular condition (e.g., diabetes); *facilitated relay of information to clinicians* involves the transmission of clinical information from patients to clinicians that would not be included in the existing medical record; *continuous quality improvement* is a process that involves assessing a current process, designing a solution, testing the solution, and then reassessing the need for further improvement; *audit and feedback* involves providing the clinician with a summary of performance, often benchmarked with their peers; *clinician education* is varied and may include conferences or workshops, print material, or more specialized educational outreach programs such as academic detailing; *clinician reminders* include either paper or

electronic systems to prompt a healthcare professional at the point of care; *financial incentives* may be positive or negative and are often linked to providing a specific process of care or achieving a target outcome; *education of patients* often involves face-to-face education by a health professional either in an individual or group setting, but it may include the distribution of print or electronic material; *promotion of self-management* includes interventions aimed at helping achieve personal goals, setting action plans, and helping with access to resources (e.g., blood glucose meter); *patient reminders* involve contacting the patient through any means (e.g., telephone, email) to remind them of an upcoming appointment or an element of self-care.

As of July 2010, there had been almost 150 individual or cluster randomized clinical trials conducted that evaluated the effect of quality improvement interventions on diabetes quality of care (Tricco et al. *2012*). In general, key process measures and intermediate outcomes were improved using a variety of quality improvement strategies (Fig. 3). However, the risk of bias in almost half of the quality improvement trials for diabetes was estimated to be high with loss to follow-up being a common problem (Ivers et al. *2013*). Unfortunately, there is no indication that the risk of bias in quality improvement trials is improving over time. Moreover, the body of literature surrounding quality improvement strategies is large and complex given the various types of interventions and variability in the risk of bias. The impact of these interventions on medical practice variation has not been well studied, and certain quality improvement strategies (e.g., financial incentives [see discussion below]) may increase disparities among certain groups. Despite these limitations, effective quality improvement strategies are critical for improving evidence-based diabetes care and potentially decreasing medical practice variation. Further studies are required to examine how specific quality improvement strategies impact variation in care. Selected quality improvement strategies are discussed below and were applicable in the context of unwarranted practice variation.

| | Studies (imputed SDs) | Number of patients | Median baseline compliance (IQR) | Median baseline values (IQR) | $I^2$ | Pooled effect (95% CI)* |
|---|---|---|---|---|---|---|
| **Dichotomous outcomes** | | | | | | |
| Aspirin use | 11 | 2258 | 10·5% (0·2 to 25·8) | NA | 38·5% | 1·33 (1·21 to 1·45) |
| Statin use | 10 | 1853 | 32·76% (20·4 to 42·8) | NA | 58·2% | 1·12 (0·99 to 1·28) |
| Antihypertensive drug use | 10 | 2264 | 61·35% (55·0 to 74·0) | NA | 91·4% | 1·17 (1·01 to 1·37) |
| Retinopathy screening | 23 | 10455 | 84·53% (57·4 to 98·0) | NA | 80·4% | 1·22 (1·13 to 1·32) |
| Renal screening | 14 | 7317 | 50·5% (21·3 to 67·8) | NA | 91·6% | 1·28 (1·13 to 1·44) |
| Foot screening | 22 | 8144 | 47·0% (39·0 to 65·0) | NA | 89·4% | 1·27 (1·16 to 1·39) |
| Hypertension control | 18 | 3813 | 69·5% (44·5 to 76·0) | NA | 67·5% | 1·01 (0·96 to 1·07) |
| Smoking cessation | 13 | 3231 | 19·8% (16·3 to 31·8) | NA | 5·3% | 1·13 (0·99 to 1·29) |
| Hypoglycaemia | 5 | 987 | NA | NA | 0 | 0·99 (0·75 to 1·31) |
| Severe hypoglycaemia | 6 | 1450 | NA | NA | 66·8% | 1·0 (0·66 to 1·51) |
| Hyperglycaemia | 2 | 450 | NA | NA | 87·4% | 0·74 (0·28 to 1·92) |
| **Continuous outcomes** | | | | | | |
| $HbA_{1c}$ (%) | 120 (28) | 22811 | NA | 8·19 (7·57 to 9·20) | 73·5% | −0·37 (−0·45 to −0·28) |
| LDL cholesterol (mmol/L) | 47 (15) | 11676 | NA | 2·93 (2·71 to 3·20) | 48·3% | −0·10 (−0·05 to −0·14) |
| Systolic blood pressure (mm Hg) | 65 (19) | 14791 | NA | 139·75 (132·69 to 145·06) | 60·3% | −3·13 (−4·06 to −2·19) |
| Diastolic blood pressure (mm Hg) | 61 (4) | 12808 | NA | 80·00 (76·67 to 83·27) | 59·0% | −1·55 (−2·15 to −0·95) |

Effective sample size was used for cluster trials. $HbA_{1c}$=glycated haemoglobin. NA=not applicable. *Data are relative risk for dichotomous outcomes and mean difference for continuous outcomes.

*Table 2:* **Meta-analysis results across all outcomes**

**Fig. 3**

Effectiveness of quality improvement strategies on the management of diabetes: a systematic review and meta-analysis (Reprinted from Tricco et al. *2012*)

## Quality Improvement at the Health System Level

Measurement itself may facilitate change (Campbell et al. *2002*; Donabedian *2005*). In fact, several jurisdictions have embraced the measurement and reporting of key diabetes indicators. These often are in the form of an "atlas" which illustrates variation in process and outcomes of care by integrating healthcare data and geographical information systems (Table 4). In addition to static print versions, many atlases offer interactive features on their websites and allow users to query local prevalence, incidence, and quality indicator parameters. Information from these atlases may be used to inform local or national policies and monitor for improvements in diabetes quality indicators assuming the atlases will be ongoing. The geographical unit used within each atlas is usually directly relevant to the local healthcare governance (e.g., primary care trusts in the UK, provincial health authorities in Canada, or hospital referral regions), but may be as granular as specific metropolitan neighborhoods (e.g., Toronto Diabetes Atlas).

Of the quality improvement strategies that target health systems, case management and team changes have been associated with a clinically meaningful degree of improvement in blood glucose control (e.g., greater than 0.5 % decrease in HbA1c). Tricco and colleagues ( *2012*) pooled 57 and 47 quality improvement trials assessing the effect of case management and team change interventions on HbA1c, LDL, and blood pressure. Case management was associated with an improvement in all three outcomes: mean difference (MD) in HbA1c (%) −0.50, 95 % CI −0.65 to −0.36; MD LDL (mmol/L) −0.11, 96 % CI −0.21 to −0.02; systolic blood pressure (mmHg) MD −4.65, 95 % CI −7.73 to −1.52; and diastolic blood pressure (mmHg) MD −0.93, 95 % CI −1.71 to −0.16. Team changes were associated with similar changes: mean difference (MD) in HbA1c (%) −0.57, 95 % CI −0.71 to −0.42; MD LDL (mmol/L) −0.17, 96 % CI −0.27 to −0.07; systolic blood pressure (mmHg) MD −4.32, 95 % CI −6.12 to −2.51; and diastolic blood pressure (mmHg) MD −0.1.75, 95 % CI −1.71 to −0.16. The effect of these interventions was more pronounced with higher baseline values of HbA1c, LDL, and blood pressure. It is important to note that the effect of these interventions on medical practice variation was not directly studied and it is unknown if unwarranted variations were reduced.

## Quality Improvement at the Healthcare Provider Level

There are numerous single provider-level interventions that have been shown to modestly improve the quality of diabetes care. One popular intervention has been to provide financial incentives to improve quality of care. These pay for performance schemes are designed to change provider behavior by linking financial incentives with the provision of evidence-based care (i.e., quality indicators) with the goal of improving patient outcomes. The financial incentive may be at the level of the hospital, group practice, or individual clinician. Despite the growing prevalence of pay for performance schemes in the USA and Europe, there is a lack of rigorous evidence suggesting they improve the quality of care (Flodgren et al. *2011*; Houle et al. *2012*; Scott et al. *2011*). In one systematic review of the literature, the authors found that studies without a control group showed an improvement in quality of care when individual physicians were provided a financial incentive linked to a quality indicator; however, studies with a control group did not consistently indicated an improvement (Houle et al. *2012*).

One of the most well-known pay for performance schemes is the UK Quality and Outcomes Framework (QOF [ www.qof.ic.nhs.uk]). The QOF provides a financial incentive for general practitioners in the UK at the level of the group practice. The voluntary program was introduced in 2004 and incentivizes better care for patients in the UK through allowing group practices to earn a percentage above their baseline salary by achieving prespecified thresholds that are quality indicators. There are points associated with each indicator, and the more points a practice receives, the higher

their remuneration. In 2013/2014 there were 16 performance targets specific to diabetes (there were 21 diabetes-specific indicators in 2004). These quality indicators include the presence of a diabetes registrar, three HbA1c goals, two blood pressure goals, and one cholesterol goal, annual albumin–creatinine ratio testing, annual retinal screening, annual foot exam, annual dietary review, referral to a structured education program, treatment with an ACE inhibitor for patients with kidney disease, query male patients regarding erectile dysfunction, and offer advice and assess contributory factors and treatment options for erectile dysfunction. Campbell and colleagues ( *2009*) conducted an interrupted time series to evaluate the impact of the implementation of the QOF on the quality of care. They found that the mean clinical quality score for patients with diabetes increased from 70.4 before the introduction of the QOF (2003) to 81.4 in the period after (2005). The mean clinical quality score remained at a similar level in 2007 (83.7) indicating that quality of care did not maintain the same level of improvement.

There are several well-documented criticisms of pay for performance systems including that they lead not to better care, but simply better documentation and any improvements gained are likely lost when the incentive is withdrawn (Lorincz et al. *2013*). Once pay for performance systems are in place, any benefits gained may be lost after the pay for performance scheme is discontinued (Lester et al. *2010*). Lester and colleagues ( *2010*) reported a 3 % decline in retinopathy screening rates each year following the removal of financial incentives and other supports. Moreover, others have pointed out the potential harms of paying for performance in that they may promote a narrow focus of care by improving tasks that are incentivized but neglecting other non-incentivized tasks (Doran and Kontopantelis *2013*). This in turn may compromise the continuity of care and widen health disparities. Studies to date have had mixed results in respect to showing a reduction in disparities in care with some studies indicating patients with a lower socioeconomic status have worse, better, or the same achievement of quality indicators as those with a higher socioeconomic status (Lorincz et al. *2013*). Therefore, it is unknown whether QOF has led to less practice variation as existing disparities in quality of care may still exist for certain subpopulations.

An alternative approach to remuneration has been incentive through recognition. For example, the US National Committee for Quality Assurance (NCQA), in conjunction with the American Diabetes Association, administers the Diabetes Recognition Program. This program rewards individual clinicians by recognizing the high level of care they provide to their patients with diabetes. Clinicians are required to provide evidence that they meet national quality standards for 11 diabetes performance indicators. As of June 2013, there were over 8,000 clinicians in the USA listed on the clinician recognition directory for the Diabetes Recognition Program.

Other quality improvement strategies aimed at the individual healthcare provider include audit and feedback, clinician education, and clinician reminders. The impact of audit and feedback appears to be modest at best and highly dependent on quality of feedback and baseline performance (Ivers et al. *2012*). Clinician education often has little effect on behavior change; however, some educational outreach programs such as academic detailing have been shown to be effective (O′Brien et al. *2007*). Clinical practice guidelines have become a common tool to translate research evidence into practice. Unfortunately the effect of guidelines has been minimal at best in changing actual practice. Interestingly, recent clinical practice guidelines have been putting more effort into knowledge translation and dissemination. The 2013 Canadian Diabetes Association Clinical Practice Guidelines have integrated videos, patient cases, and other tools for healthcare professionals to aid in the integration of the guidelines into practice.

As described above, quality improvement strategies aimed at the individual clinician involve several approaches; however, in general these approaches do not appear to have as large of impact as those aimed at the healthcare system or individual patient (Tricco et al. *2012*).

## Quality Improvement at the Patient Level

Patient-level quality improvement strategies include educating patients, promoting self-management, and reminder systems. As previously mentioned self-management is a critical component of diabetes care, and quality improvement strategies aim to increase the patient participation in both self-monitoring of diabetes and decision-making. Promotion of self-management has been shown to be one of the most effective quality improvement strategies for numerous diabetes outcomes including HbA1c (pooled MD −0.57 %, 95 % CI −0.83 % to −0.31 %), LDL (pooled MD −0.18 mmol/L, 95 % CI −0.26 mmol/L to −0.10 mmol/L), systolic blood pressure (pooled MD −3.69 mmHg, 95 % CI −5.04 to −2.34 mmHg), and diastolic blood pressure (pooled MD −1.89 mmHg, 95 % CI −2.94 to −0.84 mmHg). In addition to these intermediate outcomes, promotion of self-management has been associated with an improved quality of life, weight loss, and cardiovascular fitness (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee *2013*). Again, the impact of these patient-level quality improvement strategies on reducing unwarranted medical practice variations is unknown and an area for future studies.

# Concluding Remarks

Although the body of literature describing medical practice variation in diabetes is growing and relatively comprehensive, much of the current literature consists of descriptive studies. Due to differences in study design and population, these studies are difficult to compare or pool the results. For example, the geographical unit itself is not homogenous across studies, even within the same country. Within the same country, studies may analyze variation at the metropolitan level, county level, provincial or state level, regional level, hospital level, hospital region, or group medical practice level. Withstanding these limitations, the literature consistently demonstrates that significant variation exists in access to quality diabetes care. There remain significant gaps in our understanding of why variation exists. As more sophisticated ways to measure quality of care are developed, future studies will enhance our ability to measure quality. Given the wide variation in the uptake of effective diabetes care treatments and strategies across various locales, it is imperative that researchers continue to explore and test hypothesis surrounding why these variations exist and how to minimize their existence.

**Acknowledgments**
Dr. Gamble is currently supported as a Canadian Institutes of Health Research New Investigator and a Canadian Diabetes Association Clinician Scientist.

# References

Agency for Healthcare Research and Quality. National healthcare quality report 2012. Rockville: U.S. Department of Health and Human Services; 2013.

Alberti H, Boudriga N, Nabli M. Variations in care in diabetes in primary care centres in Tunis. Diabet Metab. 2004;30:197–200.

Ali MK, Bullard KM, Saaddine JB, et al. Achievement of goals in U.S. diabetes care, 1999–2010. N Engl J Med. 2013;368:1613–24.
PubMed

Amed S, Dean HJ, Panagiotopoulos C, et al. Type 2 diabetes, medication-induced diabetes, and monogenic diabetes in Canadian children. Diabetes Care. 2010;33:786–91.
PubMedCentral PubMed

American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care. 2009;32 Suppl 1:S62–7.
PubMedCentral

American Diabetes Association. Standards of medical care in diabetes – 2014. Diabetes Care. 2013;37:S14–80.

American Diabetes Association Workgroup on Hypoglycemia. Defining and reporting hypoglycemia in diabetes. Diabetes Care. 2005;28:1245–9.

Andrus MR, Kelley KW, Murphey LM, Herndon KC. A comparison of diabetes care in rural and urban medical clinics in Alabama. J Community Health. 2004;29:29–44.
PubMed

Arday DR, Fleming BB, Keller DK, et al. Variation in diabetes care among states: do patient characteristics matter? Diabetes Care. 2002;25:2230–7.
PubMed

Aro S, Koivisto VA, Reunanen A, Salinto M, Kangas T. Influence of morbidity and health care structure on hospitalization among adult diabetic patients. Diabet Med. 1996;13:376–81.
PubMed

Asghari S, Courteau J, Orzanco M, Vanasse A. Do geographical disparities affect the pattern of medication use in diabetic patients? Can J Diabetes. 2009;33:228.

Bergman U, Elmes P, Halse M, et al. The measurement of drug consumption. Drugs for diabetes in Northern Ireland, Norway and Sweden. Eur J Clin Pharmacol. 1975;8:83–9.
PubMed

Berkowitz SA, Gerstenblith G, Herbert R, Anderson G. Improving regional variation using quality of care measures. Risk Manag Healthc Policy. 2009;2:91–96.
PubMedCentral PubMed

Booth GL, Hux JE. Relationship between avoidable hospitalizations for diabetes mellitus and income level. Arch Intern Med. 2003;163:101–6.
PubMed

Booth GL, Zinman B, Redelmeier DA. Diabetes care in the U.S. and Canada. Diabetes Care. 2002;25:1149–53.
PubMed

Booth GL, Hux JE, Fang J, Chan BTB. Time trends and geographic disparities in acute complications of diabetes in Ontario. Can Diabetes Care. 2005;28:1045–50.
PubMed

Borchers AT, Uibo R, Gershwin ME. The geoepidemiology of type 1 diabetes. Autoimmun Rev. 2010;9:A355–65.
PubMed

Bowker S, Majumdar S, Johnson J. Systematic review of indicators and measurements used in controlled studies of quality improvement for type 2 diabetes. Can J Diabetes. 2005;29:230–8.

Braga M, Casanova A, Teoh H, et al. Treatment gaps in the management of cardiovascular risk factors in patients with type 2 diabetes in Canada. Can J Cardiol. 2010;26:297–302.
PubMedCentral PubMed

Brahm N, McKee J, Steward D. Diabetes mellitus. In: DiPrio JT, Talbert RL, Yee GC, Matzke GR, Wells BG, Posy LM, editors. Pharmacotherapy a pathophysiologic approach. 8th ed. Toronto: McGraw-Hill; 2011.

Brown LJ, Barnett JR. Influence of bed supply and health care organization on regional and local patterns of diabetes related hospitalization. Soc Sci Med. 1992;35:1157–70.
PubMed

Campbell SM, Braspenning J, Hutchinson A, Marshall M. Research methods used in developing and applying quality indicators in primary care. Qual Saf Health Care. 2002;11:358–64.
PubMedCentral PubMed

Campbell SM, Reeves D, Kontopantelis E, Sibbald B, Roland M. Effects of pay for performance on the quality of primary care in England. N Engl J Med. 2009;361:368–78.
PubMed

Canadian Diabetes Association. An economic tsunami, the cost of diabetes in Canada. Toronto: Canadian Diabetes Association; 2009.

Canadian Diabetes Association Clinical Practice Guidelines Expert Committee. Canadian Diabetes Association 2013 clinical practice guidelines for the prevention and management of diabetes in Canada. Can J Diabetes. 2013;37 Suppl 1:S1–212.

Centers for Disease Control and Prevention. National diabetes fact sheet: national estimates and general information on diabetes in the United States. Atlanta: US Department of Health and Human Services/Centers for Disease Control and Prevention; 1997.

Chan BT, Harju M. Supply and utilization of health services for diabetes. In: Hux J, Booth G, Slaughter P, Laupacis A, editors. Diabetes Australia and the National Health and Medical Research Council. Toronto: Institute for Clinical Evaluative Sciences; 2003. p. 14.249–14.68.

Chen H-F, Wang C-Y, Lee H-Y, et al. Short-term case fatality rate and associated factors among inpatients with diabetic ketoacidosis and hyperglycemic hyperosmolar state: a hospital-based analysis over a 15-year period. Intern Med. 2010;49:729–37.
PubMed

Chiasson J, Aris-Jilwan N, Bélanger R, et al. Diagnosis and treatment of diabetic ketoacidosis and the hyperglycemic hyperosmolar state. CMAJ. 2003;168:859–66.
PubMedCentral PubMed

Chudyk A, Petrella R. Effects of exercise on cardiovascular risk factors in type 2 diabetes. Diabetes Care. 2011;34:1228–37.
PubMedCentral PubMed

Colagiuri S, Dickinson S, Girgis S, Colagiuri R. National evidence based guideline for blood glucose control in type 2 diabetes. Diabetes Australia and the NHMRC. Canberra; 2009.

Colberg SR, Sigal RJ, Fernhall B, et al. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. Diabetes Care. 2010;33:e147–67.
PubMedCentral PubMed

Connell FA, Blide LA, Hanken MA. Clinical correlates of small area variations in population-based admission rates for diabetes. Med Care. 1984;22:939–49.
PubMed

Cook CB, Elias B, Kongable GL, et al. Diabetes and hyperglycemia quality improvement efforts in hospitals in the United States: current status, practice variation, and barriers to implementation. Endocr Pract. 2010;16:219–30.
PubMed

Curtis JR, To T, Muirhead S, Cummings E, Daneman D. Recent trends in hospitalization for diabetic ketoacidosis in Ontario children. Diabetes Care. 2002;25:1591–6.
PubMed

Danaei G, Finucane MM, Lu Y, et al. National, regional, and global trends in fasting plasma glucose and diabetes prevalence since 1980: systematic analysis of health examination surveys and epidemiological studies with 370 country-years and 2.7 million participants. Lancet. 2011;378:31–40.
PubMed

De Berardis G, Pellegrini F, Franciosi M, et al. Quality of care and outcomes in type 2 diabetic patients: a comparison between general practice and diabetes clinics. Diabetes Care. 2004;27:398–406.
PubMed

Diabetes Epidemiology Research International Mortality Study Group. Major cross-country differences in risk of dying for people with IDDM. Diabetes Care. 1991;14:49–54.

Donabedian A. Evaluating the quality of medical care. 1966. Milbank Q. 2005;83:691–729.
PubMedCentral PubMed

Donnelly LA, Morris AD, Frier BM, et al. Frequency and predictors of hypoglycaemia in type 1 and insulin-treated type 2 diabetes: a population-based study. Diabet Med. 2005;22:749–55.
PubMed

Doran T, Kontopantelis E. Pay-for-performance: impact on diabetes. Curr Diab Rep. 2013;13:196–204.
PubMed

Driskell OJ, Holland D, Hanna FW, et al. Inappropriate requesting of glycated hemoglobin (Hb A1c) is widespread: assessment of prevalence, impact of national guidance, and practice-to-practice variability. Clin Chem. 2012;58:906–15.
PubMed

Duckworth W, Abraira C, Moritz T, et al. Glucose control and vascular complications in veterans with type 2 diabetes. N Engl J Med. 2009;360:129–39.
PubMed

Efstathiou SP, Tsiakou AG, Tsioulos DI, et al. A mortality prediction model in diabetic ketoacidosis. Clin Endocrinol. 2002;57:595–601.

Egede LE, Gebregziabher M, Hunt KJ, et al. Regional, geographic, and racial/ethnic variation in glycemic control in a national sample of veterans with diabetes. Diabetes Care. 2011;34:938–43.
PubMedCentral PubMed

EURODIAB ACE Study Group. Variation and trends in incidence of childhood diabetes in Europe. Lancet. 2000;355:873–6.

Felner EI, Klitz W, Ham M, et al. Genetic interaction among three genomic regions creates distinct contributions to early- and late-onset type 1 diabetes mellitus. Pediatr Diabetes. 2005;6:213–20.
PubMed

Feltbower RG, Bodansky HJ, Patterson CC, et al. Acute complications and drug misuse are important causes of death for children and young adults with type 1 diabetes. Diabetes Care. 2008;31:922–6.
PubMed

Fishbein H, Palumbo P, editors. Acute metabolic complications in diabetes. 2nd ed. Bethesda: National Institutes of Health/National Institute of Diabetes and Digestive and Kidney Diseases; 1995.

Fleming BB, Greenfield S, Engelgau MM, et al. The Diabetes Quality Improvement Project: moving science into health policy to gain an edge on the diabetes epidemic. Diabetes Care. 2001;24:1815–20.
PubMed

Flodgren G, Eccles MP, Shepperd S, et al. An overview of reviews evaluating the effectiveness of financial incentives in changing healthcare professional behaviours and patient outcomes. Cochrane Database Syst Rev. 2011:7:CD009255.

Forlenza GP, Rewers M. The epidemic of type 1 diabetes: what is it telling us? Curr Opin Endocrinol Diabetes Obes. 2011;18:248–51.
PubMed

Gaede P, Vedel P, Larsen N, et al. Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. N Engl J Med. 2003;348:383–93.
PubMed

Gaede P, Lund-Andersen H, Parving H, Pedersen O. Effect of a multifactorial intervention on mortality in type 2 diabetes. N Engl J Med. 2008;358:580–91.
PubMed

Garber AJ, Abrahamson MJ, Barzilay JI, et al. American Association of Clinical Endocrinologists' comprehensive diabetes management algorithm 2013 consensus statement. Endocr Pract. 2013;19:1–48.

Gellad WF, Good CB, Lowe JC, Donohue JM. Variation in prescription use and spending for lipid-lowering and diabetes medications in the Veterans Affairs Healthcare System. Am J Manag Care. 2010;16:741–50.
PubMedCentral PubMed

Gerstein HC, Miller ME, Byington RP, et al. Effects of intensive glucose lowering in type 2 diabetes. N Engl J Med. 2008;358:2545–59.
PubMed

Glazier R, Creatore M, Gozdyra P, Weyman J, Booth G. Access to health resources. In: Glazier R, Booth G, Gozdyra P, Creatore M, Tynan A, editors. Neighbourhood environments and resources for health living – a focus on diabetes in Toronto. Toronto: Institute for Clinical Evaluative Sciences; 2007. p. 272–84.

Goldenberg RM, Cheng AY, Punthakee Z, Clement M. Use of glycated hemoglobin (A1C) in the diagnosis of type 2 diabetes mellitus in adults. Can J Diabetes. 2011;35:247–9.

Griffiths K, McDevitt DG, Andrew M, et al. Validation of observed differences in the utilization of antihypertensive and antidiabetic drugs in Northern Ireland, Norway and Sweden. Eur J Clin Pharmacol. 1985;29:1–8.
PubMed

Griffiths K, McDevitt DG, Andrew M, et al. Therapeutic traditions in Northern Ireland, Norway and Sweden: I. Diabetes. WHO Drug Utilization Research Group (DURG). Eur J Clin Pharmacol. 1986;30:513–9.
PubMed

Gulliford M, Figueroa-Munoz J, Morgan M, et al. What does ‘access to health care’ mean? J Health Serv Res Policy. 2002;7:186–8.
PubMed

Gulliford MC, Charlton J, Latinovic R. Trends in antihypertensive and lipid-lowering therapy in subjects with type II diabetes: clinical effectiveness or clinical discretion? J Hum Hypertens. 2005;19:111–7.
PubMed

Guzman JR, Lyra R, Aguilar-Loza N, et al. Treatment of type 2 diabetes in Latin America: a consensus statement by the medical associations of 17 Latin American countries. Rev Saude Publica. 2010;28:463–71.

Haller MJ, Atkinson MA, Schatz D. Type 1 diabetes mellitus: etiology, presentation, and management. Pediatr Clin North Am. 2005;52:1553–78.
PubMed

Hamblin P, Topliss D, Chosich N, Lording D, Stockigt J. Deaths associated with diabetic ketoacidosis and hyperosmolar coma. 1973–1988. Med J Aust. 1989;151:439–44.
PubMed

Henriksen OM, Prahl JB, Roder ME, Svendsen OL. Treatment of diabetic ketoacidosis in adults in Denmark: a national survey. Diabetes Res Clin Pract. 2007;77:113–9.
PubMed

Hogan DB, Maxwell CJ, Fung TS, Ebly EM. Regional variation in the use of medications by older Canadians – a persistent and incompletely understood phenomena. Pharmacoepidemiol Drug Saf. 2003;12:575–82.
PubMed

Holleman F. Introduction. [Internet] 2013 [cited 2014 June 23]. Available from http://www.diapedia.org/introduction/1104085113/introduction

Holman RR, Paul SK, Bethel MA, Matthews DR, Neil HA. 10-year follow-up of intensive glucose control in type 2 diabetes. N Engl J Med. 2008;359:1577–89.
PubMed

Houle SK, McAlister FA, Jackevicius CA, Chuck AW, Tsuyuki RT. Does performance-based remuneration for individual health care practitioners affect patient care?: a systematic review. Ann Intern Med. 2012;157:889–99.
PubMed

Institute of Medicine. Health, health care, and quality of care. In: Lohr KN, editor. Medicare: a strategy for quality assurance. Washington, DC: National Academy Press; 1990:19–44.

Institute of Medicine. In: Millman MPD, editor. A Model for Monitoring Access. Access to health care in America. Washington, DC: The National Academies Press; 1993:31045.

International Diabetes Federation. Global guideline for type 2 diabetes. Brussels: International Diabetes Federation; 2005.

International Diabetes Federation. About diabetes. [Internet] 2014 [cited 2014 June 23]. Available from http://www.idf.org/about-diabetes

International Diabetes Federation. IDF Diabetes Atlas sixth edition. 2013 [cited 2014 June 23]. Available from http://www.idf.org/diabetesatlas

Ivers N, Jamtvedt G, Flottorp S, et al. Audit and feedback: effects on professional practice and healthcare outcomes. Cochrane Database Syst Rev. 2012;6:Cd000259.
PubMed

Ivers NM, Tricco AC, Taljaard M, et al. Quality improvement needed in quality improvement randomised trials: systematic review of interventions to improve care in diabetes. BMJ Open. 2013;3:e002727.
PubMedCentral PubMed

Jarosz-Chobot P, Polanska J, Szadkowska A, et al. Rapid increase in the incidence of type 1 diabetes in Polish children from 1989 to 2004, and predictions for 2010 to 2025. Diabetologia. 2011;54:508–15.
PubMedCentral PubMed

Johnson JA, McLeod L, Edwards A, Rabi D, Balko S. Diabetes and health care utilization in Alberta. In: Johnson JA, editor. Alberta diabetes atlas 2011. Edmonton: Institute of Health Economics; 2011.

Kaul P, Johnson J, Ryan E, Chik C. Chapter 12: Gestational diabetes in Alberta. In: Johnson J, editor. Alberta diabetes atlas 2011. Edmonton: Institute of Health Economics; 2011.

Kim C, Newton KM, Knopp RH. Gestational diabetes and the incidence of type 2 diabetes. Diabetes Care. 2002;25:1862–8.
PubMed

Kirkbride K, Wallace N. Rural health clinics and diabetes-related primary care for Medicaid beneficiaries in Oregon. J Rural Health. 2009;25:247–52.
PubMed

Kitabchi AE, Umpierrez GE, Murphy MB, Kreisberg RA. Hyperglycemic crises in adult patients with diabetes. Diabetes Care. 2006;29:2739–48.
PubMed

Knowler W, Barrett-Connor E, Fowler S, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med. 2002;346:393–403.
PubMed

Ko SH, Lee WY, Lee JH, et al. Clinical characteristics of diabetic ketoacidosis in Korea over the past two decades. Diabet Med. 2005;22:466–9.
PubMed

Kodama S, Tanaka S, Heianza Y, et al. Association between physical activity and risk of all-cause mortality and cardiovascular disease in patients with diabetes a meta-analysis. Diabetes Care. 2013;36:471–9.
PubMedCentral PubMed

Krein S, Hofer T, Kerr EA, Hayward R. Whom should we profile? Examining diabetes care practice variation among primary care providers, provider groups, and health care facilities. Health Serv Res. 2002;37:1159–80.
PubMedCentral PubMed

Kristensen JK, Bro F, Sandbaek A, et al. HbAlc in an unselected population of 4438 people with type 2 diabetes in a Danish county. Scand J Prim Health Care. 2001;19:241–6.
PubMed

Law MR, Cheng L, Dhalla IA, Heard D, Morgan SG. The effect of cost on adherence to prescription medications in Canada. CMAJ. 2012;184:297–302.
PubMedCentral PubMed

Leese GP, Wild SH, Edmonds ME. Variation in practice: a useful measure or not? Looking at amputations and diabetes care. Pract Diabetes Int. 2011;28:7.

Lester H, Schmittdiel J, Selby J, et al. The impact of removing financial incentives from clinical quality indicators: longitudinal analysis of four Kaiser Permanente indicators. BMJ. 2010;340:c1898.
PubMedCentral PubMed

Lewis EJ, Hunsicker LG, Clarke WR, et al. Renoprotective effect of the angiotensin-receptor antagonist irbesartan in patients with nephropathy due to type 2 diabetes. N Engl J Med. 2001;345:851–60.

PubMed

Lin S, Lin J, Huang Y. Diabetic ketoacidosis: comparisons of patient characteristics, clinical presentations and outcomes today and 20 years ago. Chang Gung Med J. 2005;28:24–30.
PubMed

Lipscombe LL, Austin PC, Manuel DG, et al. Income-related differences in mortality among people with diabetes mellitus. Can Med Assoc J. 2010;182:E1–17.

Lorincz IS, Lawson BC, Long JA. Provider and patient directed financial incentives to improve care and outcomes for patients with diabetes. Curr Diab Rep. 2013;13:188–95.
PubMedCentral PubMed

Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380:2095–128.
PubMed

Lyon AW, Higgins T, Wesenberg JC, Tran DV, Cembrowski GS. Variation in the frequency of hemoglobin A1c (HbA1c) testing: population studies used to assess compliance with clinical practice guidelines and use of HbA1c to screen for diabetes. J Diabetes Sci Technol. 2009;3:411–7.
PubMedCentral PubMed

Majumdar SR, Johnson JA, Bowker S, et al. A Canadian consensus for the standardized evaluation of quality improvement interventions in type 2 diabetes. Can J Diabetes. 2005;29:220–9.

Margolis DJ, Hoffstad O, Nafash J, et al. Location, location, location: geographic clustering of lower-extremity amputation among Medicare beneficiaries with diabetes. Diabetes Care. 2011;34:2363–7.
PubMedCentral PubMed

Masharani U, German M. Pancreatic hormones and diabetes mellitus. In: Gardner D, Shoback D, editors. Greenspan′s basic & clinical endocrinology. 8th ed. McGraw-Hill Medical; United States of America, 2007.

Matsushima M, LaPorte RE, Maruyama M, et al. Geographic variation in mortality among individuals with youth-onset diabetes mellitus across the world. Diabetologia. 1997;40:212–6.
PubMed

Mattke S, Epstein AM, Leatherman S. The OECD Health Care Quality Indicators Project: history and background. Int J Qual Health Care. 2006;18 Suppl 1:1–4.
PubMed

McBean AM, Huang Z, Virnig BA, Lurie N, Musgrave D. Racial variation in the control of diabetes among elderly medicare managed care beneficiaries. Diabetes Care. 2003;26:3250–6.
PubMed

McGinn J, Davis C. Geographic variation, physician characteristics, and diabetes care disparities in a metropolitan area, 2003–2004. Diabetes Res Clin Pract. 2006;72:162–9.
PubMed

Metzer B. Summary and recommendations of the third international conference on gestational diabetes mellitus. Diabetes. 1991;40:197–201.

Morbach S, Lutale JK, Viswanathan V, et al. Regional differences in risk factors and clinical presentation of diabetic foot lesions. Diabet Med. 2004;21:91–5.
PubMed

Morgan S, Raymond C, Mooney D, Martin D. The Canadian Rx atlas. 2nd ed. Vancouver: The Centre for Health Services and Policy Research; 2008.

National Institute for Health and Clinical Excellence. Quality standards for diabetes in adults. 2011 [cited 2013 April 17]. Available from http://www.nice.org.uk/media/FCF/87/DiabetesInAdultsQualityStandard.pdf

Newton CA, Raskin P. Diabetic ketoacidosis in type 1 and type 2 diabetes mellitus: clinical and biochemical differences. Arch Intern Med. 2004;164:1925–31.
PubMed

Nyenwe E, Loganathan R, Blum S, et al. Admissions for diabetic ketoacidosis in ethnic minority groups in a city hospital. Metabolism. 2007;56:172–8.
PubMed

O'Brien MA, Rogers S, Jamtvedt G, et al. Educational outreach visits: effects on professional practice and health care outcomes. Cochrane Database Syst Rev. 2007:4:CD000409.

O'Connor PJ, Rush WA, Davidson G, et al. Variation in quality of diabetes care at the levels of patient, physician, and clinic. Prev Chronic Dis. 2008;5:A15.
PubMedCentral PubMed

O'Connor PJ, Bodkin NL, Fradkin J, et al. Diabetes performance measures: current status and future directions. Diabetes Care. 2011;34:1651–9.
PubMedCentral PubMed

Ohinmaa A, Jacobs P, Simpson S, Johnson J. The projection of prevalence and cost of diabetes in Canada: 2000 to 2016. Can J Diabetes. 2004;28:1–8.

Onkamo P, Väänänen S, Karvonen M, Tuomilehto J. Worldwide increase in incidence of type I diabetes – the analysis of the data on published incidence trends. Diabetologia. 1999;42:1395–403.
PubMed

Otiniano M, Wood RC. Exploring the importance of identifying geographic variation to improve diabetes treatment. J Diabetes Complications. 2012;26:255–6.
PubMed

Parving H-H, Lehnert H, Bröchner-Mortensen J, et al. The effect of irbesartan on the development of diabetic nephropathy in patients with type 2 diabetes. N Engl J Med. 2001;345:870–8.
PubMed

Patel A, MacMahon S, Chalmers J, et al. Intensive blood glucose control and vascular outcomes in patients with type 2 diabetes. N Engl J Med. 2008;358:2560–72.
PubMed

Patrick S, Tajima N, LaPorte R, Kitagawa T. A comparison of renal disease mortality among individuals with Insulin-Dependent Diabetes Mellitus (IDDM) in Japan and Allegheny County, PA, the United States. J Jpn Diabet Soc. 1992;35:993–1000.

Patterson CC, Dahlquist GG, Gyürüs E, Green A, Soltész G. Incidence trends for childhood type 1 diabetes in Europe during 1989–2003 and predicted new cases 2005–20: a multicentre prospective registration study. Lancet. 2009;373:2027–33.

PubMed

Payne CB, Scott RS. Hospital discharges for diabetic foot disease in New Zealand: 1980–1993. Diabetes Res Clin Pract. 1998;39:69–74.
PubMed

Pimouguet C, Le Goff M, Thiebaut R, Dartigues JF, Helmer C. Effectiveness of disease-management programs for improving diabetes care: a meta-analysis. CMAJ. 2011;183:E115–27.
PubMedCentral PubMed

Public Health Agency of Canada. Report from the National Diabetes Surveillance System: diabetes in Canada. Ottawa: Public Health Agency of Canada; 2009.

Radley DC, Schoen C. Geographic variation in access to care – the relationship with quality. N Engl J Med. 2012;367:3–6.
PubMed

Raymond C, Metge C, Alessi-Severini S, et al. Pharmaceutical use in Manitoba: opportunities to optimize use. Winnipeg: Manitoba Centre for Health Policy; 2010.

Rith-Najarian SJ, Gohdes DM, Shields R, et al. Regional variation in cardiovascular disease risk factors among American Indians and Alaska Natives with diabetes. Diabetes Care. 2002;25:279–83.
PubMed

Rose G, Duerksen F, Trepman E, et al. Multidisciplinary treatment of diabetic foot ulcers in Canadian Aboriginal and non-Aboriginal people. Foot Ankle Surg. 2008;14:74–81.
PubMed

Rother KI. Diabetes treatment – bridging the divide. N Engl J Med. 2007;356:1499–501.
PubMedCentral PubMed

Sargen MR, Hoffstad OJ, Wiebe DJ, Margolis DJ. Geographic variation in pharmacotherapy decisions for U.S. Medicare enrollees with diabetes. J Diabetes Complications. 2012;26:301–7.
PubMedCentral PubMed

Sargen MR, Hoffstad O, Margolis DJ. Geographic variation in Medicare spending and mortality for diabetic patients with foot ulcers and amputations. J Diabetes Complications. 2013;27:128–33.
PubMedCentral PubMed

Schneider S, Bock C, Wetzel M, Maul H, Loerbroks A. The prevalence of gestational diabetes in advanced economies. J Perinat Med. 2012;40:511–520.
PubMed

Schuyler Jones W, Patel MR, Dai D, et al. Temporal trends and geographic variation of lower-extremity amputation in patients with peripheral artery disease: results from U.S. Medicare 2000–2008. J Am Coll Cardiol. 2012;60:2230–6.
PubMedCentral PubMed

Scott A, Sivey P, Ait Ouakrim D, et al. The effect of financial incentives on the quality of health care provided by primary care physicians. Cochrane Database Syst Rev. 2011:9:CD008451.

Shah BR, Hux JE, Laupacis A, et al. Diabetic patients with prior specialist care have better glycaemic control than those with prior primary care. J Eval Clin Pract. 2005;11:568–75.
PubMed

Shah ND, Montori VM, Krumholz HM, et al. Responding to an FDA warning – geographic variation in the use of rosiglitazone. N Engl J Med. 2010;363:2081–4.
PubMed

Shojania KG, Ranji SR, McDonald KM, et al. Effects of quality improvement strategies for type 2 diabetes on glycemic control: a meta-regression analysis. JAMA. 2006;296:427–40.
PubMed

Si D, Bailie R, Wang Z, Weeramanthri T. Comparison of diabetes management in five countries for general and indigenous populations: an internet-based review. BMC Health Serv Res. 2010;10:169.
PubMedCentral PubMed

Skrivarhaug T, Bangstad HJ, Stene L, et al. Long-term mortality in a nationwide cohort of childhood-onset type 1 diabetic patients in Norway. Diabetologia. 2006;49:298–305.
PubMed

Skyler JS. Primary and secondary prevention of type 1 diabetes. Diabet Med. 2013;30:161–9.

PubMedCentral PubMed

Snorgaard O, Eskildsen P, Vadstrup S, Nerup J. Diabetic ketoacidosis in Denmark: epidemiology, incidence rates, precipitating factors and mortality rates. J Intern Med. 1989;226:223–8.
PubMed

Strauss K, MacLean C, Troy A, Littenberg B. Driving distance as a barrier to glycemic control in diabetes. J Gen Intern Med. 2006;21:378–80.
PubMedCentral PubMed

Tseng CL, Helmer D, Rajan M, et al. Evaluation of regional variation in total, major, and minor amputation rates in a national health-care system. Int J Qual Health Care. 2007;19:368–76.
PubMed

The Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. The Diabetes Control and Complications Trial Research Group. N Engl J Med. 1993;329:977–86.

The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications (DCCT/EDIC) Study Research Group. Intensive diabetes treatment and cardiovascular disease in patients with type 1 diabetes. N Engl J Med. 2005;353:2643–53.

The Diamond Project Group. Incidence and trends of childhood type 1 diabetes worldwide 1990–1999. Diabet Med. 2006;23:857–66.

The Task Force on Cardiology, Cardiovascular Diseases of the European Society of Diabetes, of the European Association for the Study of Diabetes. ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD: the Task Force on diabetes, pre-diabetes, and cardiovascular diseases of the European Society of Cardiology (ESC) and developed in collaboration with the European Association for the Study of Diabetes (EASD). Eur Heart J. 2013;34:3035–87.

Tricco AC, Ivers NM, Grimshaw JM, et al. Effectiveness of quality improvement strategies on the management of diabetes: a systematic review and meta-analysis. Lancet. 2012;379:2252–61.
PubMed

UKPDS Study Group. Effect of intensive blood-glucose control with metformin on complications in overweight patients with type 2 diabetes (UKPDS 34). Lancet. 1998a;352:854–65.

UKPDS Study Group. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). Lancet. 1998b;352:837–53.

Usher C, Bennett K, Feely J. Evidence for a gender and age inequality in the prescribing of preventative cardiovascular therapies to the elderly in primary care. Age Ageing. 2004;33:500–2.
PubMed

Usher C, Bennett K, Feely J. Regional variation in the prescribing for diabetes and use of secondary preventative therapies in Ireland. Pharmacoepidemiol Drug Saf. 2005;14:537–44.
PubMed

Usher-Smith JA, Thompson MJ, Sharp SJ, Walter FM. Factors associated with the presence of diabetic ketoacidosis at diagnosis of diabetes in children and young adults: a systematic review. BMJ. 2011;343:d4092.
PubMedCentral PubMed

van Houtum WH, Lavery LA. Regional variation in the incidence of diabetes-related amputations in the Netherlands. Diabetes Res Clin Pract. 1996;31:125–32.
PubMed

Walsh MG, Zgibor J, Borch-Johnsen K, Orchard TJ. A multinational comparison of complications assessment in type 1 diabetes: the DiaMond substudy of complications (DiaComp) level 2. Diabetes Care. 2004;27:1610–7.
PubMed

Walsh MG, Zgibor J, Borch-Johnsen K, Orchard TJ. A multinational assessment of complications in type 1 diabetes: the DiaMond substudy of complications (DiaComp) level 1. Diab Vasc Dis Res. 2006;3:84–92.
PubMed

Weingarten Jr JP, Brittman S, Hu W, et al. The state of diabetes care provided to Medicare beneficiaries living in rural America. J Rural Health. 2006;22:351–8.
PubMed

Wennberg JE. Unwarranted variations in healthcare delivery: implications for academic medical centres. BMJ. 2002;325:961–4.
PubMedCentral PubMed

Wrobel JS, Mayfield JA, Reiber GE. Geographic variation of lower-extremity major amputation in individuals with and without diabetes in the Medicare population. Diabetes Care. 2001;24:860–4.
PubMed

Yusuf S, Hawken S, Ôunpuu S, et al. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. Lancet. 2004;364:937–52.
PubMed

Zgibor JC, Gieraltowski LB, Talbott EO, et al. The association between driving distance and glycemic control in rural areas. J Diabetes Sci Technol. 2011;5:494–500.
PubMedCentral PubMed

Zhang P, Zhang X, Brown J, et al. Global healthcare expenditure on diabetes for 2010 and 2030. Diabetes Res Clin Pract. 2010;87:293–301.
PubMed