Nephrology in Canada

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Area[1]	9,093,510 km^2
Population[2]	37,590,000 (2019)
Capital	Ottawa
Three most populated cities	1. Toronto, Ontario 2. Montreal, Quebec 3. Vancouver, BC
Official languages	English and French
Gross domestic product (GDP)[3]	1.709 trillion USD (2018)
GDP per capita[3]	51,358 USD (2018)
Human Development Index (HDI)[4]	0.922 (13° position)
Official currency	Canadian dollar (C$)
Total number of nephrologists	~700
National society of nephrology[5]	Canadian Society of Nephrology www.csnscn.ca
Incidence of end-stage renal disease[6]	2016 – 202 pmp
Prevalence of end-stage renal disease[6]	2016 – 1351 pmp
Total number of patients on dialysis (all modalities)[6,7]	2017 – 22,500 (excluding Quebec) 2017 – 28,100 (estimate including Quebec)
Number of patients on hemodialysis[6,7]	2017 – 17,936 (excluding Quebec) (includes 1058 on home HD) 2017 – 23,600 (estimate including Quebec) (includes 1200 on home HD)
Number of patients on peritoneal dialysis[6,7]	2017 – 4564 (excluding Quebec) (28% CAPD and 72% APD) 2017 – 5320 (estimate including Quebec)
Number of renal transplantations per year[6,7]	2017 – 1339 (excluding Quebec) 2017 – 1580 (estimate including Quebec)

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Introduction

Any description of nephrology in Canada needs to begin with a brief review of the geography and demography of the country and of the Canadian health-care system which has some unique and highly relevant features.

Canada has a population of just over 37 million people who live in 10 provinces and 3 territories. Over 60% of the population live in just two central Canadian provinces – Ontario and Quebec. While the area of the country is very large, the overwhelming majority – about 80% – of Canadians live within 150 kilometers of the Canada-United States (US) border, and the population is predominantly urban. Canada is a wealthy country with a gross domestic product of about US$ 50,000 per capita [1, 2].

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Politically Canada is a federation which was founded in 1867 and represented a coming together of two colonial peoples – the French based mainly in what is now the province of Quebec and the British based mainly in Ontario and the Maritime provinces and later in Western Canada. The country is very multicultural with over 20% of the population having been born in another country and with over 25% belonging to a so-called visible minority. Particularly important is the approximately 4% of the population whose ancestors lived in the country before it was colonized and who are described as "First Nations" and "Inuit." The "Metis" population are a mix of First Nations and French. These three groups – the First Nations, Inuit, and Metis – are sometimes referred to collectively as "FNIM" and have suffered socioeconomic deprivation and discrimination since colonization [1, 2].

In large part because of the historical importance of ensuring the French population could maintain its culture, language, and other distinct characteristics despite its minority status within the country, Canada is a highly decentralized federation with the individual provinces having substantial power relative to the federal government. Health care, for example, is largely under provincial jurisdiction [3, 4]. The country also has a strong collectivist culture, related to the historical need to protect both French and English rights and perhaps also to its severe climate. This collectivism contrasts sharply with the much more individualistic culture of the United States and is demonstrated by a strong emphasis on government administered social programs [1, 2].

All this is reflected in the Canadian health-care system [3, 4]. The system is administered and funded at a provincial level. However, the federal government provides critical supplemental transfer payments to the individual provinces that are essential to its funding, and, in return, the provinces are required to follow the basic tenets of the federal Canada Health Act passed in 1967. Critically these include a requirement that essential health services have a single public funder only. Internationally, this is uniquely restrictive. There is no other country where essential health care cannot be paid for privately. This means that in Canada government-funded cardiac surgery or cancer chemotherapy or dialysis is available to all and cannot be paid for privately by a Canadian resident unless they leave the country to receive it. Canadian health care is therefore a true single payer system for these services. It does not however cover outpatient medications for all those aged between 18 and 65, a source of recent controversy [5]. Private provision of health care is allowed as long as it is publicly funded, and this is the case for most physician care, for most outpatient laboratory and imaging services, and for many other aspects of health care. However, "private for-profit" hospitals and private dialysis clinics are very uncommon.

For completeness it should be noted that as much as 30% of health care in Canada is paid for privately – through insurance or "out of pocket." This includes medications for most of those aged 18–65, dental care, nonessential medical care such as cosmetic surgery, a high proportion of physiotherapy, optometry, psychology, private rooms in hospitals, medical exams for insurance purposes, and so on [3, 4].

The Canadian health-care system is often criticized internationally and domestically, but it is also widely admired, and the underlying single payer principle is very popular with the general population and often seen by Canadians as a defining feature of national identity that, in particular, distinguishes the country from the neighboring United States [6, 7].

History of Nephrology in Canada

In 1945, Dr. Gordon Murray, a pioneering and somewhat controversial cardiac surgeon working in Toronto, constructed a hemodialysis (HD) machine with a cellulosic membrane and a venovenous pump as part of his investigation into heparin and extracorporeal circuits [8, 9]. He was apparently unaware of the similar and now famous work done by Dr. Willem Kolff in 1943 in German-occupied Netherlands. In 1946, Murray carried out the first successful HD in Canada for a young woman with acute kidney injury (AKI) [9].

The same Dr. Murray turned his attention in the early 1950s to kidney transplantation and performed four deceased donor transplants on patients with presumed end-stage renal disease (ESRD) using the recipients' iliac vessels, but all were soon rejected and three of the patients died [10]. A fourth survived long term but probably due to recovery of native renal function. Clearly rejection was the unsolved problem here [8].

The first successful kidney transplant in Canada was an identical teenage twin to twin donation carried out in the Royal Victoria Hospital in Montreal in 1958 by a team led by Dr. John Dossetor [11]. Both survived for decades though the recipient required chronic dialysis 16 years posttransplant. In 1963, the first Canadian non-twin transplants occurred in the same center in Montreal and in Saskatoon, and soon the practice became widespread [12, 13].

While acute dialysis was increasingly available in the late 1950s and early 1960s, chronic dialysis programs did not start until the middle to later 1960s. The first reported experience came from McLeod and colleagues in Edmonton, Alberta, in 1965 and later from Morrin and colleagues in Kingston, Ontario, who had four stations operating in 1968 [14, 15]. Chronic dialysis and kidney transplant programs became widespread in the 1970s and 1980s and grew rapidly in the 1990s. Canadian nephrology was quite innovative in

these years with, for example, the use of both intermittent and continuous ambulatory peritoneal dialysis (CAPD) in the 1970s and early 1980s being pioneered by Dr. Dimitrios Oreopoulos in Toronto Western Hospital and routine use of subclavian catheter venous access for chronic HD patients being developed by Dr. Robert Uldall at the same time in the same center [16, 17].

In the 1980s, Canada was a world leader in widespread use of CAPD with over 50% of chronic dialysis patients in some provinces being maintained on this therapy [18]. In the 1990s, there was huge growth in the ESRD population and increasing use of chronic HD with units spreading out of teaching hospitals into city suburbs and smaller towns and a consequent relative fall in peritoneal dialysis (PD) use [19, 20]. During the same period, innovative approaches to home HD (HHD) led to growth in that modality. In particular, Canada became a world leader in slow nocturnal and short daily home HD [21, 22].

Kidney transplant also prospered in the 1980s and 1990s with 13 good-sized programs across the country. Dr. Cal Stiller from London, Ontario, led randomized trials confirming that cyclosporine was a major advance in prolonging graft survival [23].

ESRD Rates

Canada has a Canadian Organ Replacement Register which records transplant and dialysis activity across the country [24]. It is considered relatively complete except for the province of Quebec which has not contributed data for the last decade and which contains about 8.5 million, or 22.5%, of the total Canadian population of 37.6 million people. Incident and prevalent rates of ESRD quoted here therefore are for Canada outside Quebec. Historically they have been somewhat lower in Quebec but this may no longer be so [25].

Canada's incident rate for ESRD varies between provinces but is approximately 200 new cases per million population (pmp) per annum (Table 11.1) [24]. Interprovincial variation is driven in part by differences in the percentage of the population that is FNIM because rates of ESRD are about three times higher in FNIM as compared to Caucasian populations [26]. Accordingly, Manitoba has a higher rate than any other province. Other factors influencing provincial differences are less clearly defined but may include ethnic differences, socioeconomic factors, age distribution, and perhaps the proportion of the population living in rural and remote areas. It is also likely influenced by completeness of reporting. The rate rose steadily during the 1990s but much less so after 2000 when it seemed to plateau at 160–170 pmp. The more recent rise to 200 pmp reflects aging of the population but also better data in Ontario particularly as a consequence of closer linkage between accurate reporting and provision of funding.

Table 11.1 Incident and prevalent treated ESRD rates per million population by province/region of Canada in 2017

Province/region	Incident rate pmp	Prevalent rate pmp
Ontario	244	1430
Quebec	206[a]	Not available
British Columbia (+ Yukon)	210	1326
Alberta (+ Northwest Territory + Nunavut)	132	1109
Saskatchewan	156	1212
Manitoba	244	1704
New Brunswick	217	1262
Nova Scotia (+ Prince Edward Island)	195	1566
Newfoundland	202	1657
Canada (excluding Quebec)	200	1372

Adapted from Canadian Organ Replacement Register data in Ref. [24]
[a]Estimate based on personal communication from Dr. A Nadeau-Fredette

Table 11.2 Comparison of incident and prevalent treated ESRD rates (including transplantation) per million population in 2016 between Canada and selected other countries

Country	Incidence pmp	Prevalence pmp
Taiwan	493	3392
USA	378	2198
Japan	296	2599
Portugal	236	1909
Canada[a]	**200**	**1346**
Brazil	197	865
France	165	1278
Poland	149	806
UK	120	956
Australia	117	988
Iran	82	652
Russia	58	303

Adapted from data in Ref. [27]
[a]Canadian rates exclude Quebec

Canada's incident rate places the country in the second highest tier worldwide where incident rates vary between 160 and 250 pmp (Table 11.2). Within this second tier, Canada is just below a small number of countries in Southern and Eastern Europe and parts of Latin America but ahead of most of Western Europe [27]. The rate is much higher than that seen in a third tier of countries which includes Scandinavia, the United Kingdom, and Australia who lie between 100 and 120 pmp. The Canadian rate however is well below that of the first tier of countries, which include the United States, as well as Japan, Taiwan, Korea, and Thailand, all close to or in excess of 300 pmp (Table 11.2).

These international differences may reflect true differences in the incidence of ESRD, driven particularly by differences in rates of diabetic kidney diseases between countries and ethnic groups [27]. They are also influenced by medical and cultural attitudes toward the use of chronic dialysis in older frailer patients, by socioeconomic fac-

tors, and by health-care delivery models, particularly the degree to which "private for-profit" providers participate in dialysis delivery, which is of course not a feature in Canada [28].

As in almost all countries, diabetic kidney disease is the largest cause of ESRD in Canada accounting for just under 40% of cases [27]. This is much less than in East Asia, the United States, and Mexico but more than in Western Europe. The proportion of cases attributed to hypertension is much lower than in the United States, perhaps reflecting the relatively small Canadian population with West African origin [29].

The prevalent rate of ESRD, including those alive with transplants, is about 1350 pmp and has risen gradually in the last two decades [24]. Prevalent dialysis rates have slowly risen to 60% of prevalent treated ESRD rates as transplant struggles to grow in proportion to chronic dialysis.

Mean ages for incident and prevalent dialysis patients are about 62 and 65 years, respectively, and have not increased much in the last two decades. Approximately 60% of incident patients are male, and over half have diabetes although in only 40% is it considered the cause of their ESRD [24].

It is important to note that the relatively modest growth in ESRD incident and prevalent rates does not reflect the experience of dialysis providers and funders who continue to see a substantial increase in absolute numbers of patients being treated. There are about 22,500 people on chronic dialysis outside Quebec and about 5700 more in Quebec for a total of over 28,200. About 7300 started chronic dialysis in 2017 including over 1700 in Quebec (personal communication, De Annie Claire Nadeau-Fredette, Universite de Montreal). Absolute numbers of dialysis patients have recently risen at about 2.5–3% per annum [24]. The growth in the Canadian population has recently been rising, largely due to increased immigration, and is now close to 1% per annum, and so even when ESRD rates stand still, the need for dialysis and transplant increases. The aging of the population also contributes approximately a further 1% to this growth in absolute numbers of patients on dialysis.

The relative plateauing in ESRD incidence rate since 2000 likely reflects that most of the unmet need for renal replacement therapy has been dealt with since the marked growth in the 1990s and there is a general opinion that few Canadians who need and wish to receive dialysis are being denied it. The proportion who receive "conservative care" has recently received more attention but has so far not been reliably measured though it is likely substantial [30].

Unadjusted survival rates on dialysis in Canada at 1, 3, 5, and 10 years are 83%, 63%, 45%, and 16%, respectively. Comparable figures a decade ago for 1, 3, and 5 years were 83%, 60%, and 43%, respectively, suggesting gradual improvement in long-term rates [24]. This is reflected in prevalent dialysis rates rising slightly faster than incident rates, 2.8% versus 2.2% annually [24]. Survival rates are, not surprisingly, substantially longer for those whose primary disease is glomerulonephritis compared to diabetes – 93% versus 86% at 1 year, 80% versus 63% at 3 years, and 66% versus 41% at 5 years. Survival is also longer in people starting on PD compared to HD – 92% versus 80% at 1 year and 73% versus 60% at 3 years – but these data are unadjusted and do not reflect the younger age and better baseline health of those doing PD [24].

Kidney Transplant

Transplant rates have been high by international standards and stable from 2000 to about 2015 at about 35–40 pmp per annum or 50–55 per 1000 dialysis patients per annum with about 40% being accounted for by living donors and the rest by deceased donors [24]. Since 2015, the rate has risen to 45–50 pmp per year or 60 per 1000 dialysis patients. This is because there has been significant growth in deceased donor transplant rates due in part to more liberal donor acceptance criteria. In 2017, there were 1338 adult transplants in Canada of which 803 were deceased donor and 535 living donor. There were about 240 in Quebec for a total of about 1680 nationwide. There are about 40–50 pediatric transplants annually [24]. Internationally, Canadian transplant rates are quite high but below those in the United States, Spain, and the Netherlands and similar to those in Scandinavia and the United Kingdom (Table 11.3). Living donor rates are also high by international standards but have been stagnant for a decade or more and below that of the United States and the Netherlands when expressed pmp or per 1000 dialysis patients [27]. Within Canada, there is significant variation in transplant rates between provinces and between renal programs [31, 32]. There is also variation in wait times and degrees of organ sharing within and between provinces [31].

Table 11.3 Comparison of kidney transplant rates per million population in 2016 between Canada and selected other countries

Country	Kidney transplant rate pmp
Spain	64
USA	62
Netherlands	59
France	54
Canada	**49**
UK	48
Australia	45
Brazil	29
Japan	13
Taiwan	13
Russia	7

Adapted from data in Ref. [27]

Home Dialysis

The proportion of Canadian ESRD patients treated with home dialysis modalities remains relatively high by international standards but is much less than in the 1980s and early 1990s when CAPD was being used in over 35% of prevalent patients [17, 23]. This was due to a combination of enthusiasm for the modality and also to scarcity of HD capacity. Home dialysis use in Canada fell dramatically between 1995 and the early 2000s and then plateaued at under 20%. This was due to a large increase in HD capacity and in particular to the proliferation of HD units in suburbs of larger cities and in smaller towns [19, 20].

There has recently been an increase in home dialysis prevalence back up toward 25%, in part related to efforts by provincial renal agencies [33–36]. This places Canada in the top 12 countries in the world for percent home dialysis use [27]. Increases in home dialysis use have also been attributed to widespread use of assisted PD initiatives, whereby home care nurses visit patients' homes and help them set up their PD cyclers and troubleshoot any problems [37], and also to pre-ESRD clinics, economic incentives, and greater use of urgent start PD [38–40].

Again, there are provincial differences in home dialysis use, and provinces which have had major initiatives to grow home dialysis, such as Ontario and British Columbia, have notably higher rates, while those in Quebec and Newfoundland are lower [24]. About 20% of home dialysis is accounted for by home HD, less than is the case for Australia and New Zealand but much more than in the United States and most of Europe [27].

HD Practices

There are some specific atypical features with regard to Canadian HD practices. HD patients mainly receive 3–4 h three times weekly with routine monitoring of urea clearances. Only a very small percent of in-center patients receives two treatments a week, but about 5–10% receive four or more treatments weekly, due to fluid overload issues and to a belief in the merits of more frequent HD. Canada has a very high incident and long-term prevalent use of cuffed tunneled jugular venous catheters for dialysis access. In some provinces, prevalent catheter use exceeds 50%. Previously this was attributed to problems with availability of good vascular surgery, but in reality it is more related to a disillusionment with the high complication and failure rates of fistulas on the part of nephrologists and an increasing preference by patients for catheters [41, 42]. In a 2016/2017 survey of prevalent vascular access in Ontario, fistulas were being used in 36% of people on HD, grafts in 5%, and central venous catheters in 59% [34]. Bacteremia rates in the same province are measured continuously and are about 0.2 per 100 catheter days equal to about 1 new episode every 15 years (unpublished data). There has been no evidence that the decline in fistula use has had any adverse effect on mortality in people on HD.

Volumetric machines and high flux dialyzers are now standard with prices for the latter having dropped dramatically in the past 20 years. As a result, dialyzer reuse costs more to do than it saves and so has declined to zero. Online hemodiafiltration is now widely available and is no longer excessively expensive, but it is not widely used due to a lack of convincing evidence of benefit [43]. There are no good data but its use is estimated to be less than 10%.

Hepatitis B and C and human immunodeficiency virus (HIV) are monitored in all people starting dialysis, but there are no recent published data. Estimated prevalence rates in the HD population are under 1% for hepatitis B and HIV and about 5% for hepatitis C. Transmission within dialysis units is considered to be rare because of good adherence to strict infection control practices.

PD Practices

In 2017, 72% of prevalent PD patients were doing automated PD (APD) using cyclers although many start with CAPD for 4–6 weeks [24]. High APD use is mainly for lifestyle reasons. There are no definitive data published, but icodextrin use is very common and thought to be prescribed to over 60% of people on PD, for metabolic as well as ultrafiltration-related indications. This is not the case for the so called "biocompatible" solutions which are used in less than 10% of patients, probably because of uncertain evidence and extra cost. Incremental PD is widely practiced but often in quite different ways [44]. Some patients are initiated on "day dry" cycler prescriptions or on three CAPD exchanges daily or even on one or two icodextrin dwells daily, especially if fluid removal is the main aim. Government-funded assisted PD is common in some provinces and less available in others. In the most populous province, Ontario, it is used in about 25% of prevalent PD patients at any given time and in about 33% at some stage in a given 12-month period. It typically involves a nurse or a health-care worker doing a patient's cycler setup for them and sometimes also attaching them to the cycler.

Catheters are mainly placed laparoscopically by surgeons, but a significant minority is placed percutaneously by nephrologists or invasive radiologists [45]. Peritonitis rates are routinely monitored. Unpublished data from the Ontario Renal Network indicates that rates in that province are typically 1 every 36–48 months [34].

Technique survival rates have improved with time and, depending on how they are measured, are about 85% at 1 year after censoring for death and transplant [46]. Despite

these results there is significant "churn" in the PD population due to the combination of about 10% mortality, 15% technique failure, and 15% transplant rate so that after 1 year 40% of new starts are no longer on the therapy [46]. As mentioned above patient survival rates for PD appear to be good in Canada relative to those for HD though this may partly or wholly reflect positive patient selection with baseline age and comorbidities being generally less in PD patients [47, 48].

Home HD Practices

HHD is relatively widely used in Canada, at just under 5% of prevalent dialysis patients [24]. Practices are diverse, and at least half receive "frequent" or long duration HHD prescriptions [22, 24, 48, 49]. Slow nocturnal HHD, 5–6 nights weekly for 6–8 h each time, is particularly popular [21, 50]. Others use short daily HHD for about 2 h 5–6 days weekly, and alternative day conventional HD is also used [22, 48, 50]. The "Next Stage" machine which is so popular for HHD in the United States and parts of Europe is used in only about 20% of HHD patients in Canada and is perceived as more expensive and less easily supported outside major cities [51]. Online remote monitoring of HHD patients is now rarely done. Some provinces, notably British Columbia and Ontario, provide specific funding for frequent HHD. A number of provinces reimburse electricity and water costs incurred by patients doing HHD.

Just as is the case with in center HD, central catheters are often the vascular access in HHD, and this has the advantage of avoiding the challenge to patients of learning to needle. For those who do have fistulas, button hole needling has been a source of concern for infection and is less frequently used [52].

Survival rates for people on home HD are very high exceeding those on both center HD and PD [24, 48, 50]. This partly reflects baseline differences in health and perhaps functionality and education, though the benefit persists even when these are adjusted for. However, technique failure rates have risen in recent years and are now similar to those on PD, at least for the first 12 months, likely due to the recruitment of more "marginal" patients to take on the therapy [50].

Pre-ESRD Care

Specialized multidisciplinary pre-ESRD clinics for patients with advanced chronic kidney disease (CKD) have become standard practice across the country. The purpose of these is to prepare people for dialysis or transplant or conservative care and also to slow progression of advanced CKD and to treat complications [40]. With the increased emphasis on patient-centered care over the past decade, there is a big focus on education, shared decision-making, and patient empowerment in these clinics [40]. Specifically, these clinics are supposed to focus on key decisions around modality selection, access choice, and preemptive transplant where possible.

Eligibility for these clinics varies with some going by estimated glomerular filtration rate (eGFR) levels and others using the Kidney Failure Risk Equation which incorporates proteinuria as well as kidney function [53].

Transplantation Practices

As stated earlier, Canada has a relatively high rate of kidney transplantation, and about 40% of transplants are from living donors [24]. Despite the high transplant rate when expressed per million population, the lifetime likelihood of a person starting chronic dialysis receiving a transplant is only about 20% [54]. This reflects the high incident rate of ESRD, the relative shortage of donated kidneys, and the fact that the large majority of people on dialysis is not eligible to receive a transplant due to comorbidities and consequent short life expectancy [54].

There are 15 transplant centers, all based in university centers. Organ sharing is largely within provinces or clusters of provinces, rather than nationwide. However, the Canadian Blood Services does facilitate some nationwide organ sharing, such as with highly sensitized patients, kidney paired donors, and living donor recipient "chains" [55].

Rules for organ sharing vary. In Ontario, for example, the region in which a pair of kidneys is retrieved from a deceased donor is allowed to keep one kidney for use by the local transplant center, and the other is shared across the province, with preference given to children and younger adults, to the highly sensitized, and to those with longer time on dialysis [55, 56].

There are significant differences in the likelihood of a person on chronic dialysis receiving a kidney transplant between renal programs that cannot be attributed to organ availability [31, 32]. These are thought to reflect differences in perception by referring nephrologists as to who is eligible for transplant and differences in the efficiency with which candidates are worked up and referred, but there also are patient socioeconomic factors that reduce access for people living further away from transplant centers [31, 32, 54].

Standard immunosuppression involves induction with basiliximab, the chimeric interleukin-2 receptor monoclonal antibody. Thymoglobulin, an antihuman thymocyte globulin polyclonal preparation, is used in induction of patients at higher risk of rejection. Transplant recipients also typically receive a regimen of tacrolimus, mycophenolate, and tapering doses of steroids. Some centers reduce steroids rapidly [56].

Cytomegalovirus mismatching is common and ganciclovir prophylaxis is used. Cellular rejection is usually treated with steroids and thymoglobulin, while antibody-mediated rejection treatment also includes plasma exchange and intravenous immunoglobulin [56].

Recipients with uncomplicated courses are often discharged within 5–7 days posttransplant. Graft survival rates for deceased donor transplants at 1, 3, 5, and 10 years are 93%, 88%, 82%, and 63%, respectively, and the half-life of deceased donor transplants is now at least 12 years. For living donor transplants, graft survival at 1, 3, 5, and 10 years is 97%, 95%, 91%, and 74%, respectively, and half-life is likely at least 18 years [24].

Funding

As already stated and consistent with Canadian health-care principles, dialysis delivery is completely and only funded by provincial governments, either directly or through provincial renal agencies. Dialysis is almost entirely delivered through hospitals which are either public or, more commonly, not-for-profit independent entities heavily dependent on provincial government funding and therefore answerable to that government. There are almost no private dialysis providers in Canada and a complete absence of the so called 'chains' or large dialysis organizations that are so dominant in the United States and elsewhere. There are also no physician-owned dialysis units [57].

The units themselves are mainly located inside acute care hospitals. Those in hospitals which have multiple nephrologists and a reasonable range of renal services, including facility-based HD, PD, acute dialysis, and general nephrology clinics, are often called "hubs," while those with an HD unit but no nephrologists of their own and very limited ancillary renal services are called "satellites." Typically, "hub" hospitals receive government funding for dialysis and contract with their satellites to deliver HD. Some of the hubs and satellites locate their HD units in leased buildings not on the main hospital site, and some of these are in shopping malls or office blocks, but this is still not very common. In Ontario with over 14 million population, for example, there are 27 renal programs, some very large and some very small. Between them they operate 100 HD units. All 27 of them provide PD, but only 21 of them do home HD, and just 6 do transplant [58].

The method by which government funds the "hub" hospitals providing dialysis varies by province [57, 59]. Some provinces such as Alberta and Manitoba fund dialysis through the hospital's global budget in the same way that they fund surgical operating rooms and medical wards. This approach has become less popular because of the sensitive life sustaining nature of dialysis and because of its tendency to grow from year to year. Accordingly, volume-based funding is becoming more common and is used in Ontario and British Columbia. It is modality specific with different rates for facility-based HD, CAPD, APD, HHD, etc. Recently, "bundled" funding has become popular so that, for example, the rate for facility HD might also include vascular access provision or intradialytic medications or laboratory tests, but no jurisdiction has bundled erythropoiesis-stimulating agents as has occurred in the United States. There is talk of quality-based funding, but, strictly speaking, this has not yet occurred, and there would be little consensus about how "quality" might be measured in such a diverse population as those with ESRD. If the annual bundled funding for center HD is divided by 156, the typical number of HD treatments per year, the rate per dialysis is about US$ 250.

In general, modality-based funding for facility HD is about 50% higher than that for home PD and home HD, consistent with costing studies (Table 11.4) [39, 58, 59]. The higher cost of facility HD is mainly accounted for by nursing salaries. A number of provinces including Ontario and British Columbia have introduced specific "bundled" fees for frequent home HD and even for frequent facility HD, typically defined as five or more treatments a week [9, 58]. It should be noted that provincial modality-based funding formulas do not generally cover outpatient medications, imaging studies, hospital admissions, transport costs, or physician fees. In Ontario, there is a specific annual "bundle" for pre-ESRD multidisciplinary care of patients with a 2-year risk of ESRD greater than 10% or an eGFR of 15 ml/min or less.

Transplantation is generally funded out of the global budget of the hospital where the procedure is performed and often comes from the surgical rather than the renal portion of that budget. In Ontario, there is a one-off payment of

Table 11.4 Ontario renal network annualized reimbursement bundles by modality, expressed in US$ using exchange rate of C$ 1 = US$ 0.75

Modality	Annualized payment (US$)	Additions (US$)
CAPD	21,822	Up to 1725 for initial training
APD	28,609	Up to 1725 for initial training
Home HD	17,348	11,400 for initial training
Frequent home HD (>4 treatments weekly)	26,695	11,400 for initial training
Facility HD[a]	38,459	
Facility HD (>4 treatments weekly)	64,056	
Facility slow nocturnal HD	64,056	

[a]Equivalent to US$ 247 per treatment in person receiving 3 treatments weekly

C$25,000 by the Ministry of Health to the hospital performing the transplant and an additional C$5800 if there is a living donor. This funding usually goes to the surgical transplant unit rather than to the nephrology unit. There is no dedicated funding for potential transplant recipient work up. There is funding available in most provinces to cover medical and personal costs of living donors [60, 61].

Glomerular Diseases

Glomerulonephritis is listed as the primary cause of ESRD in about 11% of incident cases and 21% of prevalent cases receiving renal replacement therapy in Canada [24]. The higher prevalent rate reflects the longer survival of people with glomerulonephritis compared to other causes of ESRD.

Driven by the greater complexity and cost of immunosuppressive medications for glomerular diseases, there has been an increasing trend toward specialized clinics for nondiabetic glomerular diseases, including vasculitis. Provincial renal agencies in British Columbia and Ontario have set up networks of specialist clinics with multidisciplinary teams comprising nephrologists, nurses, pharmacists, and social workers as well as affiliated pathologists to help people navigate renal biopsies, diagnosis, choice and funding of required immunosuppressive agents, and subsequent follow-up [62–64]. Standardized protocols and approval processes for funding of medications such as rituximab and eculizumab have been developed in some provinces.

Acute Kidney Injury

The incidence of AKI requiring dialysis in Canada is difficult to measure because many of the cases labeled "acute" are actually people with ESRD who are hospitalized [65]. People with AKI severe enough to require dialysis and to be treated in intensive care units may receive conventional acute HD for 3–4 h 3–6 times weekly. However, it is estimated that more than half now receive at least some treatment with either sustained low-efficiency dialysis (SLED) using a conventional HD machine with low blood flows for 6–12 h daily or continuous renal replacement therapy (CRRT), most often delivered using the Baxter "Prisma" machine in either hemofiltration or hemodiafiltration mode [65–67]. SLED and CRRT are about equally popular. In intensive care units where CRRT is used, intensivists are often in charge of initiation and prescription of the therapy. Where conventional HD or SLED is used, it is typically initiated and prescribed by nephrologists.

First Nations Populations and Kidney Disease

As alluded to earlier, First Nations or FNIM populations in Canada represent about 4% of the country's total population, and with high birth rates, this proportion is likely to increase. FNIM groups have high rates of ESRD, related primarily to high rates of type 2 diabetes mellitus which have rapidly increased over the past 60 years with alteration in diet and lifestyle [26, 68, 69].

The problems associated with CKD and ESRD in FNIM populations are aggravated by the high rates of socioeconomic deprivation, mental health problems, and substance abuse, associated in turn with the legacy of colonialism and displacement that these people have suffered [70].

Incident ESRD rates are estimated to be about three times as high as in the general population, and this raises particular challenges in provinces like Manitoba and Saskatchewan where close to 20% of the population is FNIM. As many as half of FNIM people live on reserves, and in a proportion of these, the reserve location is remote from hospitals and dialysis units. In these scenarios, relocation for HD is required if home dialysis is not feasible or is unsuccessful. In general rates of both home dialysis and transplant are relatively lower in FNIM populations, in part due to social reasons [71, 72].

Initiatives to alleviate the excess load of CKD in FNIM people have included screening and treatment programs for early CKD and use of telemedicine to deliver remote care [73]. Networks of small satellite HD units on or close to reserves have also been developed [74]. However, nothing short of major social change is likely to alleviate this burden of diabetic CKD.

Medications

There is no universal payment system for medications in Canada, analogous to that for hospital and physician care, and this is frequently criticized by advocates of socialized medicine [5]. The provinces do provide medications free of charge from a broad provincial formulary to all those aged 65 or over and often to those under 18 and also to those on social welfare. Many working Canadians have an employment-related private insurance drug benefit plan that covers a similar or wider range of medications, but there is a significant population between 18 and 65 years of age who have no such insurance. These individuals may receive supplemental provincial funding for medications once their annual costs exceed an income-related deductible. Expensive medications such as erythropoiesis-stimulating agents are often covered completely by special provincial drug pro-

grams, and pre-ESRD and dialysis patient have easy access to these in almost all cases. Access to immunosuppressive medications is also rarely an obstacle to kidney transplant patients although income-related deductible payments may be required for those aged under 65.

Relatively newer more expensive medications for dialysis patients such as non-calcium phosphate binders, vitamin D analogues, and cinacalcet are not routinely available free of charge to patients in every province, and typically specific clinical criteria have to be met before the government will fund them [75]. Newer expensive medications such as rituximab or eculizumab, used in the treatment of some types of glomerulonephritis and microangiopathies, are more difficult to access but most provinces have evidence-based criteria in place to fund them for those people who truly need them [62–64].

Nephrologists

Canada has about 700 practicing adult nephrologists, equal to about 1 per 50,000 population or 1 per 40 chronic dialysis patients [76]. About half have some form of academic appointment, and a large proportion of these have full-time academic positions. The other half are in "community" nephrology, a notable increase from 25 years ago when most chronic dialysis was being delivered through academic centers [19, 20]. The proliferation of new community-based renal programs in the late 1990s led to this increase in non-academic community nephrologists. About a third of nephrologists are women, a notable increase from a decade ago. Over 90% of Canadian nephrologists, both in academic and community nephrology groups, are involved in the care of chronic dialysis patients. Less than 10%, all in academic centers, spend a large part of their clinical time caring for patients with kidney transplants.

Like the majority of Canadian physicians, most nephrologists, including those in full-time academic positions, are paid "fee for service" by provincial government "insurance" plans. These fees are set through negotiations between the provincial health ministries and the provincial medical association. Nephrologists must adhere to this billing arrangement, and "extra billing" of patients is forbidden. Patients do not and may not pay nephrologists. The combination of single government payer and fee for service is unusual in healthcare systems and, to some extent, was a compromise between government and physician groups at the time of the establishment of Canadian Medicare. While it may be seen by some as an imposition on physician independence and on the physician-patient relationship, the reimbursement system does give physicians security of income, the simplicity and time saving of a single payer system, and a proportionality between work done and reimbursement received which is not typically found in salaried systems.

The bulk of nephrologists' income comes from fees for chronic dialysis. Historically these were procedural fees, and those for center-based HD were paid for physician provision/supervision of each treatment, whereas for home dialysis or for satellite HD, there was either no physician fee or a modest specific retainer fee paid per week [77]. This arrangement persists in some provinces, but in others it was perceived as giving physicians a perverse incentive to direct patients to expensive center-based HD and away from home and satellite dialysis. In the late 1990s, Ontario therefore introduced a modality-independent capitation fee, analogous to that in the United States at the time, and other provinces followed suit leading to a fee that is not related to the actual dialysis procedure but rather to the overall care of the patient [78].

Academic nephrologists in most provinces pay a variable percentage of their salary as a "tithe" to their university department of medicine. This can vary from as low as 10% to as much as 30%. However, the same department of medicine typically pays a modest and variable base salary to their nephrologists as reimbursement for teaching, research, and administrative activities and in proportion to their productivity in those areas. The end results of these dollars going in circles are broadly revenue neutral for nephrology groups as a whole. Most academic nephrology groups pool and share their income to some degree so that productive research-focused nephrologists earn similar income to clinical and education-oriented academics who have higher clinical billings. The fee for service system is notably less rewarding for nephrologists who mainly work in kidney transplantation, as distinct from chronic dialysis, but again income pooling in university nephrology groups addresses this. However, the point is often made that chronic dialysis fee for service income is indirectly funding academic nephrology activities. In recognition of this, academic nephrologists in many provinces receive some income from government "alternate funding plans." Transplant nephrologists may also have specific supplemental "alternate funding" government payments allocated to them in recognition of limited billing opportunities. In the province of Alberta, some academic physicians forgo "fee for service" altogether and are reimbursed through a full "alternate funding plan" in order to avoid "fee for service" incentive unduly disrupting or disincentivizing academic activities [79].

There are 15 active nephrology training programs in Canada, though not all consistently have trainees, and only half would consistently have over five trainees at a time [80]. All are affiliated with medical schools, and between them they accept about 25 internal medicine-trained residents annually. Additional trainees come from other countries to do nephrology fellowships in Canada,

with or without an eventual plan to return to their home countries, and some eventually stay long term. Training takes a minimum of 2 years though it is typically longer for those interested in acquiring specialized clinical skills or in developing an academic career. Basic training includes teaching in HD and PD, transplant, and general outpatient, inpatient, and intensive care nephrology [81]. Subsequent specialist training fellowships in areas such as transplantation, home dialysis, glomerular disease, clinical research methodology, education, and quality improvement are increasingly popular for those wishing to work in academic centers particularly [81].

The combination of fee for service payment and of the growth that has occurred over the past four decades in the numbers of prevalent dialysis patients has led to relatively high incomes for Canadian nephrologists who typically rate third among internal medical specialists behind cardiologists and gastroenterologists in annual reimbursement received. Incomes in excess of US$ 250,000 annually are not unusual for clinically busy nephrologists who are caring for large numbers of dialysis patients. Partly because of this, nephrology remains a relatively popular specialty among Canadian medical school graduates, and most training positions and staff nephrologist positions are filled. Indeed, there is often keen competition for nephrologist positions in larger Canadian cities [81, 82]. A large majority of nephrologist appointments are now Canadian medical school graduates.

Canada has the Canadian Society of Nephrology (CSN) which meets annually and is very active [83]. The CSN promotes education, research, and debate and develops its own disease management guidelines. Quebec has its own mainly Francophone Societe Quebecoise de Nephrologie [84]. There is also the Canadian Society of Transplantation [85]. At a provincial level, physician groups such as the Ontario Association of Nephrologists promote the economic and professional interests of their members.

Nurses and Allied Health Professionals

In general dialysis in Canada has been delivered by unionized registered nurses, and this contrasts with the situation in the United States where much less well-reimbursed dialysis technicians provide HD under nursing and physician supervision. However, the ongoing growth in numbers of dialysis patients and the increasing cost constraints in the whole health-care system have led to increased use of less expensive "practical nurses" and dialysis technicians in some provinces. There is a lot of variation across provinces and between centers, but in recent times, this trend has been accentuated because some renal programs have found recruitment of dialysis registered nurses to be a challenge [86, 87].

Registered nurses are increasingly likely to have nursing degrees rather than college diplomas and will have 3–4 years of training. They are typically paid in the range of US$40,0000–70,000 annually, depending on seniority and varying by province. Many academic renal programs employ nurse practitioners who have extra training and who act as physician extenders and often as advocates and practitioners of patient-centered and multidisciplinary care.

Senior nurses have always played a crucial role in administrative, fiscal, and clinical leadership of renal programs in Canada. The director of each program, appointed and employed by the hospital concerned, is typically a senior nurse. In the past nephrologists were often less involved with program administration, but, in recent times, co-management between hospital administrators and nephrologists has become more typical.

Nephrology services in Canada have generally emphasized multidisciplinary patient care, and the roles of allied health professionals such as renal dietitians and social workers have been paramount [88, 89]. Renal pharmacists play a greater role with increasing complexities of medications in many relevant areas including anemia, bone mineral osteodystrophy, glomerular disease, and kidney transplant management [90].

Pediatric Nephrology

Pediatric nephrology is by its nature much more centralized than its adult counterpart. Canada has about 70 pediatric nephrologists concentrated in 13 major academic centers with chronic pediatric dialysis programs. There are nine pediatric kidney transplant programs of which two only operate on patients aged 12–18 [91] (personal communication Dr. Guido Filler, Western University, London, Canada, July 10, 2019).

Canada has a quite stable incident rate of ESRD in children aged 0–19 year of about 10 per million population (aged 0–19), equivalent to about 75 cases annually. These children have a 10-year survival rate in excess of 80%. This age group is transplanted promptly so that at any given time there are about 400 children alive with ESRD in Canada excluding Quebec, for a prevalent rate of 65 per million, but 330 of them are living with transplants. Of the approximately 70 on chronic dialysis, just over half use PD, and just under half do HD [24].

Renal Agencies

A feature of Canadian nephrology over the past decade has been the growing popularity of provincial renal "agencies." British Columbia was the pioneer in this regard

when it set up the British Columbia Renal Agency in the 1990s [32]. The Ontario Renal Network was established in 2009, and there are similar bodies in Manitoba, Nova Scotia, and Alberta [33, 34, 92, 93]. In general, these are government agencies with a budget provided by their provincial Ministry of Health. They operate at varying degrees of "arm's length" from the ministry and supervise the budget for renal services and act to ensure that patients receive equitable, cost-effective, and good quality renal care.

Generally, these agencies commit to the principles of patient-centered care and, in particular, to that care being better integrated and available closer to home. Accordingly, these agencies promote initiatives such as shared decision-making, growing home dialysis modalities, increasing transplant rates, promoting appropriately deferred start on chronic dialysis, ensuring patients' goals of care are discussed and documented and that palliative options are available when requested, monitoring patient reported outcomes and experience, and developing specialized services for patients with glomerular diseases [62–64, 94].

A particular feature of these agencies is the involvement of nephrologists in policy development and implementation, to a degree that had not occurred in the past. This co-management principle also involves a role for renal program administrators and multidisciplinary groups. Patient involvement is also a strong feature, and in Ontario no policy is now implemented without input from patient and family advisory committees [34].

There is a general impression that these agencies have changed the culture of Canadian nephrology and have had success in growing home dialysis in a number of provinces [33, 34].

It should be noted that, unlike in the United States, these renal agencies do not have specific guidelines for the detailed care of individual people with CKD. Areas, such as dialysis clearances, access and ultrafiltration in people on dialysis, and management of anemia and mineral bone metabolism in CKD and ESRD, are not regulated by these government agencies. Guidelines are provided by the Canadian Society of Nephrology and by other international agencies, but there is no direct governmental policing of these [83, 84]. However renal programs generally self-regulate these practices and outcomes.

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