KI REPORTS
KIReports.org
CLINICAL RESEARCH

Outcomes of Living Kidney Donors Following Donor Nephrectomy in Aotearoa New Zealand

Lai Wan Chan[1,2,3,9], Georgina L. Irish[3,4,5,9], Tze L. Goh[2], Basil Alnasrallah[2,6], Christopher E. Davies[3,4], Matthew P. Sypek[3,7,8], Philip A. Clayton[3,4,5] and Michael G. Collins[2,3,4,5]

[1]Department of Renal Medicine, Waikato Hospital, Hamilton, New Zealand; [2]Department of Renal Medicine, Auckland City Hospital, Auckland, New Zealand; [3]Transplant Epidemiology Group, Australia and New Zealand Dialysis and Transplant Registry, South Australian Health and Medical Research Institute, Adelaide, South Australia, Australia; [4]Faculty of Health and Medical Sciences, Adelaide Medical School, University of Adelaide, Adelaide, South Australia, Australia; [5]Central and Northern Adelaide Renal and Transplantation Service, Royal Adelaide Hospital, Adelaide South Australia, Australia; [6]Qatif Central Hospital, Eastern Province, Saudi Arabia; [7]Department of Nephrology, Royal Melbourne Hospital, Melbourne, Victoria, Australia; and [8]Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne, Melbourne, Victoria, Australia

Introduction: Living donor kidney transplantation is the optimal treatment for people with kidney failure (KF). Because living donors do not derive health benefits from donation, contemporary relevant information on post donation outcomes need to inform decision-making. Studies of donor outcomes are largely restricted to donations in the USA and Europe. We studied donors over a 30-year period in Aotearoa New Zealand (NZ) to investigate short-term and long-term outcomes.

Methods: This was a retrospective observational cohort study of all living kidney donors in NZ (1988–2018). The primary outcome was the incidence of KF. Secondary outcomes were death, cardiovascular disease (CVD), and the incidence of complications within 90 days after nephrectomy. Donors were identified using multiple data sources: the NZ Blood Service, the Ministry of Health (MoH), hospital records, and the Australia and New Zealand Live Kidney Donor Registry. Outcomes were determined via data linkage with the Australia and New Zealand Dialysis and Transplant (ANZDATA) registry and the MoH. Follow-up was until December 31, 2019.

Results: A total of 1339 people donated a kidney from 1988 to 2018. During 16,272 person-years of follow-up, 5 people developed KF, an incidence of 3 per 10,000 person-years (95% confidence interval [CI]:1.3–7.4). Patient survival was 99% (98.2%–99.5%) at 10 years; 30 people died during follow-up. The incidence of CVD was 11.6 (95% CI: 7.4–19.2) per 10,000 person-years; 292 donors (22%) experienced a complication following donor nephrectomy and 69 (5%) required intervention.

Conclusion: There is a low risk of KF and other complications among living kidney donors in NZ. These findings represent important contemporary data to support decision making.

Kidney Int Rep (2025) **10,** 762–771; https://doi.org/10.1016/j.ekir.2024.11.1362
KEYWORDS: kidney failure; kidney transplantation; living donor

Kidney transplantation improves quality of life and survival at lower cost for patients with KF compared with dialysis.[1–3] Globally, living donor kidney transplants constitute approximately 38% of transplant activity[4] and help overcome the shortage of deceased organ donors. From a recipient perspective, receiving a living donor kidney transplant is associated with superior patient and graft survival compared with deceased donor kidneys, with 5-year patient survival exceeding 95%.[5] However, from a potential donor's perspective, kidney donation is a unique situation whereby a donor will undergo a medical procedure to assist another person, accepting the associated risks.

Potential living kidney donors are rigorously screened to ensure they do not have health conditions that might increase risks for recipients, such as through transmission of infection or malignancy.[6] They are assessed to minimize the risk of the early postoperative

Correspondence: Michael G. Collins, Transplant Epidemiology Group, Australia and New Zealand Dialysis and Transplant Registry, C/O South Australian Health and Medical Research Institute, PO Box 11060, Adelaide, South Australia 5001, Australia. E-mail: michael.collins@sa.gov.au

[9]LWC and GI are joint first authors

Received 9 May 2024; revised 6 November 2024; accepted 26 November 2024; published online 4 December 2024

complications of surgery and anesthesia[7] In addition, donors are carefully selected to ensure they are at low risk of developing chronic kidney disease post donation.

Historically, donors were not considered to be at an increased risk of adverse outcomes compared with healthy non donors; studies reported similar or improved rates of mortality, KF, and CVD comparable with age-matched general population.[8–11] However, several more recent studies with matched healthy controls raised concerns that the risk of living kidney donation may have been underestimated. The risk may be underestimated given that donors are heavily screened before proceeding with donation, and so an appropriate comparison is matched controls but not the general population. Mjøen *et al.*[12] (Norway) and Muzaale *et al.*[13] (USA) found increased risks of KF, death, and CVD in donors compared with healthy controls. The relative risk of KF after 10 to 15 years was substantially increased in donors (5–10-fold) although the overall absolute risk of KF remained low. Nevertheless, both studies provide estimates of the absolute risks for KF associated with donation in their populations that may be broadly applicable to populations of potential donors elsewhere, including in NZ. Regarding other complications post donation, kidney donation is associated with occurrence of hypertension and proteinuria post nephrectomy.[14,15]

The global health impacts of KF are increasingly recognized; there are significant geographical variations of the burden of KF and the availability and accessibility of living kidney transplants across the world.[16] Many healthy adults are eager and willing to accept the risk of donor nephrectomy to help their loved ones who have KF. However, clinicians need to be able to provide donors with accurate data about their risks so they can make informed decisions. Population-specific data will guide clinicians and improve efforts to address practices that can better inform and prepare future donors. Despite an increase in living donor kidney transplantation activity in NZ,[5] there is no published data on outcomes for NZ living kidney donors. The risk of KF are population-specific and vary widely for different ethnic groups. Both the studies by Mjøen *et al.*[12] (Norway) and Muzaale *et al.*[13] (USA) reflect outcomes from a different population than for people living in NZ. NZ has a diverse population of approximately 5 million people, with the largest self-reported ethnicities in 2023 being European descent (70%), indigenous Māori (15%), Asian (15%), and non-Māori Pacific Islanders (8%).[17] In addition, residents of NZ have access to universal health care coverage. This is important when considering that much of the existing data is from the USA and Europe. We designed and conducted Live Donate NZ, an observational cohort study of living kidney donors in NZ, to investigate the long-term risks of KF, death, and CVD in this population. It will inform discussions between clinicians and potential donors in the future and provide long-term outcomes for people who are contemplating kidney donation.

METHODS

Inclusion Criteria

NZ has almost universal health care coverage with publicly funded hospital care and subsidized outpatient services. All living donor kidney transplantations performed in NZ transplant hospitals (Auckland, Christchurch, Waikato, and Wellington hospitals) between 1988 and 2018 were included in this study. The follow-up of the study was completed in December 2019. People were excluded if they were not residents of Australia or NZ owing to lack of follow-up data.

Living Kidney Donor Identification

Living donors were identified by interrogation of multiple data sources. Since 2004, all living donors were recorded in the Australian and New Zealand Living Kidney Donor registry. For transplants before 2004, or where data were not recorded in the living donor registry, details of recipients of living kidney transplants were recorded in the ANZDATA registry. To ensure that all donors were identified, individual transplanting hospital records were additionally manually searched to identify the donors. Owing to the limitations of the data available, we are unable to report data on the clinical characteristics of donors at the time of donation, including details of pre donation kidney function or comorbidities.

Data Linkage

All residents of NZ are assigned a national health index number, a unique individual health system identifier that identifies and links them with national health records. We linked study data using the NZ Blood Service, the MoH, hospital records, and the ANZDATA registry for all living kidney donors from 1988 to 2018 who donated within NZ (Figure 1). This was done using deterministic linkage for donations from 2004 onward. For donors who donated before 2004, records of living donors were linked with records at NZ Blood Service and archives from the hospital tissue typing laboratory, using the national health index for deterministic linkage where available and probabilistic linkage for those without the national health index. This was done based on name, date of birth, and other identifiers. The NZ national collection of clinical information, mortality, and cause of death were available after 1988 in the National Minimum Dataset and the National Mortality Collection from the NZ MoH. The National Minimum

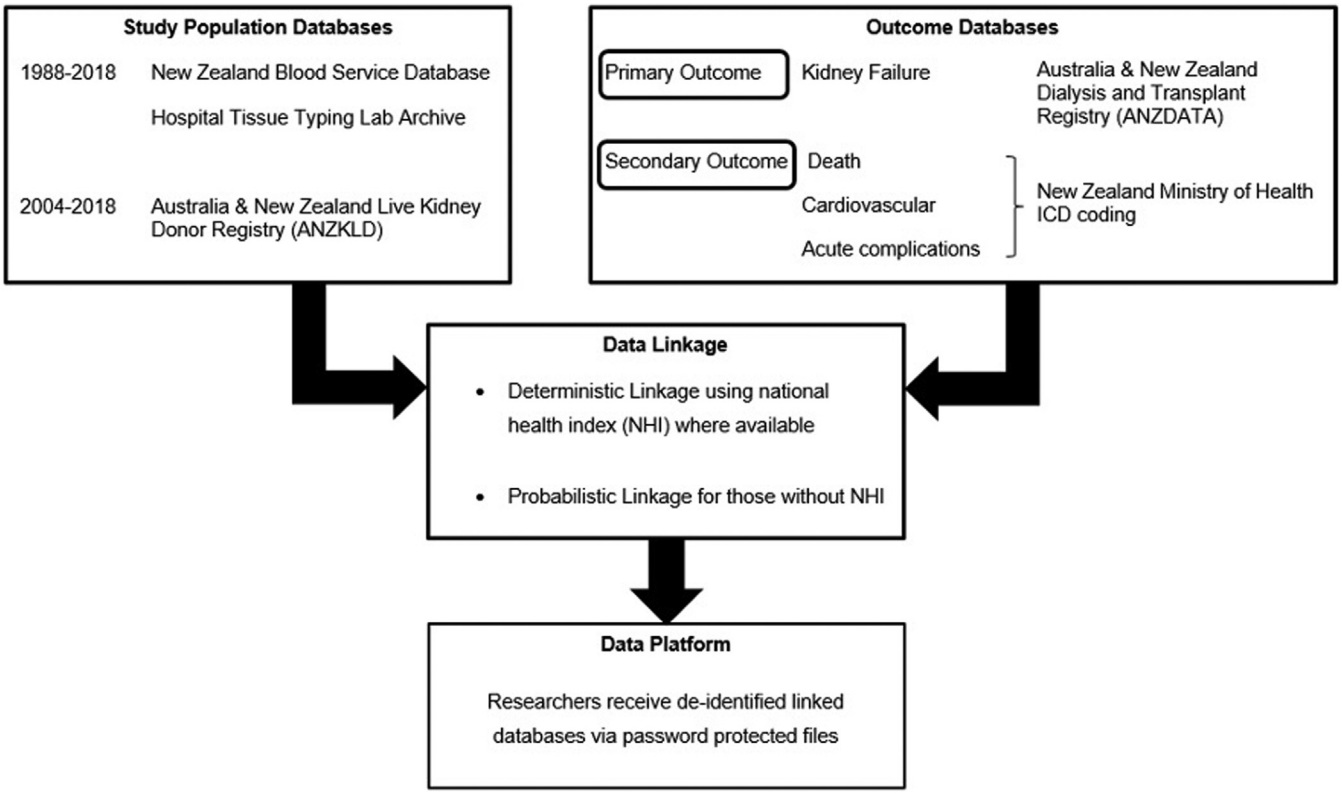

Figure 1. Process of data linkage.

Dataset is a national collection of public and private hospital discharge information for inpatients and day patients, including clinical information. It provides statistical data, reports, and analyses about all hospital inpatient and day patient health services nationally for the purpose of policy formation, performance monitoring, research, and review. Data collected from the donors' medical records include national health index where applicable, age, sex, ethnicity, relationship to recipient, residency status, and date of kidney transplant.

Statistical Analysis

Datasets were merged and analyzed in Stata/IC 17.0 (Stata Corp, College Station, TX). All continuous variables were presented as means with SDs or medians with interquartile ranges (IQRs), depending on their distribution which was assessed visually. Categorical variables were presented as proportions. Specific analyses based on the different outcomes are detailed in the next section. To calculate the 95% CIs for the incidence rates, we used the quadratic approximation to the Poisson log likelihood.

Outcomes

Primary Outcome: KF

KF was defined as the commencement of dialysis treatment, or the receipt of a kidney transplant, whichever occurred first. The outcome of KF in living donors was obtained via data linkage of donor details with records held in the ANZDATA registry. The registry records cases of KF in Australia and NZ, where a patient received treatment with long-term maintenance dialysis or received a kidney alone or had multiorgan transplant that included a kidney, to identify live donors who developed KF without dialysis. The linked data was reviewed for KF as a cause of death, or if during hospital admissions, there was a diagnosis or procedure as per International Classification of Diseases (ICD) code that indicated acute or chronic KF (Supplementary Tables S1–S4).[18]

Secondary Outcome: Death

Causes of death were recorded using the ICD 9th and 10th revision, Australian Modification codes. Cause of death was categorized. Patient survival post donation was analyzed using Kaplan-Meier survival curves.

Secondary Outcome: CVD

CVD outcomes were defined using ICD 9th and 10th revision, Australian Modification codes during hospital admissions. Codes used to identify CVD events are listed in Supplementary Tables S4 to S8. Given that death is a competing risk for CVD, the cumulative incidence of competing events is graphically displayed.

Secondary Outcome: Acute Complications

All hospital admissions within 90 days of donation were obtained from the National Minimum Dataset.

Complications were defined using ICD 9th revision, Clinical Modification and ICD 10th revision, Australian Modification external cause code. External cause ICD codes are used to classify the mechanism of an event or injury, which coders determine at the time of admission. We determined that there was a complication if an admission had the external cause code group "Complications of medical and surgical care." Admissions up until December 31, 1999, used ICD 9th revision coding, and after January 1, 2000, used ICD 10th revision coding. Complications were calculated on a per patient basis. The type of complications were determined using the diagnostic codes for that admission. Complications were then categorized based on severity and major and minor categories. Severity was determined using the adapted Clavien-Dindo Classification of surgical complications.[7,19,20] This grades the complication based on the level of treatment required, that is, grade 2: transfusion, grade 3: radiological procedure or surgical intervention, and grade 4: organ failure. Any diagnoses within an admission were categorized into minor and major categories based on work from Lentine *et al.*[7] These categories were assigned by 2 separate authors (GI and LC) with consensus by discussion. Adjudication from coauthors (MC, MS, and PC) occurred if consensus was not reached. A patient could have multiple complications per admission.

Sensitivity Analysis: Definition of Complication

Two sensitivity analyses were conducted for the analysis of complications to ensure the robustness of estimates:

1. Any complications within 30 days.
2. Any complications within initial admission for donor nephrectomy.

Ethics

The study was approved by the Northern Health and Disability Ethics Committee (reference 15/NTA/47) and received funding from Auckland District Health Board Charitable Trust.

RESULTS

Records of transplants performed between 1988 and 2018 were complete, and all living donors were identified for transplants performed during that period. There were 1339 donors from 1988 to 2018, with an increase in donors over time. The demographics of the living donors are displayed in Table 1. Most donors were female (58%). The median age at donation was 44 (IQR: 35–52) years. Europeans (79%) were the predominant ethnicity group followed by Māori (10%), Asian (6%), and Pacific (3%). Of the donors, 62% were genetically related to the transplant recipients. The median follow-up time was 11.2 (IQR: 5.5–17.7, range: 1.0–30.2) years.

Table 1. Live Kidney donor demographics

Factor	Value (N = 1339)
Age at donation, median (IQR)	44.7 (35.7–52.5)
Donor sex, n (%)	
Female	777 (58.0%)
Male	562 (42.0%)
Ethnicity, n (%)	
European	1060 (79.2%)
Māori	139 (10.4%)
Pacific	47 (3.5%)
Asian	80 (6.0%)
Other	13 (1.0%)
Related Donor, n (%)	834 (62.3%)
Year of Donation, n (%)	
1988–1997	189 (14.1%)
1998–2007	431 (32.2%)
2008–2018	719 (53.7%)

IQR, interquartile range.

Outcomes

KF

Five people developed KF treated with kidney replacement therapy during follow-up (Figure 2). No additional donors who were not receiving kidney replacement therapy had KF reported as a cause of death. The incidence rate of KF was 3 per 10,000 person-years (95% CI: 1.3–7.4) with a follow-up time of 16,272 person-years. The death-censored KF was 0% at 5 years, 0.1% (95% CI: 0.1%–0.9%) at 10 years, 0.7% (95% CI: 0.2%–2.4%) at 20 years, and 2.6 (95% CI: 1%–7.5%) at 30 years. One donor developed KF and commenced kidney replacement therapy after 8 years post–kidney donation because of glomerulonephritis. In contrast, the remaining 4 developed KF, all attributed to diabetic kidney disease, more than 15 years after kidney donation.

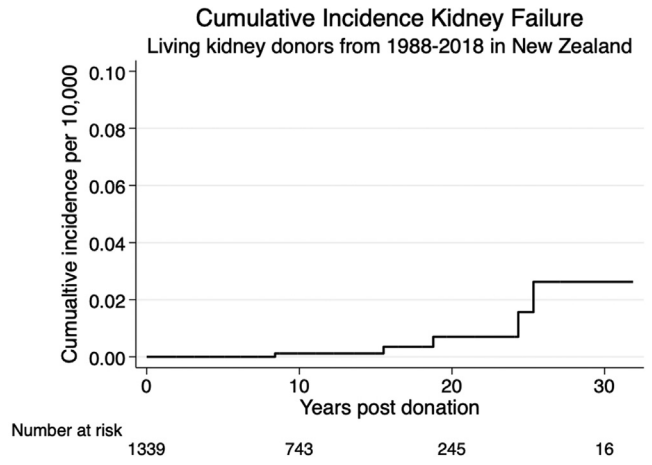

Figure 2. Cumulative incidence of kidney failure after live kidney donation.

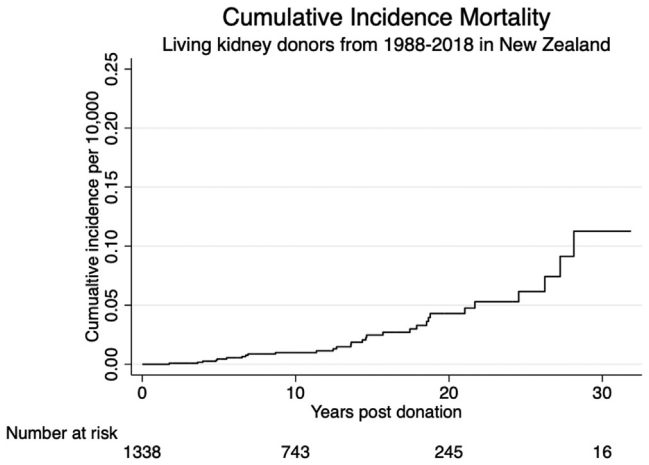

Figure 3. Cumulative incidence of mortality after live kidney donation.

Death

There were 30 deaths (0.08%) of kidney donors recorded during the study follow-up period. The most common cause of death was malignancy 67% ($n = 20$), followed by CVD 20% ($n = 6$). The mean age at death was 63 (SD: 10.8) years. The Kaplan-Meier survival curve for death is shown in Figure 3. Patient survival was 0.4% (95% CI: 0.2%–1.1%) at 5 years, 1.0% (95% CI: 0.5%–1.8%) at 10 years, 4.3% (95% CI: 2.8%–6.6%) at 20 years, and 11.3% (95% CI: 6.3%–19.5%) at 30 years.

CVD

Nineteen people (1%) had an acute cardiovascular event during follow-up after donation.These were primarily because of ischemic heart disease 68% ($n = 13$), with the remaining because of cardiovascular death ($n = 6$, 32%). Of the donors who had a cardiovascular event, 73.7% ($n = 14$) were men. The median time from donation to admission with a cardiovascular event was 16.4 (IQR: 9.9–22.1) years. The cumulative incidence curves for cardiovascular events and the competing risk of noncardiac death are displayed in Figure 4. The follow-up time was 16,439 person-years, with an estimated incidence rate of 11.6 (95% CI: 7.4–19.2) per 10,000 person years.

Complications

Two hundred ninety-two donors (22%) had reported a complication following donation. Of these, 69 (5%) had a complication requiring an intervention (Clavien-Dindo complication >1: Table 2). The major types of complications are documented in Table 3, with the most frequent being "other" complications followed by gastrointestinal; the minor categories are documented in Supplementary Table S10. No living donors died in the first 3 months after donation. Sixty-seven people (5%) were readmitted because of complications and 1 person was readmitted twice. For a donation admission, the median length of stay, if there was a complication was 5 (IQR: 4–7; range: 2–24) days compared with a median stay of 4 without a complication (IQR: 3–5; range: 1–17) days ($P < 0.001$). The median length of stay for readmission was 2 (IQR: 1–3; range: 0–40) days. The length of stay decreased over time, with the median length of stay being 7 (IQR: 6–8) days in 1988 to 1999, compared with 4 (IQR 3-4) days in 2010 to 2018.

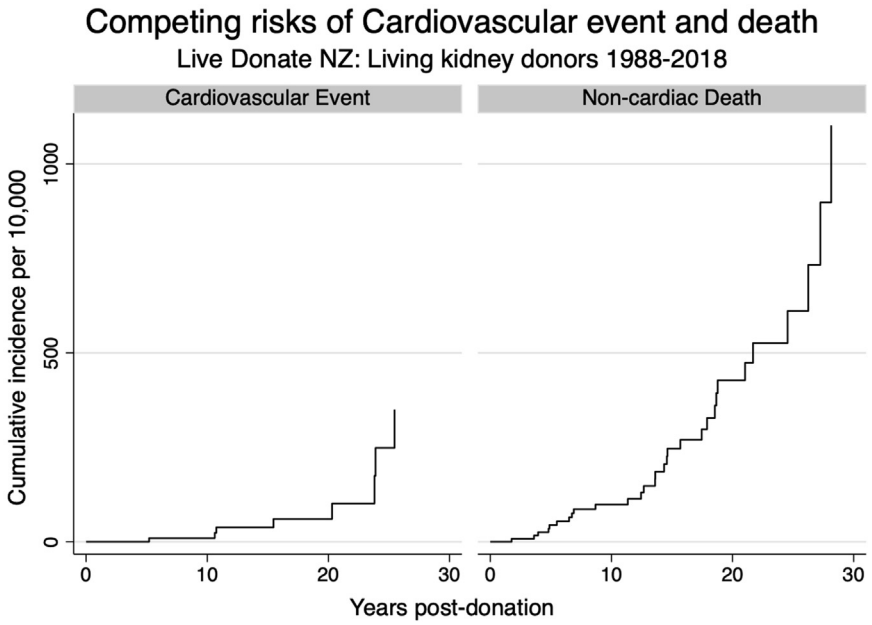

Figure 4. Cumulative incidence curves for the competing risks of cardiovascular events and non–cardiac death over time after live kidney donation.

Table 2. Acute complications based on severity

Clavien-Dindo complication grade	Number	Percentage
1	223	76.4%
2	7	2.4%
3	61	20.9%
4	1	0.3%

Sensitivity Analysis 1: Readmission Within 30 days

When restricted to complications within 30 days of donation, there were 286 people with complications (22%), with 65 people with complications requiring an intervention (Clavien-Dindo complication > 1). These are documented in Supplementary Table S11.

Sensitivity Analysis 2: Complications Within Donation Admission

When restricted to complications only within the donation admission, 239 people (18%) had a complication. Of these, 55 (4%) required an intervention (Clavien-Dindo complication > 1). Restriction to only donation admission excluded complications from the minor categories of hematuria, peritonitis, and gastrointestinal hemorrhage.

Missingness

There was limited missing data. Twenty-one donors (1.6%) had no records of hospital admissions within −14 to +90 days of donation. All other data had no missingness.

DISCUSSION

This study explored multiple short-term and long-term patient important complications post donation.

Table 3. Complications categorized into major categories

Complication	Number (% of total complications) $n = 292$
Bleeding	38 (13.0%)
Cardiac	54 (18.5%)
Fluid imbalance	43 (14.7%)
Gastrointestinal	126 (43.2%)
Genitourinary	41 (14.0%)
Hernia	1 (0.3%)
Infection	65 (22.3%)
Injury	33 (11.3%)
Kidney impairment	12 (4.1%)
Other complications	181 (62.0%)
Respiratory	66 (22.6%)
Thrombosis	1 (0.3%)
Vascular	10 (3.4%)
Wound	25 (8.6%)

Note: there can be multiple diagnoses per patient.

KF

In this analysis, 5 of 1339 donors developed KF in the follow-up period, and the incidence rate of KF was 3 per 10,000 person-years (95% CI: 1.3–7.4). Although these risks of KF after kidney donation do not exceed KF rates in the general population,[10,21,22] 2 studies comparing donors with donation-attributable risk found that donation is associated with a small but significant risk of KF. However, the absolute increase in KF attributable to donation was minimal.[11,12] Mjøen *et al.*[12] showed that the overall incidence of KF among donors was 302 cases per million, with a median follow-up of 15 years.[11] Muzaale *et al.*[13] reported that the cumulative incidence of KF at 15 years was 30.8 per 10,000 donors compared with 3.9 per 10,000 in matched donors (risk attributable to donation of 26.9 per 10,000).[12] Our findings reaffirm that low risk of KF post donation is consistent with previous reports of KF in donors.[11,12] In our study, only 1 donor developed KF because of glomerulonephritis after 8 years post–kidney donation, and the remaining 4 donors developed later KF with diabetic kidney disease as the most common cause of KF after 15 years post–kidney donation. Our findings confirm the findings of an earlier study that showed early KF in donors within 10 years post–kidney donation was predominantly attributed to glomerulonephritis. In contrast, later KF in donors was because of diabetic kidney disease and hypertension.[23] Diabetic kidney disease and hypertension were unlikely to be the cause of KF in donors in the early period post–kidney donations because these conditions were absolute or relative contraindications for living kidney donation.[24,25] This highlights that, as a community we need to be vigilant in screening and managing diabetes in the donor population.

Death

Although previous studies reported that the living donor population experienced fewer deaths when compared with matched general population, there were no data on relative survival.[9–12,26–28] More recent studies with alternative methods have reported the observed and expected survival.[29,30] The Swedish study had 459 donors from 1964 until the end of 1994 and reported observed survival of 85% in the donor group after 20 years of follow-up, whereas the expected survival rate was 66%.[29] The study was from an earlier era and better survival among donors may be due to more selective criteria for donation. In a Japanese study, the observed survival in living donors were 98.2%, and the expected survival was 97% at 5 years after donation.[30] Our study demonstrates that living kidney donors in NZ have a low mortality risk on long-term follow-up.

CVD

There is plausibility for an excess of cardiovascular risk or mortality after kidney donation. Most studies have a short follow-up period after donation, with few cases of ischemic heart disease, resulting in a lack of statistical power.[9,28,31] The aforementioned studies all suffer from few events, relatively short follow-up period, and uncertainty about whether the control group was considered an appropriate comparison (low CVD risk). Another study[32] found significantly higher risk CVD compared with healthy controls. In the latter study, after a mean observation time of 11.3 (SD: 8.1) years for donors and 16.4 (SD: 5.7) years for controls, 3.5% ($n = 35$) of donors were diagnosed with ischemic heart disease versus 1.7% ($n = 267$) of the controls. The adjusted odds ratio for CVD was 1.64 (95% CI: 1.1–2.4, $P = 0.01$) in donors compared with controls. However, diagnoses of CVD were based on self-reports among the controls, which may result in underreporting and recall bias.[32] Mjøen *et al.*[12] found increased CVD and mortality in living donors compared with healthy donors and attributed the difference in the findings compared with previous studies because of the longer follow-up in their study.[11] Our study reported that 1.4% ($n = 19$) donors suffered CVD requiring admission post donation and an incidence rate of 11.6 (95% CI: 7.4–19.2) per 10,000 person years which remains low and reassuring for donors. This, however, needs to be interpreted that our data only captured those with CVD requiring hospitalization; thus any less severe CVD managed in the community may be missed.

Secondary Complications

The perioperative mortality rate of living donor nephrectomy ranges from 0.02% to 0.04% and morbidity varies from 8% to 18%.[7,33,34] The variation in the complication rates is likely because of the differences in the definition of perioperative complications and ascertainment methodology. The higher incidence of overall complications in our study likely reflects differing definitions of the outcome measure. Our study broadens the definition to encompass specific complications, including cardiac, respiratory, gastrointestinal, bleeding, and infection, and includes any complication within 90 days rather than the initial hospital admission. The longer length of hospital stay in the earlier era between 1988 and 1999 compared with later period in 2010 to 2018 may be due to the difference in surgical technique for living donor nephrectomy or changes in postoperative models of care. Open donor nephrectomy was implemented in the earlier era, and laparoscopic nephrectomy was introduced in June 2000. Since then, the laparoscopic approach has become the standard surgical approach for donor nephrectomy in NZ. The laparoscopic technique benefits from a shorter hospital stay.[35,36] Data on admission to intensive care were not collected within the MoH dataset, which is one of the inclusion criteria for grade 4 for Clavien-Dindo; thus, this could not be included within the categories of complications and may underestimate complication severity. This highlights some of the difficulties in using administrative datasets for complications. The external codes are assigned by coders using clinical information at the time of the event. This increase in granular information presumably can allow the coders to discriminate whether a complication is attributable to donation or not. The limitation of using the coding approach is that coders may not recognize some complications at the time, and thus underreport potentially more minor complications.

Examining comprehensive longitudinal outcomes into a contemporary era is imperative to provide donors with short-term and long-term risks of donation, particularly given the change in who we accept as donors.[26] Effective risk communication is essential for shared decision-making, the gold standard for health care decisions.[37] Being able to provide donors with accurate information risks, benefits, and consequences of donation are part of the informed consent process from the decision-making framework set out within the Kidney Disease Improving Global Outcomes Clinical Practice Guideline on the Evaluation and Care of Living Kidney Donors Guidelines.[6] Ideally, these risks would be individualized, include the degree of uncertainty,[6] and presented as absolute values.[38] Grams *et al.*[39] have developed an internet-based risk prediction calculator which can calculate the risk of KF pre donation at 15 years and over the donors life time.[40] Unfortunately, the usefulness of this tool for decision making is hampered by the lack of risk post donation. The difficulty in creating a risk score post donation based on individual donor characteristics is hampered by the need for both long-term follow-up and a large number of donors, because of fortunately low numbers of donors who have KF.

Strengths

This is a comprehensive longitudinal study of all living donors in NZ spanning 30 years. Long-term follow-up of healthy living kidney donors can be difficult to maintain because they may default from regular follow-up leading to incomplete post donation information. We could use data linkage to national registries and ANZDATA to ascertain KF, CVD, death; and reduce loss to follow-up in our study population. There is complete capture of all cases of treated KF and all death data. Other studies have restricted to donation admission,

which may miss essential complications that cause readmission to hospital.

Limitations

There are limitations to the study. This is a small population study of a rare outcome which limits the studies power. There are limited data on living donors' characteristics at the time of donation, particularly in respect to kidney function and comorbidities. Given the low rate of all outcomes, we cannot adjust for any other covariates which may confound the various outcomes in this analysis.[41] This analysis does not include a comparison control group of nondonors (there was no longitudinal cohort study over the same period on the same population to allow comparison), so a relative risk cannot be calculated. Over the years, the living donor criteria have expanded to include acceptance of genetically unrelated living donors (including nondirected donors), development of exchange programs (established in 2011), and use of expanded-criteria living donors, particularly elderly donors. There needs to be caution with the extrapolation of risk from previous eras of donors to the current potentially more marginal donors. The uncertainty of risk as donor criteria expand will need further prospective monitoring of complications to quantify the future risks better. This means that the rates of KF and complications may not be as generalizable to the current cohort of donors. The major limitation of this study is the use of coded administrative datasets, particularly to determine post-operative complications. These were derived from administrative coding at the time of admission rather than clinical judgment. This analysis only included complications that led to a hospital admission which may have excluded less severe complications. The outcome of CVD was derived from hospital admissions or procedures. Thus, if someone was diagnosed with CVD in primary care this would not be captured, potentially missing less severe CVD. These limitations must be acknowledged when interpreting the rates of post-operative complications and the outcome of CVD. In addition, these data sets are administrative datasets for NZ. There is a risk if a person migrated, both the time and risk, and the risk of outcomes may be underreported.

This study demonstrated a low risk of several short-term and long-term outcomes for donors post–living kidney donation. There are clear limitations to this study with small overall numbers and no control population. There is a low risk of long-term patient important complications of KF, CVD, and death over a 30-year follow-up period. Perioperative complications are common in keeping with the previous literature; however, severe complications are rare. Being able to inform donors about these risks may help with consent and decision-making about kidney donation. Further research presenting the absolute risk for donors post donation should be the aspiration for the living donor community.

DISCLOSURE

All the authors declared no competing interests.

ACKNOWLEDGEMENT

We are grateful to the Australian and NZ kidney units, patients, and staff for their cooperation and contributions to ANZDATA. The ANZDATA Registry supplied some of the data reported here. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy or interpretation of the Registry.

Funding

MC received research funds from Auckland District Health Board Charitable Trust for this study. PC was supported by a Jacquot Research Establishment Award (Royal Australasian College of Physicians). GI was supported by a Postgraduate Research Scholarship (National Health and Medical Research Council, Australia).

DATA AVAILABILITY STATEMENT

Data for this study are not available for public review.

AUTHOR CONTRIBUTIONS

LWC contributed to design, data collection, and article writing. GI contributed to design, analysis, and article writing. TG and BA contributed to data collection. CD, MS, and PC contributed to design, analysis and editing. MC conceived the study concept, and contributed to design, data collection, analysis, article preparation, and editing. All the authors contributed to revising the manuscript and approved the final version submitted for publication.

SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Table S1. ICD-9 diagnosis codes for kidney failure.

Table S2. ICD-10 diagnosis codes for kidney failure.

Table S3. ICD-9 procedure codes for kidney failure.

Table S4. ICD-10 procedure codes for kidney failure.

Table S5. ICD-9 diagnosis codes for cardiovascular disease.

Table S6. ICD-10 diagnosis codes for cardiovascular disease.

Table S7. ICD-9 procedure codes for cardiovascular disease.

Table S8. ICD-10 procedure codes for cardiovascular disease.

Table S9. Primary and sensitivity analysis of complications categorized into major categories.

Table S10. Primary and sensitivity analysis of complications categorized into minor categories.

Table S11. Primary and sensitivity analysis of complications reviewing major categories of complications requiring intervention (with a Clavien-Dindo score $>$ 1).

REFERENCES

1. Laupacis A, Keown P, Pus N, et al. A study of the quality of life and cost-utility of renal transplantation. *Kidney Int*. 1996;50:235–242. https://doi.org/10.1038/ki.1996.307
2. Tonelli M, Wiebe N, Knoll G, et al. Systematic review: kidney transplantation compared with dialysis in clinically relevant outcomes. *Am J Transplant*. 2011;11:2093–2109. https://doi.org/10.1111/j.1600-6143.2011.03686.x
3. Wolfe RA, Ashby VB, Milford EL, et al. Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant. *N E J M*. 1999;341:1725–1730. https://doi.org/10.1056/NEJM199912023412303
4. Those. Data Are Based on the Global Observatory on Donation and Transplantation (GODT) Data the WHO, prods-ONT collaboration, 2021, World Health Organization Global Observatory on Donation and Transplantation; Geneva. Accessed December 23, 2024. https://www.transplant-observatory.org/
5. ANZDATA registry [45th Report]. Chapter 7: Kidney Transplantation. Australia and New Zealand Dialysis and Transplant Registry, Adelaide, Australia. 2022. Accessed August 1, 2024. http://www.anzdata.org.au
6. Lentine KL, Kasiske BL, Levey AS, et al. KDIGO clinical practice guideline on the evaluation and care of living kidney donors. *Transplantation*. 2017;101:S1–S109. https://doi.org/10.1097/TP.0000000000001769
7. Lentine KL, Lam NN, Axelrod D, et al. Perioperative complications after living kidney donation: a national study. *Am J Transplant*. 2016;16:1848–1857. https://doi.org/10.1111/ajt.13687
8. Cherikh WS, Young CJ, Kramer BF, Taranto SE, Randall HB, Fan PY. Ethnic and gender related differences in the risk of end-stage renal disease after living kidney donation. *Am J Transplant*. 2011;11:1650–1655. https://doi.org/10.1111/j.1600-6143.2011.03609.x
9. Garg AX, Meirambayeva A, Huang A, et al. Cardiovascular disease in kidney donors: matched cohort study. *BMJ*. 2012;344:e1203. https://doi.org/10.1136/bmj.e1203
10. Ibrahim HN, Foley R, Tan L, et al. Long-term consequences of kidney donation. *N Engl J Med*. 2009;360:459–469. https://doi.org/10.1056/NEJMoa0804883
11. Segev DL, Muzaale AD, Caffo BS, et al. Perioperative mortality and long-term survival following live kidney donation. *JAMA*. 2010;303:959–966. https://doi.org/10.1001/jama.2010.237
12. Mjøen G, Hallan S, Hartmann A, et al. Long-term risks for kidney donors. *Kidney Int*. 2014;86:162–167. https://doi.org/10.1038/ki.2013.460
13. Muzaale AD, Massie AB, Wang MC, et al. Risk of end-stage renal disease following live kidney donation. *JAMA*. 2014;311:579–586. https://doi.org/10.1001/jama.2013.285141
14. Boudville N, Prasad GV, Knoll G, et al. Meta-analysis: risk for hypertension in living kidney donors. *Ann Intern Med*. 2006;145:185–196. https://doi.org/10.7326/0003-4819-145-3-200608010-00006
15. Garg AX, Muirhead N, Knoll G, et al. Proteinuria and reduced kidney function in living kidney donors: a systematic review, meta-analysis, and meta-regression. *Kidney Int*. 2006;70:1801–1810. https://doi.org/10.1038/sj.ki.5001819
16. Mudiayi D, Shojai S, Okpechi I, et al. Global estimates of capacity for kidney transplantation in world countries and regions. *Transplantation*. 2022;106:1113–1122. https://doi.org/10.1097/TP.0000000000003943
17. Stats. Population. 2024. Accessed August 1, 2024. https://www.stats.govt.nz/topics/population
18. Sparke C, Moon L, Green F, et al. Estimating the total incidence of kidney failure in Australia including individuals who are not treated by dialysis or transplantation. *Am J Kidney Dis*. 2013;61:413–419. https://doi.org/10.1053/j.ajkd.2012.10.012
19. Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo classification of surgical complications: five-year experience. *Ann Surg*. 2009;250:187–196. https://doi.org/10.1097/SLA.0b013e3181b13ca2
20. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004;240:205–213. https://doi.org/10.1097/01.sla.0000133083.54934.ae
21. Fehrman-Ekholm I, Dunér F, Brink B, Tydén G, Elinder CG. No evidence of accelerated loss of kidney function in living kidney donors: results from a cross-sectional follow-up. *Transplantation*. 2001;72:444–449. https://doi.org/10.1097/00007890-200108150-00015
22. Fournier C, Pallet N, Cherqaoui Z, et al. Very long-term follow-up of living kidney donors. *Transpl Int*. 2012;25:385–390. https://doi.org/10.1111/j.1432-2277.2012.01439.x
23. Anjum S, Muzaale AD, Massie AB, et al. Patterns of end-stage renal disease caused by diabetes, hypertension, and glomerulonephritis in live kidney donors. *Am J Transplant*. 2016;16:3540–3547. https://doi.org/10.1111/ajt.13917
24. Lentine KL, Kasiske BL, Levey AS, et al. Summary of kidney disease: improving global outcomes (KDIGO) clinical practice guideline on the evaluation and care of living kidney donors. *Transplantation*. 2017;101:1783–1792. https://doi.org/10.1097/TP.0000000000001770
25. Garg AX, Levey AS, Kasiske BL, Cheung M, Lentine KL. KDIGO Clinical Practice Guideline on the Evaluation and Care of Living Kidney Donors Work Group and Evidence Review Team. Application of the 2017 KDIGO guideline for the evaluation and care of living kidney donors to clinical practice. *Clin J Am Soc Nephrol*. 2020;15:896–905. https://doi.org/10.2215/CJN.12141019
26. Clayton PA, Saunders JR, McDonald SP, et al. Risk-factor profile of living kidney donors: the Australia and New Zealand dialysis and transplant living kidney donor registry 2004-2012. *Transplantation*. 2016;100:1278–1283. https://doi.org/10.1097/TP.0000000000000877

27. De La Mata NL, Clayton PA, Kelly PJ, et al. Survival in living kidney donors: an Australian and New Zealand cohort study using data linkage. *Transplant Direct*. 2020;6:e533. https://doi.org/10.1097/TXD.0000000000000975
28. Reese PP, Bloom RD, Feldman HI, et al. Mortality and cardiovascular disease among older live kidney donors. *Am J Transplant*. 2014;14:1853–1861. https://doi.org/10.1111/ajt.12822
29. Fehrman-Ekholm I, Elinder CG, Stenbeck M, Tydén G, Groth CG. Kidney donors live longer. *Transplantation*. 1997;64:976–978. https://doi.org/10.1097/00007890-199710150-00007
30. Okamoto M, Akioka K, Nobori S, et al. Short- and long-term donor outcomes after kidney donation: analysis of 601 cases over a 35-year period at Japanese single center. *Transplantation*. 2009;87:419–423. https://doi.org/10.1097/TP.0b013e318192dc95
31. Rizvi SA, Zafar MN, Jawad F, et al. Long-term safety of living kidney donation in an emerging economy. *Transplantation*. 2016;100:1284–1293. https://doi.org/10.1097/TP.0000000000001075
32. Haugen AJ, Hallan S, Langberg NE, et al. Increased risk of ischaemic heart disease after kidney donation. *Nephrol Dial Transplant*. 2022;37:928–936. https://doi.org/10.1093/ndt/gfab054
33. Patel S, Cassuto J, Orloff M, et al. Minimizing morbidity of organ donation: analysis of factors for perioperative complications after living-donor nephrectomy in the United States. *Transplantation*. 2008;85:561–565. https://doi.org/10.1097/TP.0b013e3181643ce8
34. Schold JD, Goldfarb DA, Buccini LD, et al. Comorbidity burden and perioperative complications for living kidney donors in the United States. *Clin J Am Soc Nephrol*. 2013;8:1773–1782. https://doi.org/10.2215/CJN.12311212
35. Greco F, Hoda MR, Alcaraz A, Bachmann A, Hakenberg OW, Fornara P. Laparoscopic living-donor nephrectomy: analysis of the existing literature. *Eur Urol*. 2010;58:498–509. https://doi.org/10.1016/j.eururo.2010.04.003
36. Nanidis TG, Antcliffe D, Kokkinos C, et al. Laparoscopic versus open live donor nephrectomy in renal transplantation: a meta-analysis. *Ann Surg*. 2008;247:58–70. https://doi.org/10.1097/SLA.0b013e318153fd13
37. Barry MJ, Edgman-Levitan S. Shared decision making–pinnacle of patient-centered care. *N Engl J Med*. 2012;366:780–781. https://doi.org/10.1056/NEJMp1109283
38. Zipkin DA, Umscheid CA, Keating NL, et al. Evidence-based risk communication: a systematic review. *Ann Intern Med*. 2014;161:270–280. https://doi.org/10.7326/M14-0295
39. Grams ME, Sang Y, Levey AS, et al. Kidney-failure risk projection for the living kidney-donor candidate. *N Engl J Med*. 2016;374:411–421. https://doi.org/10.1056/NEJMoa1510491
40. ESRD risk tool for kidney donor candidates. Johns Hopkins University. Accessed June 2, 2023. http://www.transplantmodels.com/esrdrisk/
41. Peduzzi P, Concato J, Feinstein AR, Holford TR. Importance of events per independent variable in proportional hazards regression analysis. II. Accuracy and precision of regression estimates. *J Clin Epidemiol*. 1995;48:1503–1510. https://doi.org/10.1016/0895-4356(95)00048-8