Canadian Blood Services
BLOOD
PLASMA
STEM CELLS
ORGANS
& TISSUES

Interprovincial organ sharing national data report:

Kidney Paired Donation Program

2009–2018

Organs & Tissues for Life

Permission for use of data

Extracts of the information in this report may be reviewed, reproduced or translated for educational purposes, research or private study but not for sale or for use in conjunction with commercial purposes. Any use of the information should be accompanied by an acknowledgement of Canadian Blood Services as the source. Any other use of this publication is strictly prohibited without prior written permission from Canadian Blood Services.

Canadian Blood Services assumes no responsibility or liability for any consequences, losses or injuries, foreseen or unforeseen, whatsoever or howsoever occurring, which might result from the implementation, use or misuse of any information or recommendations in this report. This report contains recommendations that must be assessed in the context of a full review of applicable medical, legal and ethical requirements in any individual case.

Production of this report has been made possible through a financial contribution from Health Canada, and the provincial and territorial governments. The views expressed herein do not necessarily represent the views of the federal, provincial or territorial governments.

For more information, please contact:

Organ and Tissue Donation and Transplantation
Canadian Blood Services

1800 Alta Vista Drive
Ottawa, ON K1G 4J5
Canada

Email: transplantregistry@blood.ca

This report is accessible online at

https://professionaleducation.blood.ca

Canadian Blood Services
BLOOD
PLASMA
STEM CELLS
ORGANS
& TISSUES

Table of contents

Data sources

A glossary of terms can be found in Appendix A.

Data has been extracted from the Canadian Transplant Registry (CTR). The CTR is the information technology system developed and maintained by Canadian Blood Services in which patient data is stored and the matching algorithm is run. Additional data has also been provided directly by the provincial donation and transplant programs and provincial human leucocyte antigen (HLA) laboratories.

National and provincial populations used to calculate rates per million population (PMP) are based on Statistics Canada estimates[1]. Data for the Yukon, Northwest Territories and Nunavut are included with the populations for British Columbia, Alberta, and Ontario, respectively, in alignment with the transplant programs that serve those areas. Population-based rates for results-to-date are based on 2018 estimates.

The Kidney Paired Donation (KPD) program operates using Match Cycles, which typically begin every four months. Match Cycles can include any number of runs of the matching algorithm to repair chains or identify new chains. A Match Cycle is complete when all the chains identified during the Match Cycle months are either collapsed or completed. Unless otherwise stated, this report refers to data from all Match Cycles since the initiation of the KPD program in January 2009 to the final Match Cycle in 2018, which was initiated in October. Transplants reported include all transplants that resulted from the chains proposed in the October 2018 Match Cycle[2]. Potential donors and transplant candidates whose information has been entered in the Canadian Transplant Registry but who have not actively participated in at least one KPD Match Cycle are not included in the results presented. Data is based on registry participants and those recipients who receive transplants through the KPD program.

Unless otherwise stated, results presented here are based on the most recent data available; calculated Panel Reactive Antibody (cPRA) values reflect the data in the patient's record as of the initiation of Match Cycle 34 (June 2019). The term "average" as used here refers to the arithmetic mean unless otherwise specified.

[1] Statistics Canada. Table 17-10-0134-01 Estimates of population (2016 Census and administrative data), by age group and sex for July 1st, Canada, provinces, territories, health regions (2018 boundaries) and peer groups. Extraction date: July 1, 2019.

[2] One chain of three transplants proposed in October 2018 remains on hold at the time of this report development; this chain will be considered as collapsed for the purposes of this report.

Foreword from Canadian Blood Services

Amber Appleby, RN, BScN, MM

Director, Organ and Tissue Donation and Transplantation

Canadian Blood Services manages and operates national programs that support interprovincial sharing of organs and the national technology platform essential to the success of these programs.

The Kidney Paired Donation (KPD) program, established in 2009 (as the Living Donor Paired Exchange Program) by Canadian Blood Services in collaboration with transplant programs across the country, is a living donation program that finds and facilitates medically compatible kidney transplants through chains of donor exchanges from medically incompatible pairs. The program serves patients who have a willing living donor with whom they are not medically compatible by finding another pair with whom they can swap donors so both patients receive a transplant. The KPD program significantly expands access to potential donors for all Canadians with an incompatible donor; every patient who receives a living donor transplant comes off the deceased donor waitlist and thereby decreases the demand on the waitlist for others.

Digital technology is transforming the way healthcare services are delivered in Canada. The KPD program is supported by the Canadian Transplant Registry (CTR), a sophisticated technology platform operated by Canadian Blood Services. The CTR matches available donor organs with potential waitlist recipients anywhere in the country. This national web-based technology is currently used by more than 400 health professionals coast-to-coast.

This year we are pleased to share individual reports for each of the interprovincial organ sharing programs, which is an evolution from previous reporting that combined annual data for the KPD program, the National Organ Waitlist (NOW), and the Highly Sensitized Patient (HSP) program. These new individual data reports also offer greater insights into the growth of each program by reporting on longer periods of data collected.

Collaboration is an essential component of a high-performing organ donation and transplantation system and Canadian Blood Services is committed to working together with provincial organ donation organizations and other system stakeholders to continue to lead national data collection, collation and reporting on KPD program activity.

Canadian Blood Services remains focused on working to deliver a better future for Canadian patients. Together, we are Canada's lifeline.

Amber Appleby, RN, BScN, MM
Director, Organ and Tissue Donation and Transplantation
Canadian Blood Services

Executive summary

Canadian Blood Services currently operates three interprovincial organ sharing programs that serve to maximize transplant access for patients most in need. These include the National Organ Waitlist (NOW), the Kidney Paired Donation (KPD) program and the Highly Sensitized Patient (HSP) program. These programs are operated on the Canadian Transplant Registry (CTR) web-platform, which is maintained by Canadian Blood Services.

Working in collaboration with the provincial living donation programs, the KPD program serves patients who have a willing living donor with whom they are not medically compatible by finding another pair with whom they can swap donors so both patients receive a transplant.

The registry contains medical information about incompatible pairs of donors and transplant candidates from across Canada and identifies pairs that might be able to exchange kidneys. From there, it's a matter of finding a suitable exchange and creating "chains" of matching donors and recipients. There are different types of donor and recipient chains: some are straightforward swaps (called a "paired exchange"), some involve multiple donor–candidate pairs (called a "closed chain"), and some include a non-directed anonymous donor and a person on the waitlist (called a "domino chain"). Non-Directed Anonymous Donors (NDADs) are very important to the success of the KPD Program. An NDAD is someone who wishes to donate a kidney anonymously to someone who needs one.

The KPD program runs its match cycle algorithm three times a year to compare the medical information on all the pairs and non-directed donors in the Registry and identifies kidney transplant opportunities.

Typically, between 140 and 150 pairs and eight NDADs[3] participate in each Match Cycle, and it is expected that results for upcoming Match Cycles will be consistent with this level of participation.

The matches proposed in a Match Cycle result in 27 transplants on average, with chains being completed approximately four months from the date they are initially proposed. Just over half (51%) of the transplant candidates who have participated in at least one Match Cycle received a transplant. Many of those who withdrew from the KPD program did so because they received a transplant from another source, including those who received a deceased donor transplant through the HSP program.

Overview of key program performance metrics, 2009–2018

Scheduled Match Cycles Run	32

KPD participants		**Transplants**	
Pairs	**1,180**	Total KPD transplants	**664**
Transplant candidates	**1,082**	Transplants to registered recipients	**551**
Non-Directed Anonymous Donors (NDADs)	**146**	Transplants to recipients from provincial waitlists	**113**

[3] For more information on the impact of NDADs on KPD performance, see section on Match Cycles and Chains

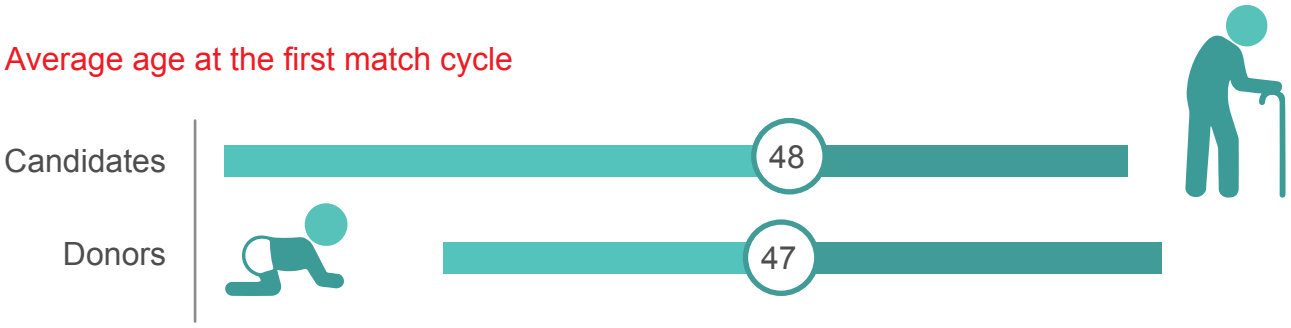
Kidney Paired Donation program participation

There have been 1,082 candidates in need of a kidney transplant who have participated in one or more KPD Match Cycles up to the end of 2018, making up 1,180 registered pairs. From 2011 to 2018, Match Cycles have included an average of 150 registered pairs. In addition, 146 NDADs have participated in the program, with between two and 12 NDADs participating in each Match Cycle.

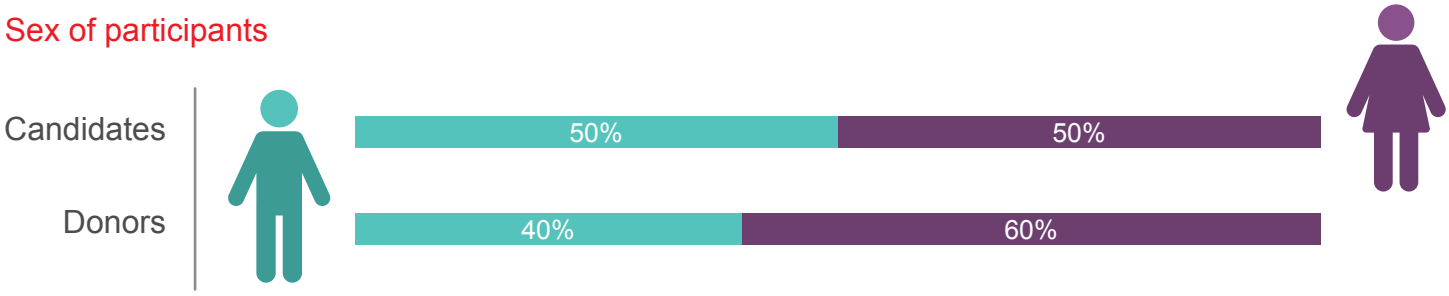
Demographic profiles

Summary of KPD candidate and donor attributes

Average age at the first match cycle



Sex of participants



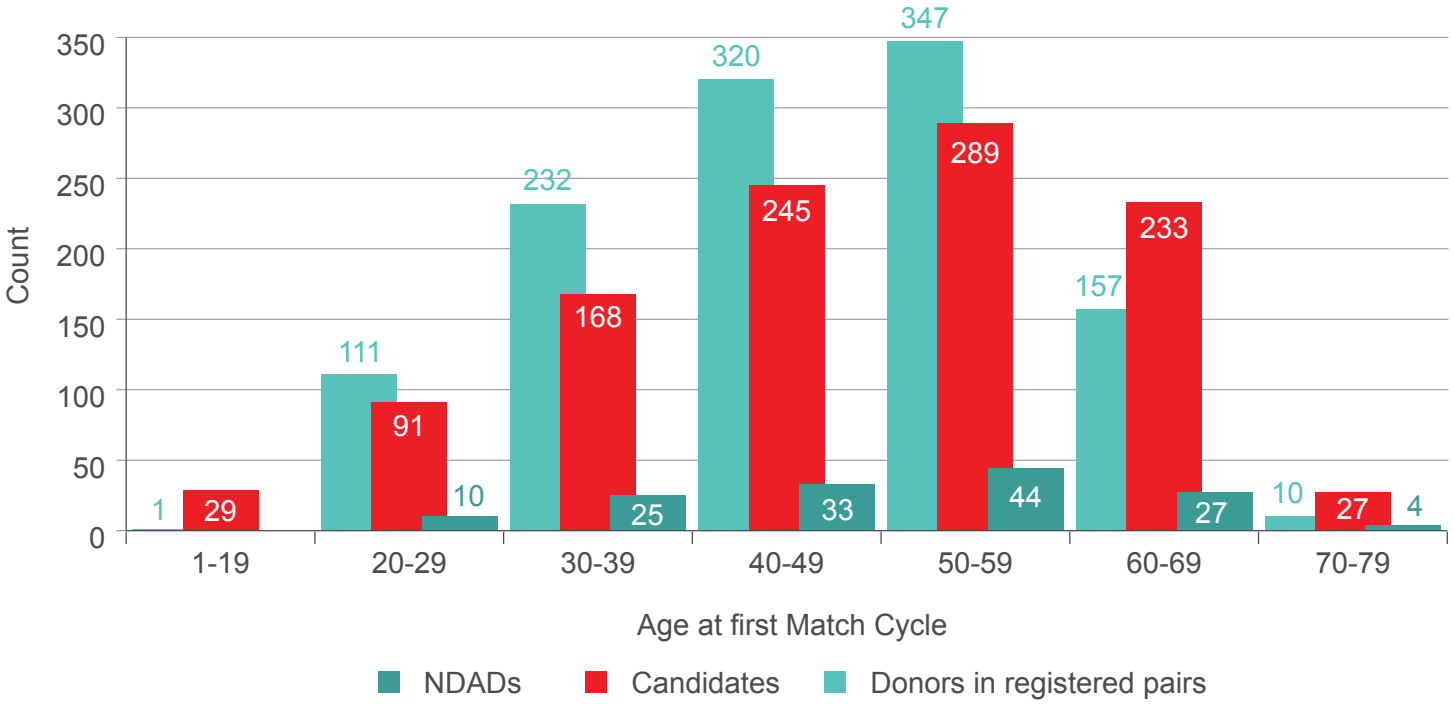
On average, candidates and donors registered as pairs differ in age by 11.3 years. For the majority of pairs (54%, n=641), the donor is the elder of the two, with 40% of pairs (n=475) having the transplant candidate older. In 5% (64) of the pairs, the donor and candidate are the same age.

For the 655 transplants where the recipient's age is available, the donor and recipient differ in age by 13.1 years on average. The recipient received a transplant from an older donor in 54% of cases (n=356) and from a younger donor in 44% of cases (n=287), with the donor and recipient being the same age for 2% (n=12) of transplants.

Sex is not taken into consideration in identifying potential matches. However, the majority of paired donors are female, with female donor/female candidate being the most common sex combination among registered pairs.

There have been 33% more transplants from female donors than from male donors through the KPD program, with recipients being approximately equally divided between sexes.

Active transplant candidates by organ[4]



[4] Donors who initially participated in the program as part of a pair and later participated as an NDAD are represented in these results by the date and type of their first participation only.

Blood groups

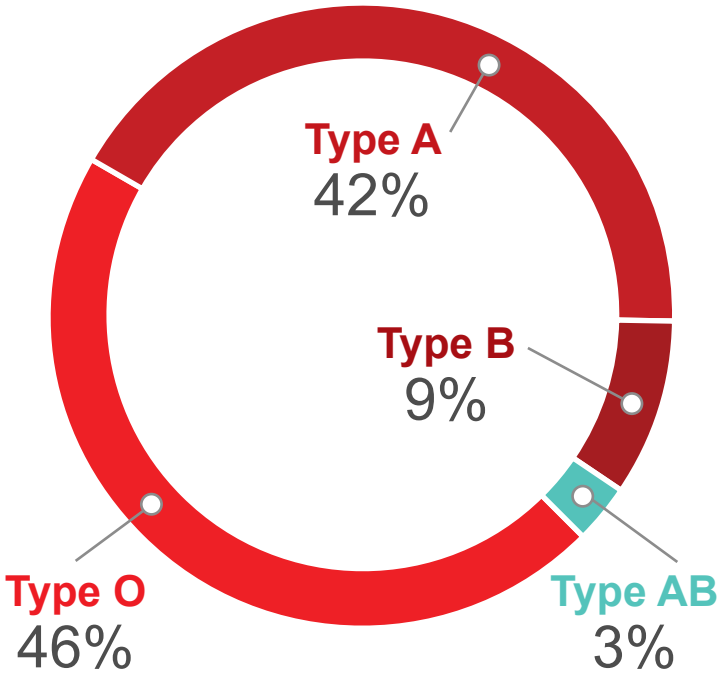
ABO blood group is a significant factor in identifying potentially compatible matches between donors and candidates, as the KPD program does not currently match incompatible blood types or non-A1 sub-type.

Between 54% and 69% of pairs in a given Match Cycle had a transplant candidate with blood type O, with 62% of pairs having a blood type O candidate on average across Match Cycles. The candidates' blood group has been O for 56% of the pairs participating in the KPD program overall.

Pairs with a blood type A candidate have made up 20%-30% of almost all Match Cycles since 2010, and pairs with a blood type B candidate have made up 7%-16% of pairs since 2011. There have been very few pairs with a type AB candidate (approximately 2% overall). This parallels the proportions at which new pairs join the program.

Pairs that include a transplant candidate with a blood type O, particularly those with a donor whose blood type is A or AB, are generally proposed less frequently than pairs with other blood group combinations; however, recipient sensitization and histocompatibility is also a key determinant of the likelihood of being included in a proposed chain.

Blood type distributions in the Canadian population



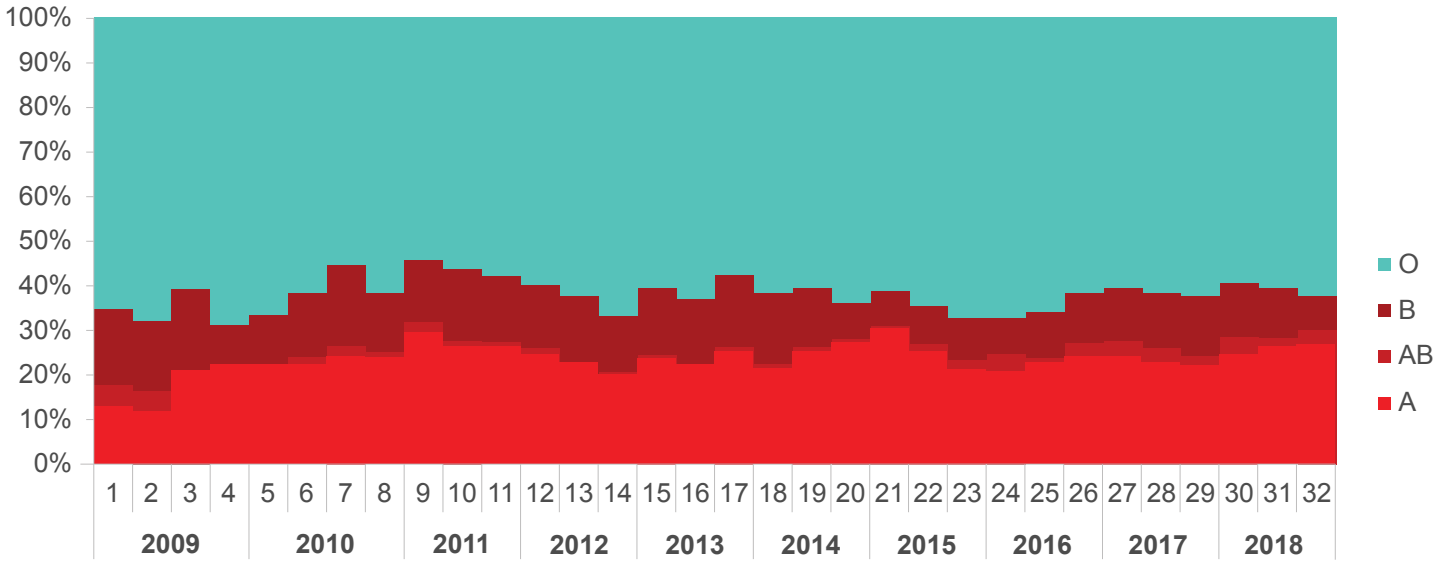
Proportion of pairs proposed by donor and candidate blood groups

Donor	Pairs proposed in their first Match Cycle — Recipient A	AB	B	O
A	56%	60%	73%	15%
AB	78%	100%	73%	15%
B	82%	60%	31%	42%
O	61%	75%	55%	48%

Donor	Pairs proposed in any Match Cycle to date — Recipient A	AB	B	O
A	63%	60%	81%	40%
AB	83%	100%	80%	20%
B	86%	60%	38%	60%
O	70%	88%	74%	62%

Preferential matching of blood type O donors to O candidates by the allocation algorithm has resulted in a majority of O donor kidneys going to O recipients, as would be expected. However, type O candidates continue to accumulate in the registry. Given the blood type limitations associated with finding compatible matches for blood type O transplant candidates, these patients are underrepresented among KPD transplant recipients; 56% of candidates in the registry are blood type O, but only 44% of all KPD transplant recipients are O blood type.

KPD pairs by blood type of candidates over time

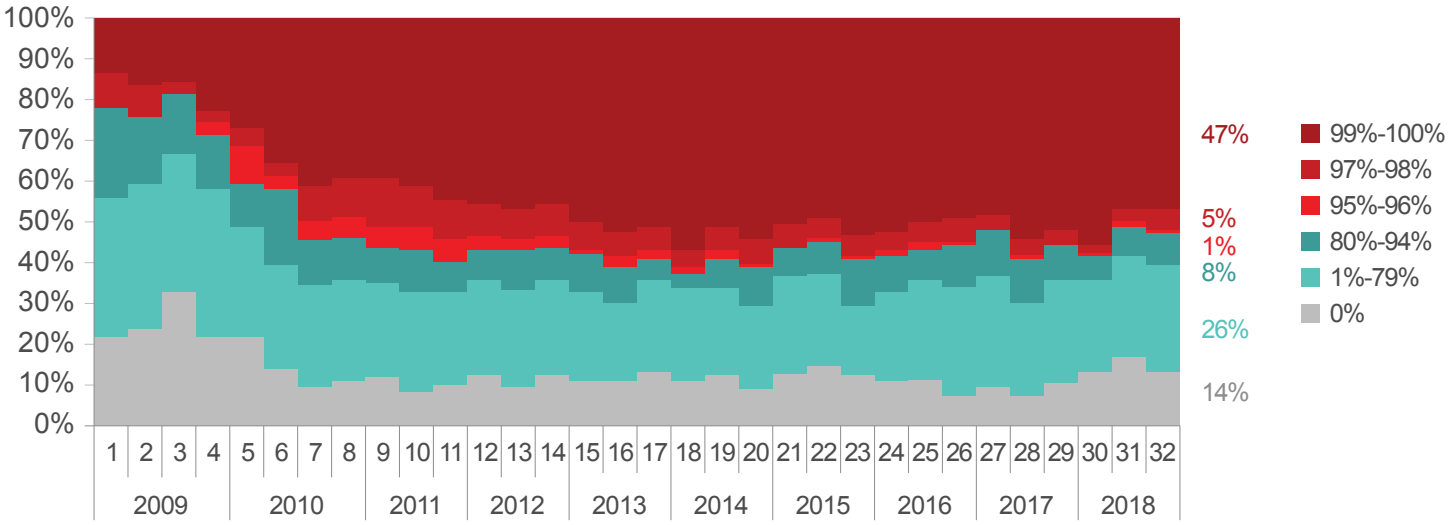


Calculated Panel Reactive Antibody

Compatibility between potential donors and potential recipients is determined in part by their respective Human Leukocyte Antigen (HLA) profiles. Some candidates are incompatible with their registered donor (and other donors) due to donor-specific HLA antibodies (DSA), which can form after exposure to foreign HLA antigens from prior transfusions, transplantations or pregnancies.

The candidate's Calculated Panel Reactive Antibody (cPRA) indicates the percentage of the past deceased donor population to which the candidate has antibodies. A candidate with a higher cPRA will be incompatible with more donors.

KPD pairs by cPRA of candidates over time[5]



[5] In cases where candidate cPRA changed over time, results reflect cPRA as of MC 32

Candidates with a cPRA greater than or equal to 95% are considered highly sensitized and are expected to be incompatible with 95% or more of potential donors. It is estimated that approximately one in five kidney transplant candidates in Canada is highly sensitized, and 30% of the patients in need of a kidney transplant who participate in the KPD program are highly sensitized. In light of the difficulty in finding compatible matches for these candidates, matches of donors to highly sensitized candidates are provided extra points in the matching algorithm to try to include the matches in chains.

Among highly sensitized patients, candidates with a cPRA of 99% or higher are the most biologically difficult to match population in the registry; 24% of all pairs who participated in the KPD program have recipients with a cPRA of 99% or higher, with 46% to 57% of the pairs in each KPD Match Cycle since 2012 having recipients with a cPRA of 99% or higher.

Match Cycles and Chains

Facilitating KPD transplants requires collaboration and focused effort on the part of Canadian Blood Services personnel (including experts who provide medical oversight and guidance) and clinicians and support staff from living kidney donation and transplantation programs across Canada.

Overview: Match Cycles

At the start of each Match Cycle, all possible matches between participating donors and candidates are identified by the CTR. Each potential donor-candidate match is allocated points based on attributes representing priorities for access (please see Appendix B for details).

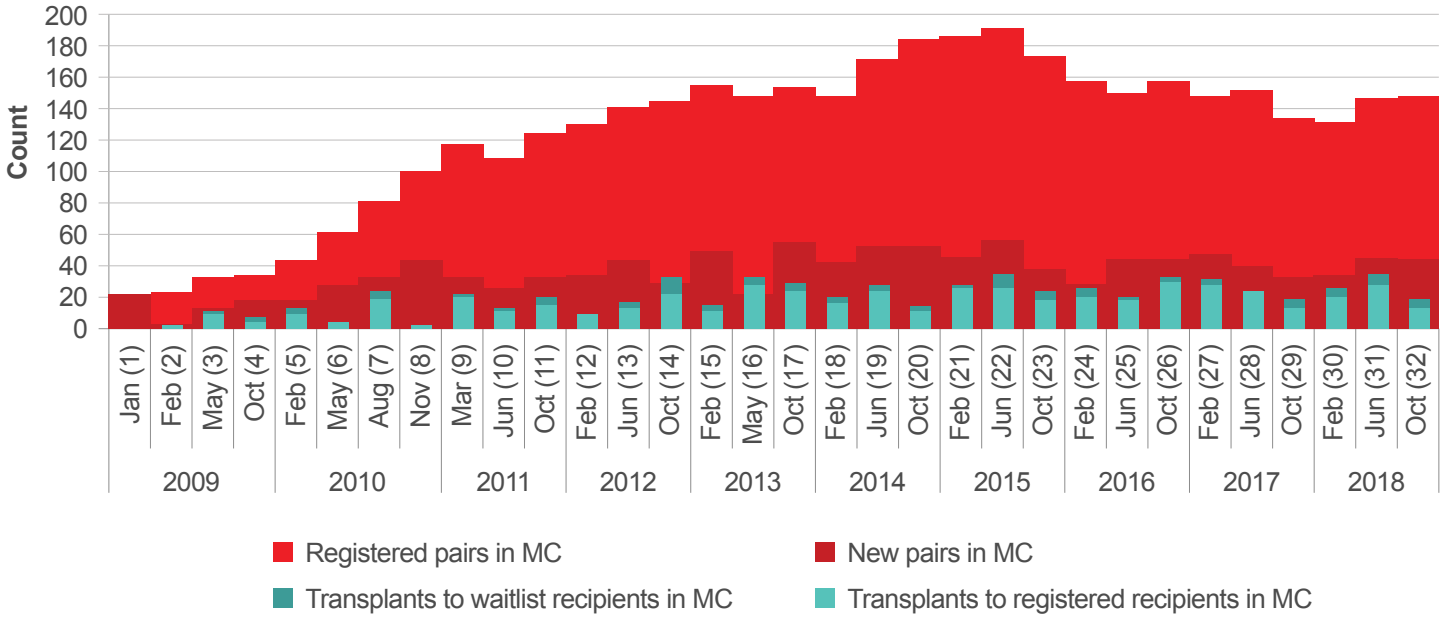
The points for each match that make up a chain are added together to make a chain score, and the chain scores are totalled to make a score for each combination of mutually exclusive chains. The combination of chains with the highest total points is selected to move forward, since this represents the most optimal combination of transplants possible. Incompatible pairs that are not matched in a given Match Cycle are carried forward into the next Match Cycle.

These pairs are also included in any other runs of the algorithm during that Match Cycle. The algorithm may be run to identify a replacement for a pair that can no longer proceed in a chain (a chain repair) or to identify new chains from pairs remaining in the cycle plus pairs from collapsed chains.

A typical Match Cycle involves approximately 140 to 150 registered pairs and 5 to 12 NDADs and can be expected to result in 16 to 36 transplants.

Match Cycle participation

Registered pairs and transplant counts by Match Cycle (month) and year



The KPD program population has remained relatively stable in recent years, with the number of pairs being added to the registry in each Match Cycle being roughly equivalent to the number of pairs going on to donation and transplantation or withdrawing from the registry for other reasons (e.g. receiving a transplant outside of the registry).

A Non-Directed Anonymous Donors (NDAD) is a person who does not have an intended recipient yet wishes to donate a kidney altruistically to a stranger in need. NDADs are extremely important to the success of the KPD program as they greatly increase the number of matches that can be made among the registered pairs. This allows the KPD program to identify chains of exchanges (domino chains) which would otherwise not be possible. The majority of transplants facilitated by the KPD program are made possible because of these domino chains.

NDADs will typically be included in a proposed chain in the first Match Cycle for which they are available.

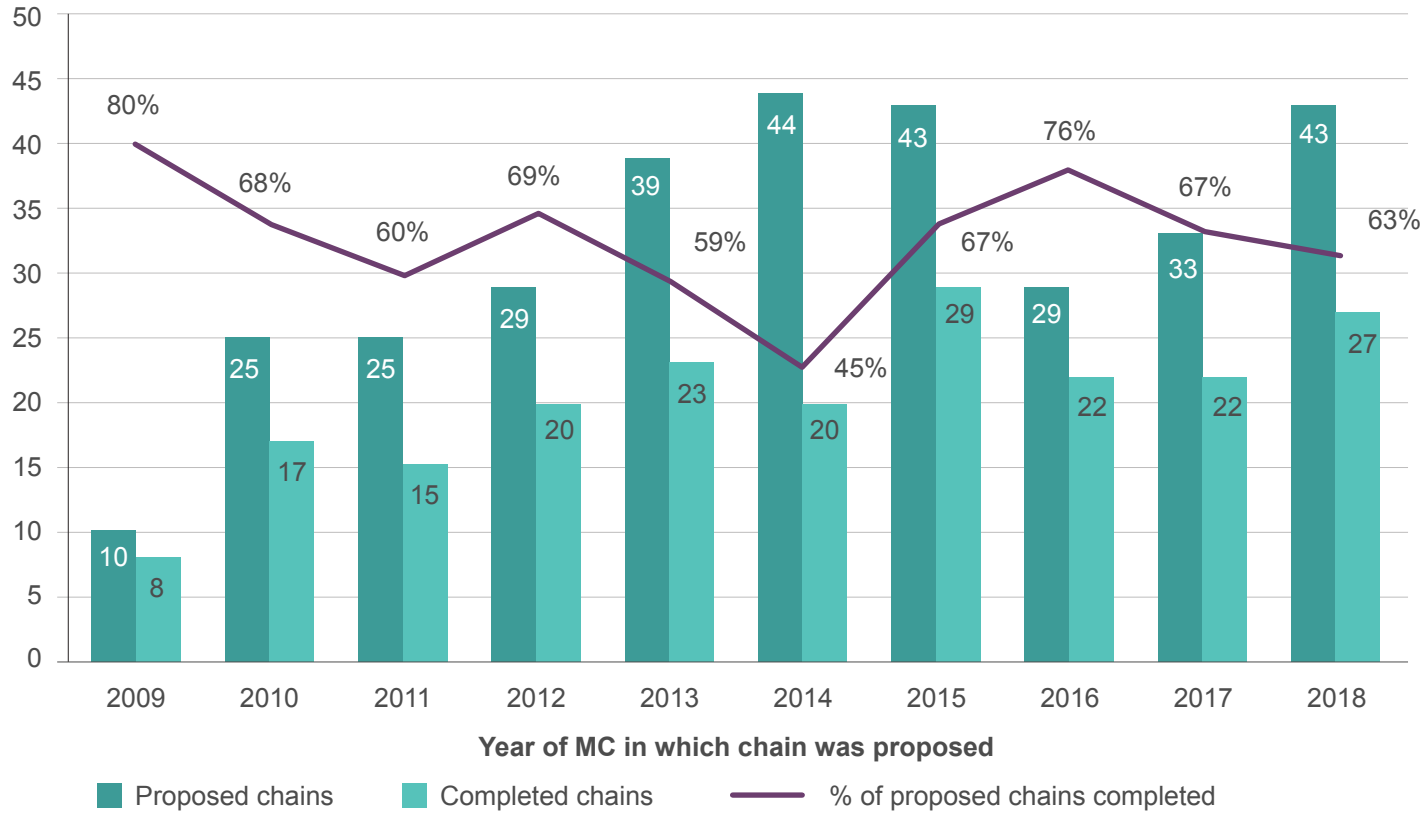
Chain completion

In recent Match Cycles (2013-2018), on average 13 chains were proposed and eight of those proceeded to transplant. On average, seven of every 12 chains proceed to transplant.

Just under two-thirds of proposed chains proceed to completion, with 63% of the chains that were proposed in Match Cycles from 2013 to 2018 resulting in one or more transplants.

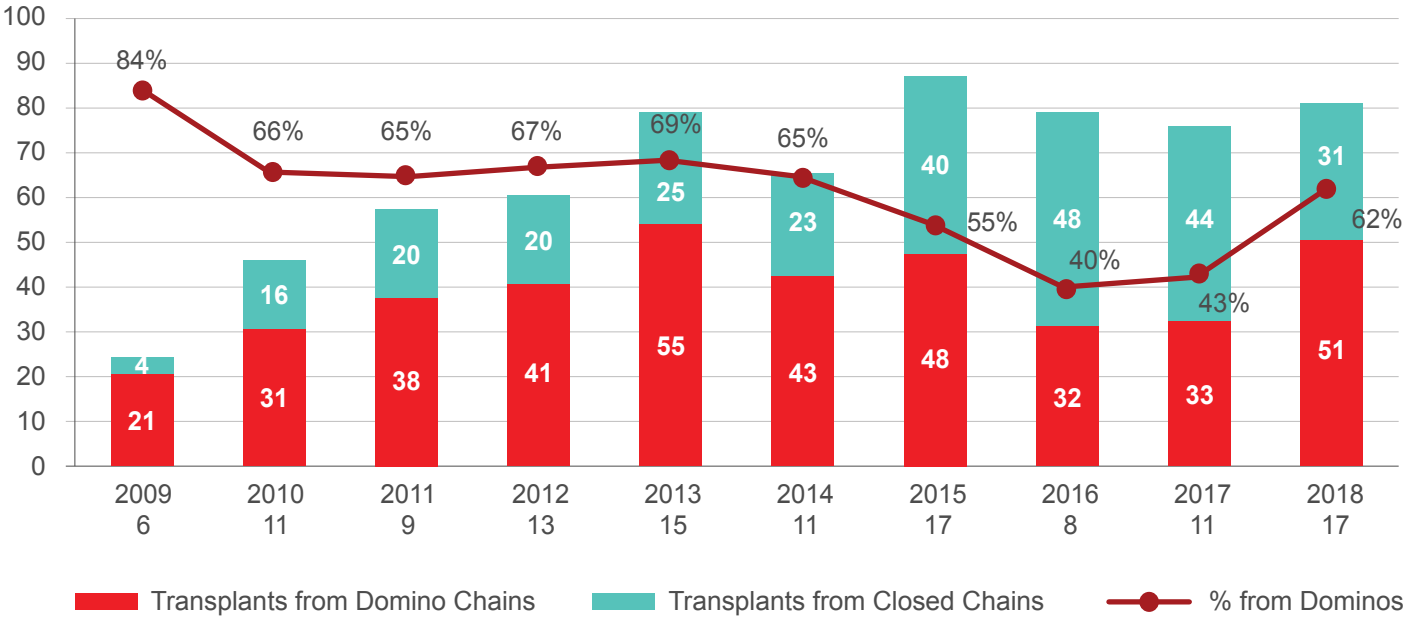
Overall, of the 320 chains that were proposed in all Match Cycles, 203 (63%) were completed.

Chains completed over time



One-third of the transplants that are proposed are from paired exchanges (two pairs exchanging donors), with paired-exchanges accounting for 10% of completed transplants. Of the 664 transplants completed, 393 (59%) have been from domino exchanges made possible by NDADs who start the chains.

The power of the domino: Transplants by chain type over time



One of the advantages of a national program is that potential donor matches for candidates can be found from donors from different provinces. Many candidates would never have found a match without access to this larger number of potential donors. Although the donor and candidate in 95% of registered pairs are from the same province, 90% of completed chains involved at least one interprovincial transplant (a donor donating to a transplant recipient from a different province). Half of the transplants in the average completed chain are interprovincial. Interprovincial transplants account for 53% of all completed transplants.

Moving matches from proposal to transplantation

Not infrequently, circumstances arise that make it impossible for one or more matches in a chain to proceed as proposed. In many cases, when this is in the early days of match evaluation or nothing can be done to continue the other matches in the chain, the chain is collapsed. Pairs and NDADs from collapsed chains are included in all other runs of the matching algorithm to try to identify new chains.

In some cases, it may be possible to repair a chain by substituting in one or more new pairs for the pair(s) that can no longer proceed. Of the 203 chains that have proceeded to transplant, 43 (21%) were repaired one or more times.

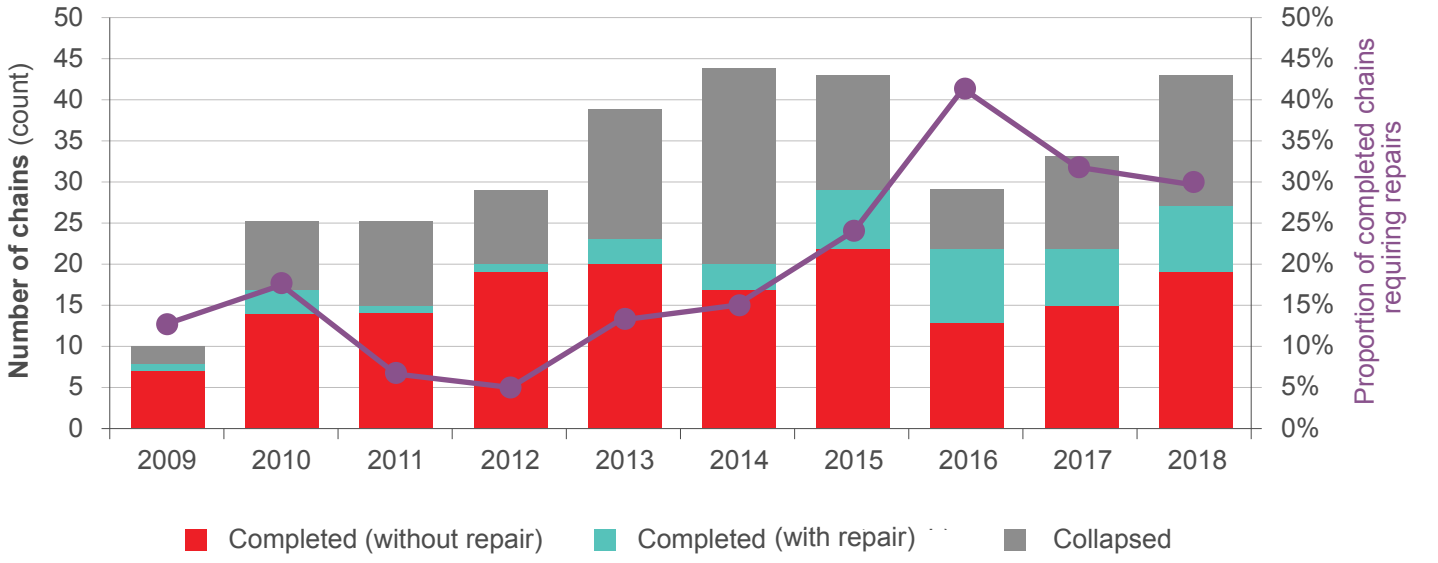
The three methods used for repairing a chain include:

1. Substitution: removing one or more pairs who are impacted by the issue and substituting in alternative pairs who would be compatible with remaining members of the chain;
2. Truncation: shortening the chain by removing pairs that can no longer participate and continuing with only the transplants up to that point in the chain; or
3. Splitting: dividing the chain into two separate shorter chains.

In recent years, the proportion of repaired chains has increased. From 2009 to 2014, 12% of chains were repaired to complete some of the originally proposed transplants plus the newly proposed transplants, but from 2016 to 2018, just over one-third (34%) of chains were repaired rather than collapsed. Additionally, chains have been repaired multiple times more frequently in recent years.

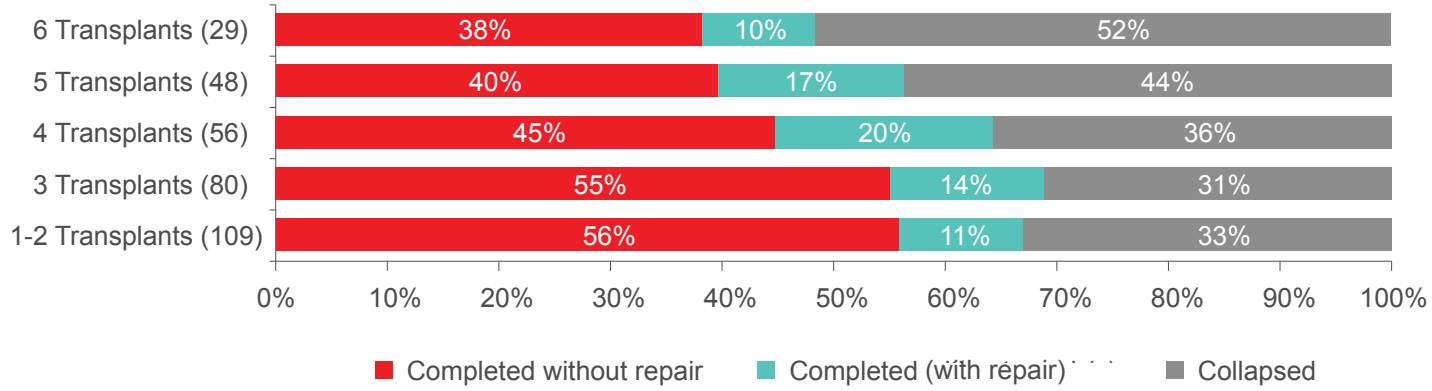
From 2009 to 2014, only one chain was completed after multiple (2) repairs, representing <1% of completed chains in that period, but 11 chains (11%) completed since then were repaired multiple times.

Proportion of chains repaired to complete transplants over time



In general, the more transplants there are in a chain, the more opportunities there are for issues to arise that could lead to a repair or prevent the chain from completing. For chains resulting in three or fewer transplants, over half (56%) were able to be completed without requiring repairs; conversely, half of chains with six transplants collapsed.

Chain completion by number of transplants in final version of chain

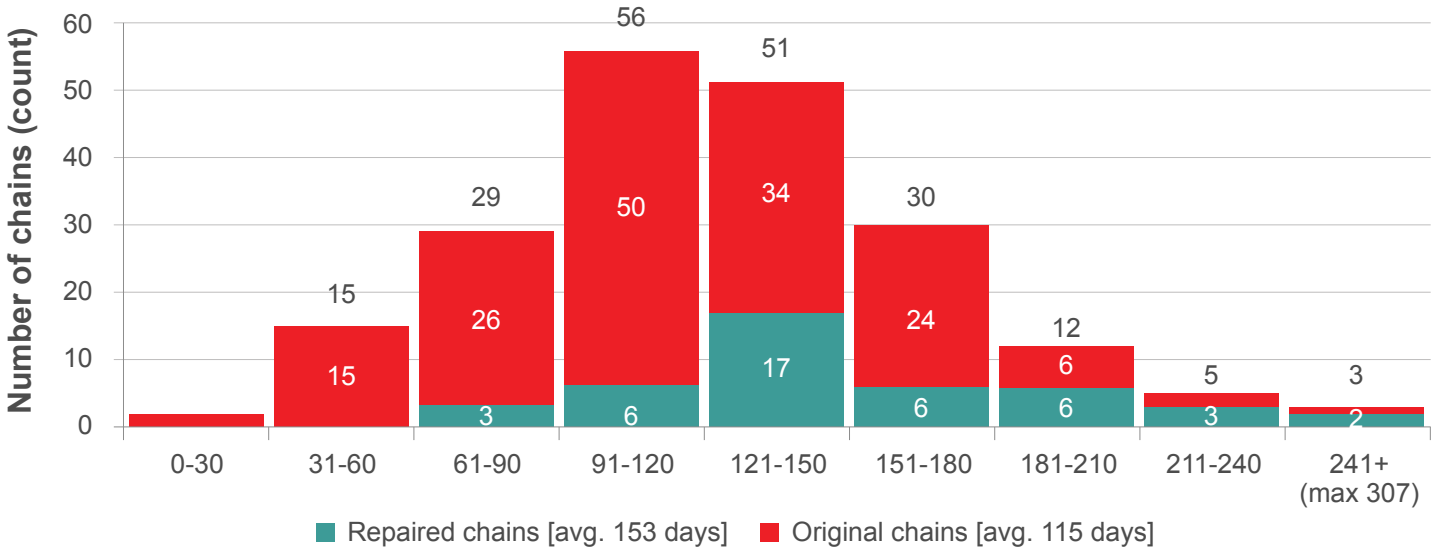


Conducting repairs to chains for which a portion of the necessary evaluation, processing and logistics work has already been completed is a more efficient alternative to collapsing chains and losing all the time and effort already invested in some of the matches. However, chains that are repaired generally take more time to complete than chains that can proceed as originally proposed. On average, repaired chains take 33% longer to complete than non-repaired chains.

The target timeframe for chain completion is 120 days from the chain's initial proposal to the completion of the final transplant in the chain. Half of the completed chains were completed within this timeframe, making the median completion time 120 days (mean = 123 days).

The majority (79%) of repaired chains required longer than 120 days to complete while the majority (58%) of non-repaired chains were completed in 120 days or fewer.

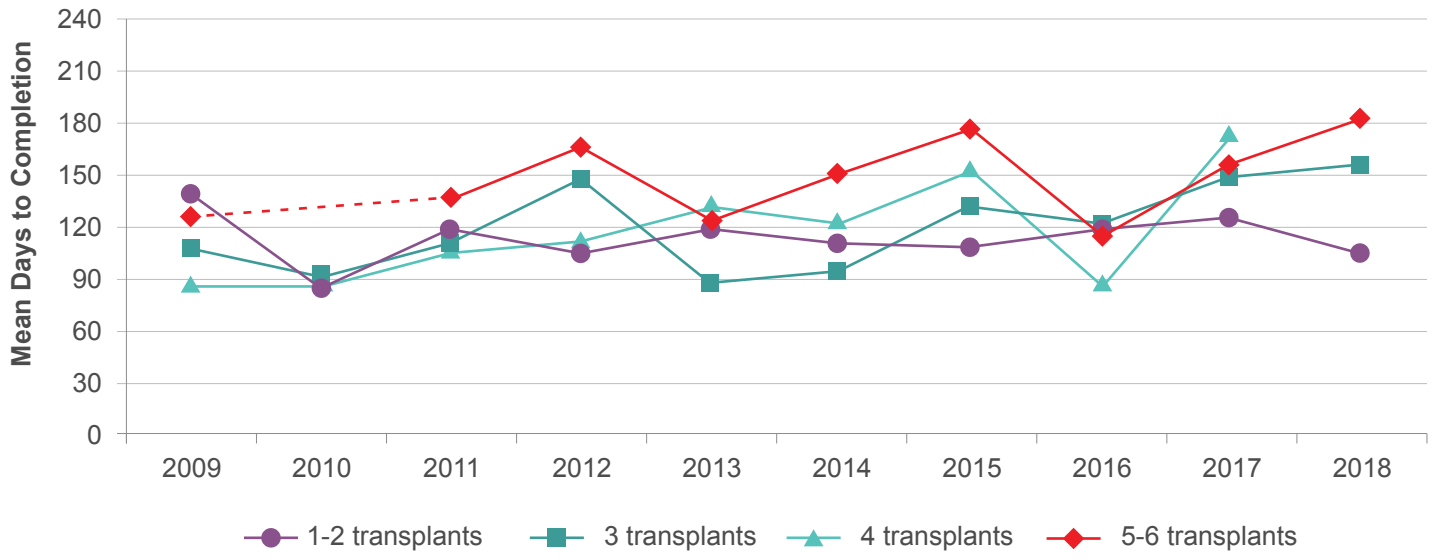
Original chains and repaired chains by days to completion



Although there is a correlation between the chain length and time to completion, chain length isn't the major determinant of time to completion. Chain completion time is impacted more by factors such as medical complications and operating room availability rather than the number of transplants proposed or completed

Average days to completion for KPD chains

Chain completion time by number of transplants completed in chain over time (average)

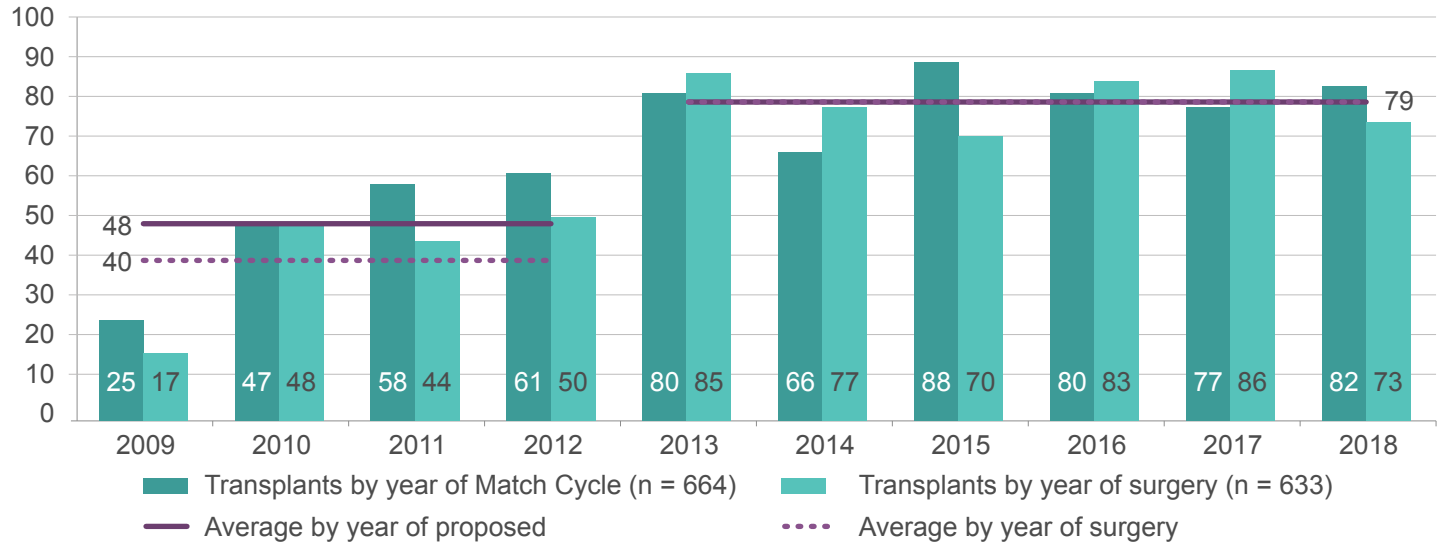


Kidney Paired Donation transplants

Overview

In total, 664 transplants were facilitated by the KPD program from Match Cycles initiated in 2018 or earlier. It took four years to build the program to what appears to be a stabled size and consistent volume of annual transplants. Since 2013, the KPD program has facilitated an average of 79 transplants per year, with 66% being transplanted in the same year that they were proposed as part of a KPD Match Cycle. Transplants identified in fall Match Cycles are often completed in the next calendar year.

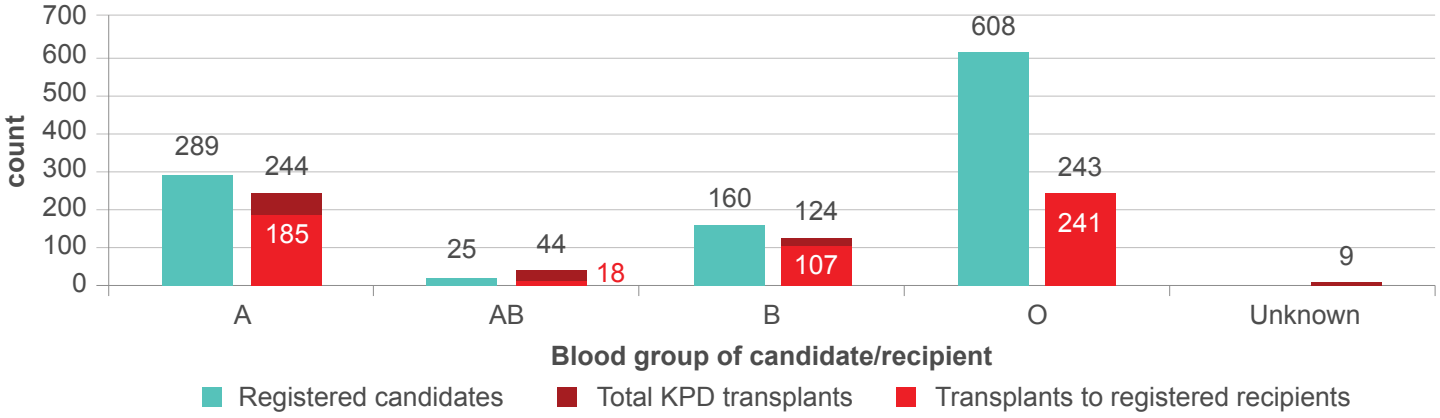
Transplants by year



Transplants by patient attributes

Blood group and HLA compatibility are two of the primary factors that determine whether a potential transplant can take place.

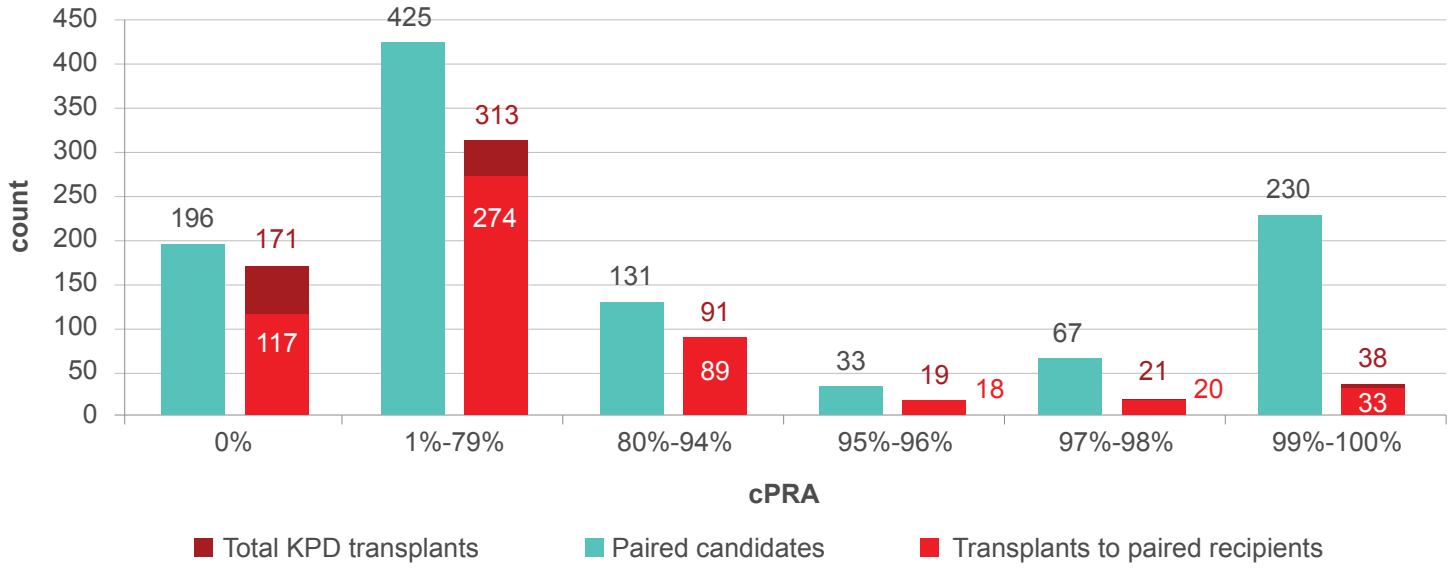
KPD candidates and transplant recipients by blood group, 2009-2018



Of the type O candidates (who require type O donors for compatible matches), approximately 40% have received a transplant through the registry. This is a lower than typical rate for type A and type B candidates (who can also receive transplants from type O donors), with 64% and 67% having received a transplant, respectively. Type AB recipients, who can receive a transplant from donors in any blood group, are transplanted with slightly higher frequency, with 72% having received a KPD transplant.

In domino chains, the end-of-chain donor, who donates to a waitlist recipient, is rarely a blood type O donor, with the majority of end-of-chain donors (58%) being type A. Consequently, over 75% of recipients from provincial waitlists who benefit from a KPD-facilitated transplant are type A or AB. Although half of the NDADs who donated are type O, it is extremely rare that a KPD domino chain will end with a type O recipient.

Transplant candidates and transplant recipients by cPRA, 2009-2018



Total KPD transplants include transplants to waitlist recipients and paired recipients

A candidate's HLA profile is also a critical determinant of donor compatibility. Patients with a cPRA of 95% or higher are considered highly sensitized, with those having cPRA of 99% or higher being the most biologically difficult to match population in the registry. Although 21% of paired candidates have a cPRA of 99% or higher, only 6% of transplants to paired candidates go to recipients with a cPRA at this level.

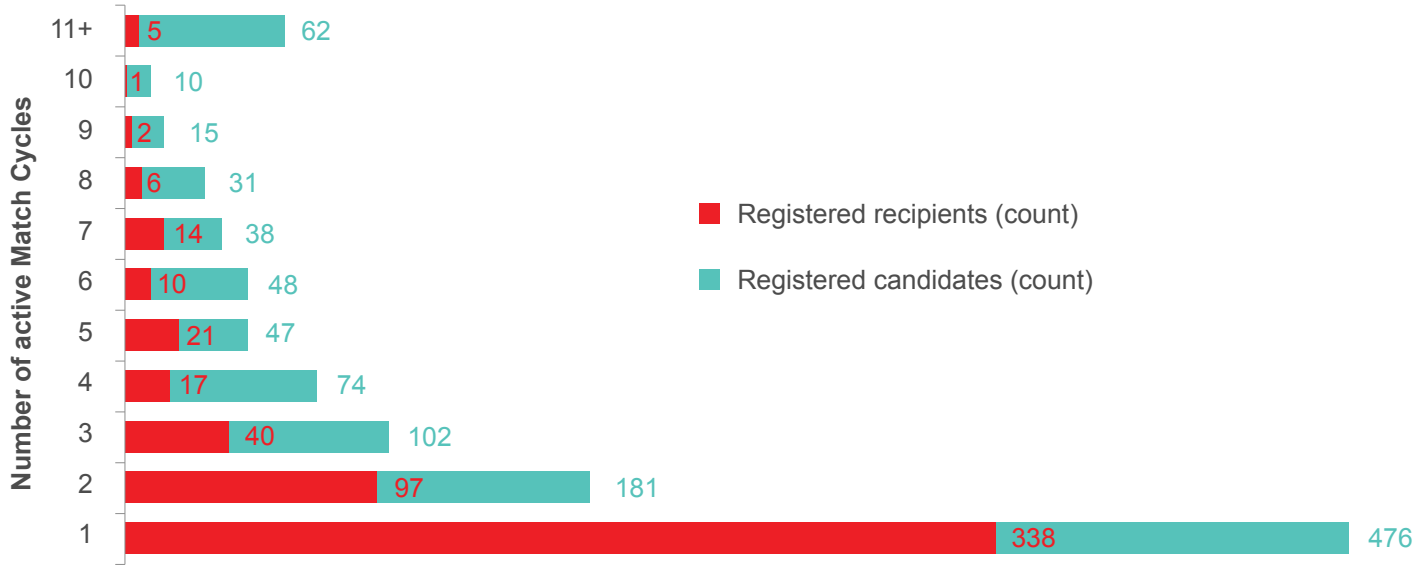
While 64% of candidates with a cPRA below 95% received a transplant, only 14% of candidates with a cPRA of 99% or higher received one. In comparison, candidates with a cPRA of 95-98% make up 9% all KPD candidates and received 7% of transplants to paired recipients, with 38% of cPRA 95%-98% candidates receiving a transplant.

Transplant probability and time to transplant

On average, transplant recipients who received a transplant were matched in the second Match Cycle in which they participated; 338 of the 551 recipients (61%) received their transplant through a chain in the first Match Cycle in which they participated. The average time from the start of the first Match Cycle in which they participated to receiving their transplant is 286 days, or approximately nine and a half months.

Although the results above suggest relatively short wait times for those who receive a transplant, other candidates wait considerably longer and potentially will never receive a transplant through the program. Of the 149 pairs in Match Cycle 32, just over half (53%) began participating one year or longer before the start of that Match Cycle, with one pair having been enrolled since the initiation of the KPD program 10 years prior.

Candidates and recipients by number of Match Cycles[6] in which they participated



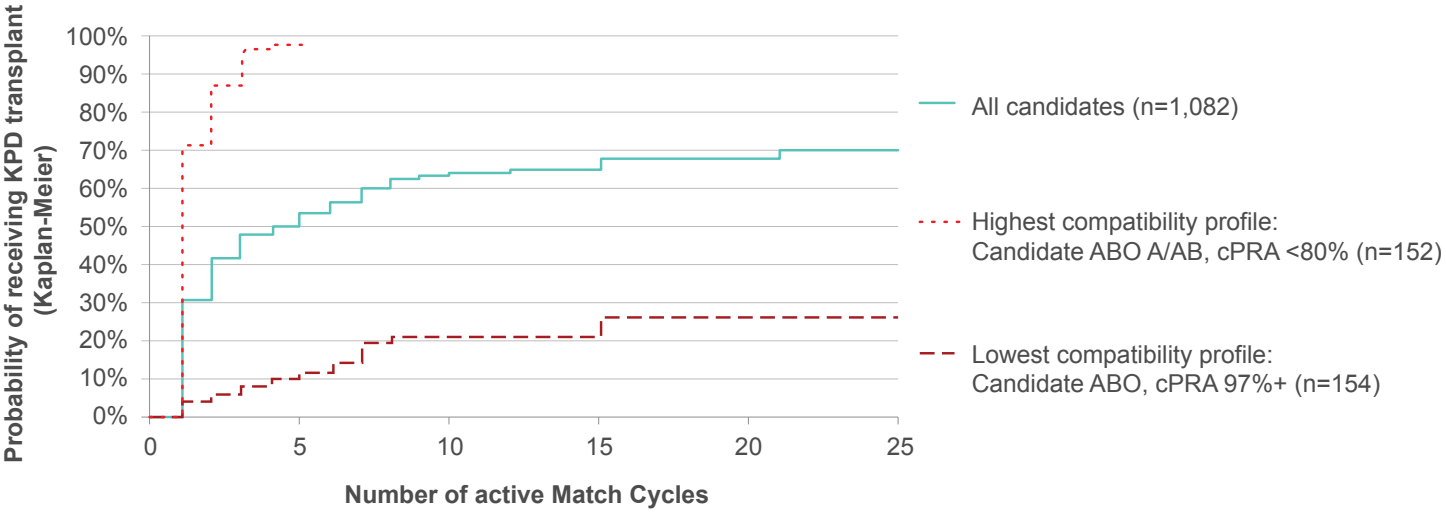
[6] Results reflect the number of Match Cycles in which the recipient participated prior to receiving a transplant or in which the candidate participated prior to withdrawing from the KPD program or the end of 2018. Two cases in which recipients received a second transplant through the KPD program are counted as separate patient cases.

Approximately 7% of transplant recipients participated in Match Cycles as part of more than one pair, in many cases being paired with multiple donors simultaneously in order to increase the potential match possibilities available to the recipient. Other factors that affect the likelihood of receiving a transplant include candidate cPRA and the blood types of the donor and recipient, as these factors directly impact the number of potential matches to each pair.

In general, the probability of receiving a KPD transplant within their first four Match Cycles is greater than 50% for candidates; however, certain attributes can dramatically affect that likelihood. This can be illustrated by comparing the probability profiles of candidates who would be compatible with a higher number of donors based on their blood type and cPRA against those whose blood type and cPRA suggest that they would match with fewer donors (blood type O and cPRA of 97% or greater).

For example, candidates with blood type A/AB and a cPRA of less than 80% would generally have a very high compatibility profile, and 80% of candidates with these attributes received a transplant within their first two Match Cycles. Conversely, only 12% of candidates with blood type O and cPRA of 97% or greater received a transplant within their first six Match Cycles (or the equivalent of two years in the KPD program).

Probability of receiving a transplant relative to the number of Match Cycles in which the transplant candidate participates[7]



[7] The accuracy of these results is impaired by the divergence from the assumptions of Kaplan-Meier probability models inherent to the KPD program's operation, including cohort effects. Horizontal axis reflects the number of Match Cycles prior to receiving a transplant or withdrawing from the KPD program. Two cases in which recipients received a second transplant through the KPD program are counted as separate patient cases.

Another key factor that determines the probability of receiving a transplant is the size and composition of the candidate and recipient pool at each Match Cycle (MC). For instance, although there has been a great deal of consistency in the number of participants for the Match Cycles over time, the number of participating pairs from MC 19 (mid-2014) to MC 23 (late 2015) averaged 182 pairs per Match Cycle, which is 24% higher than the average for all other Match Cycles from 2012 to 2018. Conversely, MC 25 (mid-2016) to MC 28 (mid-2017) saw only three NDADs in each Match Cycle on average, which is less than half the normal level of NDAD participation from 2012 to 2018 outside of that period.

Although higher participation levels are generally beneficial to participants overall (since it allows for more match possibilities for each participating pair), the composition of the participant pool is also a key determining factor. The profile of key factors influencing compatibility and match options of participants has generally remained stable over time. However, if meaningful deviations from these established patterns in participating pairs occur in the future, these differences may impact the likelihood of matches being identified and proceeding to transplant.

Expectations of receiving a transplant based on pair characteristics

The table below predicts whether or not KPD candidates can be expected to receive a transplant in a given Match Cycle based on blood group and cPRA[8]. While this rubric applies to KPD participants in general, many candidates who are not expected to receive a KPD transplant on the basis of this rubric will still be transplanted.

Will the candidate be transplanted in a given Match Cycle?

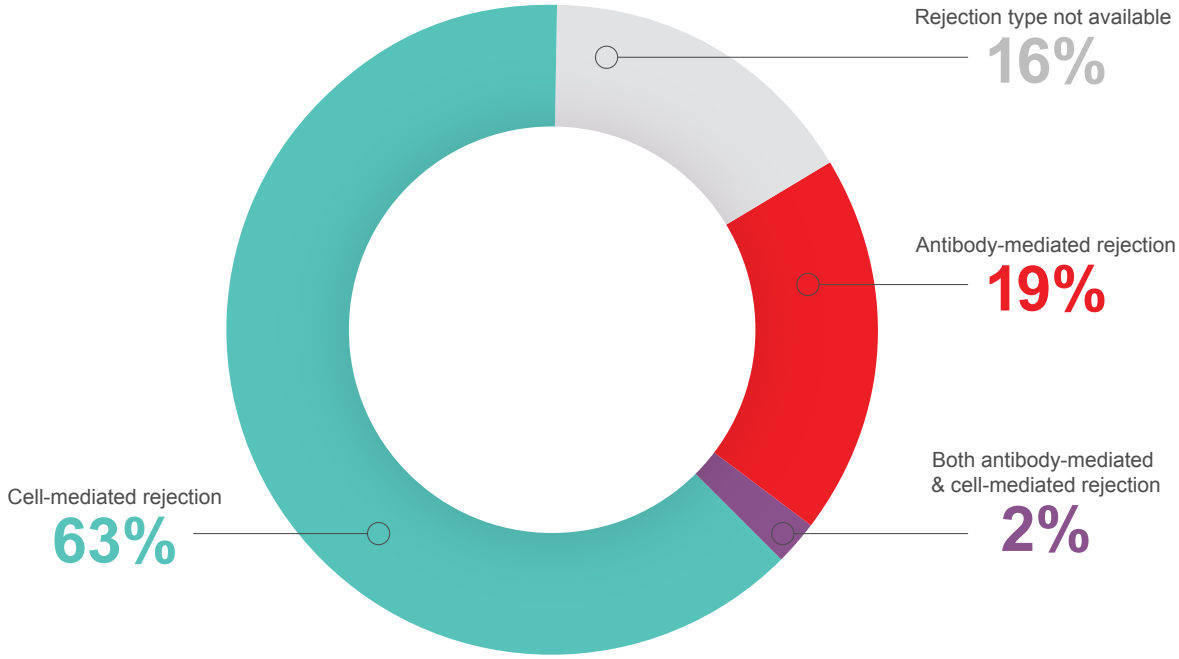
Recipient	cPRA	0%		1%-79%		80%-94%		95%+
	ABO	A, AB, B	O	A, AB	B, O	A, AB	B, O	Any
Donor ABO	A, AB, B	Yes	No	Yes	No	No	No	No
	O	Yes	Yes	Yes	Yes	Yes	No	No

[8] Overall accuracy based on pairs participating in Match Cycles 2 to 32 is 89.2% (33% false positive rate, 8% false negative rate).

Transplant outcomes[9]

Consistent with the generally favourable outcomes associated with living donation relative to other treatment options (such as deceased donor transplants and dialysis), short-term patient outcomes for the recipients of KPD transplants are very favourable, with one-year post-transplant graft and patient survival rates of 97.7% and 99.5%, respectively, for patients whose data is available. The majority of KPD transplant recipients (over 86% based on known cases) experienced no rejection episodes within the first year.

Type of rejection episodes experienced by recipients within the first year post-transplant (n=49)



Graft survival, patient survival and rejection episodes at one month and one year

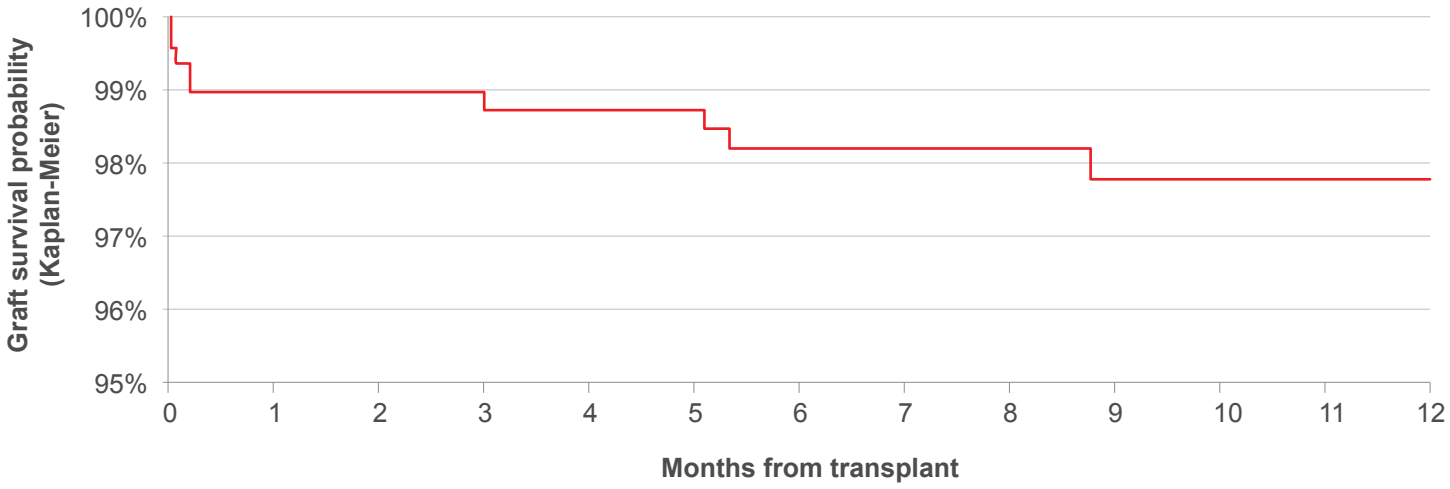
	Functioning graft		Patient alive		Patients experiencing rejection episodes		
	At one month	At one year	At one month	At one year	Within first month	From second to twelfth month	At any point within first year
Yes	490	386	493	391	34	37	49
Proportion of known cases	99.0%	97.7%	99.8%	99.5%	7.1%	9.8%	13.4%
No	5	9	1	2	445	339	318
Data pending (unknown)	79	179	80	181	95	197	207

[9] Results based on outcomes for patients receiving a transplant from the initiation of the KPD registry to Feb. 28, 2018 (N = 574), including recipients from provincial waitlists. Results for graft survival would include patients who died with a functioning kidney as a graft failure case.

For all of the recipients who experienced graft failure, their kidney failed within the first week following the transplant.

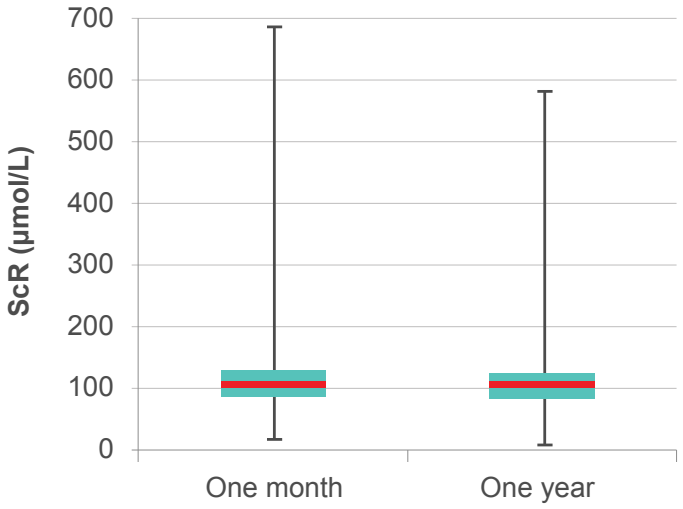
Canadian Blood Services is currently collecting outcome data at five years post-transplant for KPD transplant recipients where available. To date, five-year survival outcome data is available for 33 of the 244 patients who received a transplant from 2009 to 2014. Results for this sample suggest a five-year post-transplant graft survival rate of 76% and patient survival rate of 93%. However, given the nature of the data collection process, rates based on this sample likely under-represent actual survival rates.

Kaplan-Meier graft survival over time



For patients with functioning grafts, serum creatinine levels at one month tend to be within normal ranges, with little difference overall in the first year.[10]

Serum Creatinine (SCr) level at one-month and one-year post-transplant



	One month	One year
Results available (N)	483	386
Mean SCr	115 µmol/L	112 µmol/L
Median SCr	109 µmol/L	108 µmol/L
Interquartile range	87-131 µmol/L	86-128 µmol/L
Range (minimum to maximum)	18-683 µmol/L	11-580 µmol/L

[10] MD = -3 µmol/L for patients for whom both one month and one year SCr levels are available (n = 383)

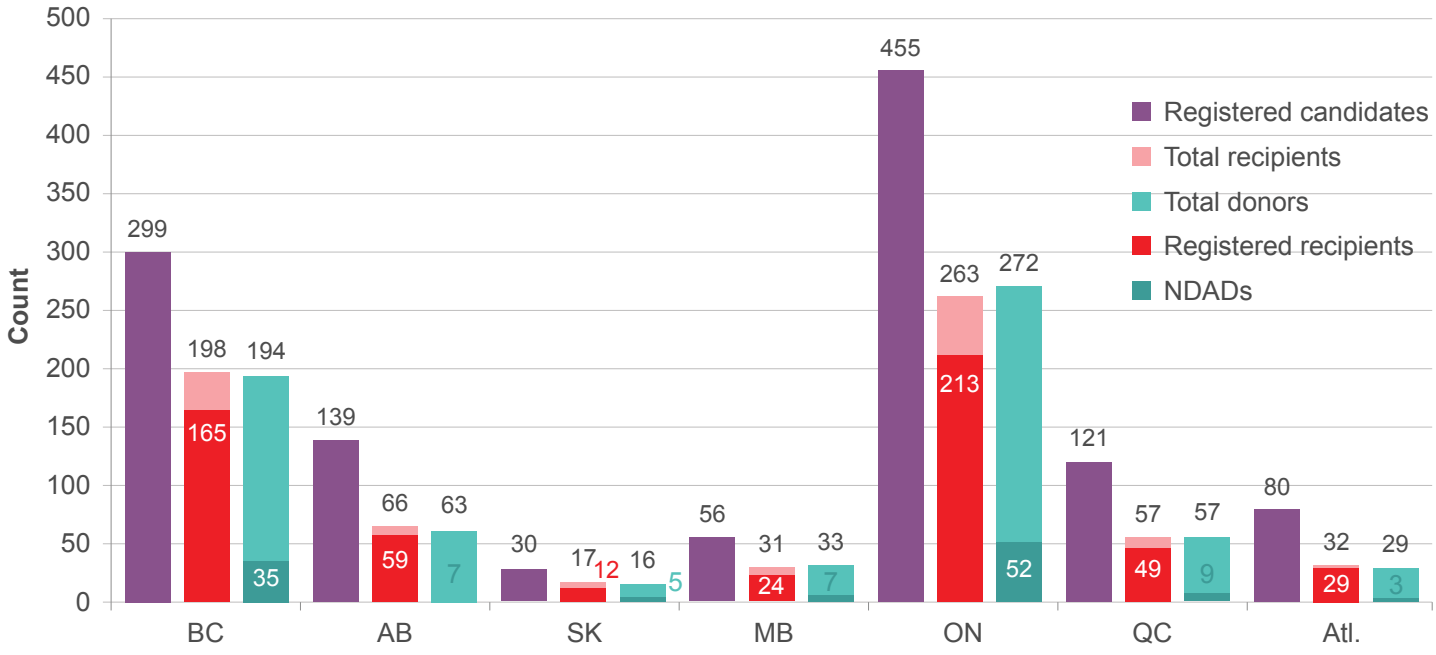
Provincial results

Provincial participation and transplant rates

For the majority of pairs, both the donor and the candidate are registered in the same province. Just under two-thirds of the candidates are from Ontario (39%) or B.C. (25%), with comparable representation among donors at 40% and 24%, respectively.

Provincial participation is approximately proportional to the relative population distribution between provinces, with the exception of B.C. which makes up only 14% of the national population and Quebec which comprises 23% of the national population while Quebec candidates comprise only 10% of those who have participated in KPD.

Transplant candidates, recipients and donors by province

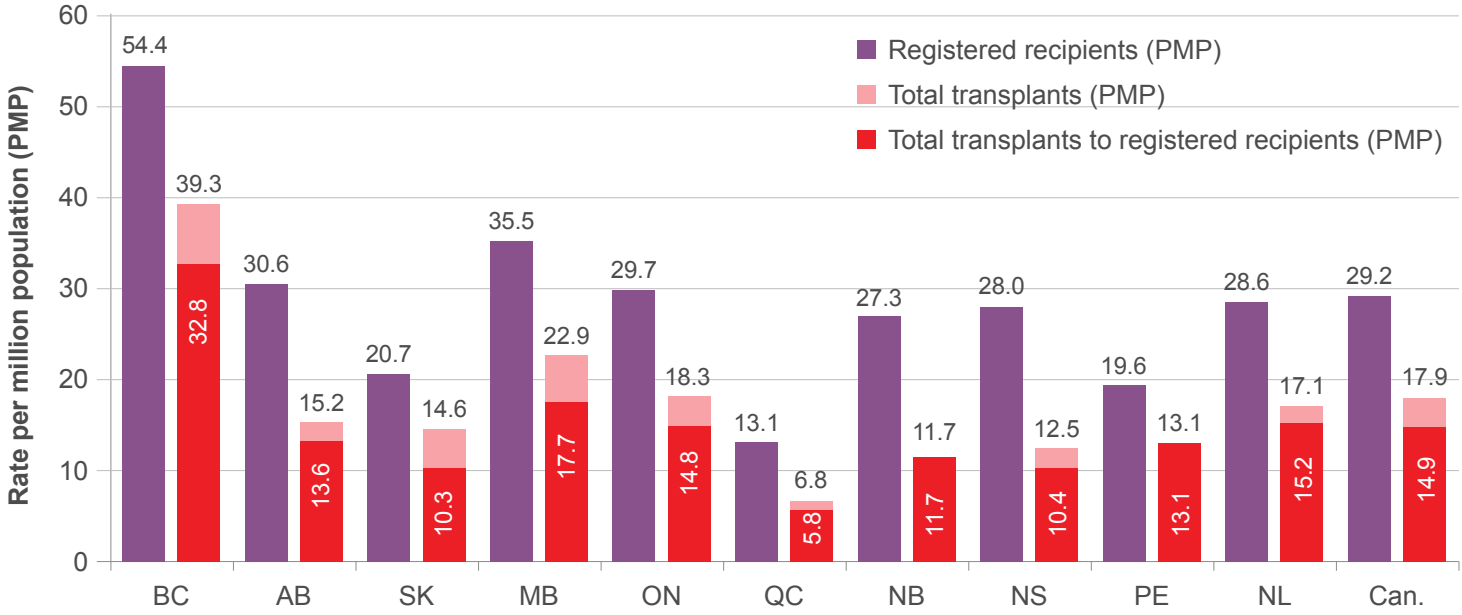


Total recipients includes waitlist recipients and paired recipients

Similarly, provinces such as Ontario (contributing 44%) and B.C. (contributing 30%) accounted for a higher proportion of NDADs who donated than would be expected given their populations. Quebec and Alberta accounted for comparable proportions of NDADs who donated at 6%–7% respectively, while collectively representing over one-third of the Canadian population (34%). Aside from these cases, the number of NDADs from each province who donate are reasonably consistent with the population distribution among provinces.

There is also a great deal of consistency among provinces in relation to the number of KPD transplants, with 44%-50% of candidates in most provinces having received a transplant. British Columbia is a notable exception, as 60% of registered candidates in that province have received a transplant.

Candidates and transplants by province of recipient: Rate relative to population[11]

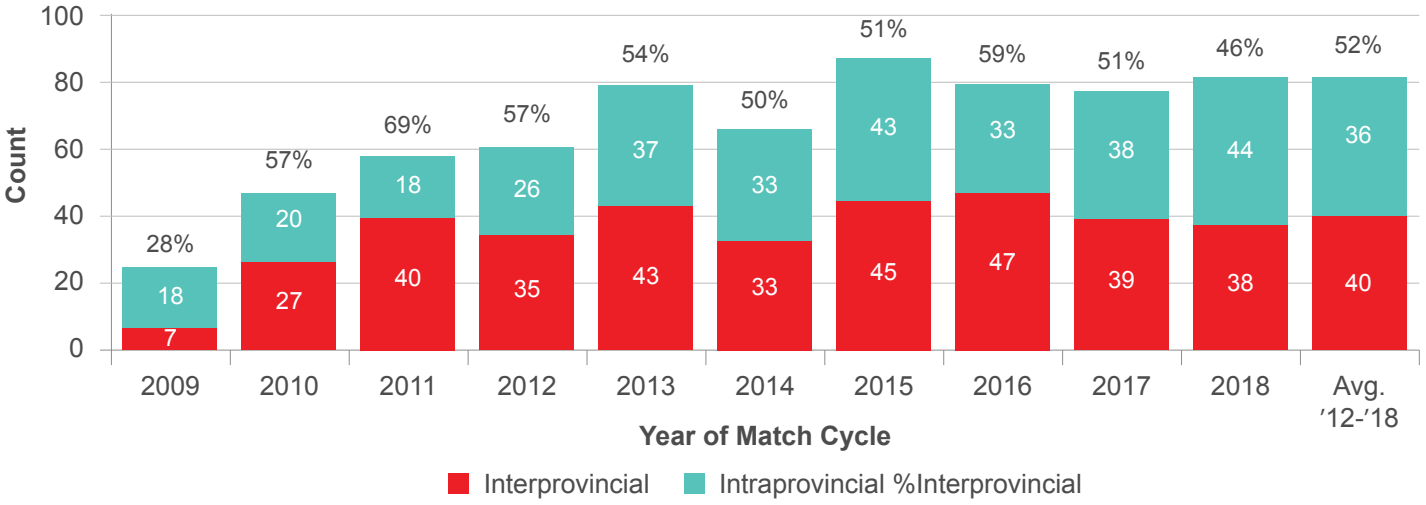


[11] Rates are relative to provincial populations as provided by Statistics Canada. Results based on registration province; for Atlantic candidates and recipients, results are based on PHN number province. One recipient whose PHN province outside of the Atlantic region but who was registered in Nova Scotia is included in Nova Scotia results.

Provincial participation and transplant rates

One of the main advantages of the KPD program is that it operates on a national basis, providing transplant candidates access to more potential donors at different living donation programs both within the same province and from different provinces. Although 95% of KPD pairs are made up of a donor and a transplant candidate who are registered in the same province, 54% of paired recipients transplanted through the KPD program received a transplant from a donor registered in a different province.

Inter- and intraprovincial transplants over time with proportion that are interprovincial and average for recent years



Overall, 53% of all KPD transplants, including 54% of transplants to registered KPD candidates, were from donors residing in a different province than the recipient. This has been fairly consistent over time. Over two-thirds (68%) of completed chains have included at least one interprovincial transplant. When the donor and recipient lived in different cities or provinces, in most cases the donor travelled to the recipient's facility to donate. In a few cases the recipient travelled to the donor's facility and in 30 cases (4.5%), the donor's kidney was shipped to the recipient's transplant centre.

Appendix A: Glossary of terms

ABO (or Blood Type/Blood Group)

A term used interchangeably with “blood group.” For example, ABO-O refers to blood group O whereas ABO-B refers to blood group B.

Algorithm (or Matching Algorithm)

An automated computer program which is used to determine potentially compatible pairs within the KPD program and groups of mutually exclusive chains of matched pairs.

Antibody

A protein molecule produced by the immune system in response to a foreign body (known as an antigen).

Antigen (ABDR Antigen or HLA Antigen)

An HLA protein on a cell surface (such as those on a donor kidney) which can cause the recipient immune system to react and injure or reject the organ. These helps determine donor/recipient compatibility.

Blood Group

See ABO.

Blood Type

See ABO.

Calculated Panel Reactive Antibody (cPRA)

A population-based estimate of the percentage of donors that will be incompatible with a given candidate due to the presence of antibodies.

Canadian Transplant Registry (CTR)

A web-based database for interprovincial listing of donors and potential recipients and for allocating the donor organs to the recipients. It is operated by Canadian Blood Services and supports the KPD program, the Highly Sensitized Patient (HSP) program for high-cPRA kidney transplant candidates and the National Organ Waitlist (NOW) for non-renal transplant candidates.

Candidate (or Transplant Candidate)

A patient who needs a solid organ transplant and who is registered in the Canadian Transplant Registry (CTR) with a paired donor.

Chain

A group of pairs, with or without an NDAD, in which all the candidates are able to get a kidney transplant from a donor in the group and all the donors are able to donate to someone in the group. Chains may be closed (involving only registered pairs) or domino (involving an NDAD and a waitlist recipient).

Chain Completion

The completion of all transplants proposed as part of a given chain.

Closed Chain (or N-way Exchange)

A chain in which the donor of the last pair must match the candidate of the first pair.

Collapsed Chain (or Cancelled Chain)

A chain that cannot proceed because one or more proposed transplants cannot proceed.

Compatible Match

A transplant candidate and donor whose ABO and HLA types are compatible for transplantation.

Domino Chain

A chain of donor exchanges that begins with an NDAD and ends with the last donor in the chain donating to a patient on the deceased donor waitlist, waiting for a kidney transplant.

Donor

A person, either living or deceased, who provides cells, tissues, or organs for transplantation. In the case of the KPD program, donors can participate either with a transplant candidate as part of a registered pair (referred to as a paired or registered donor) or without a specific candidate as a non-directed anonymous donor (NDAD).

Donor-Specific Antibodies (DSA)

Recipient HLA antibody or antibodies against a given donor’s antigens.

Graft

A transplanted organ, tissue, or cells. In the case of CTR renal registries, a transplanted kidney.

Appendix A: (cont.)

Highly Sensitized Patient

Patients whose antibody profile suggests that they would be compatible with 5% of organ donors or fewer. Approximately 20% of patients requiring a kidney transplant are classified as highly sensitized.

Incompatible Pair

A transplant candidate and a donor whose blood types and/or HLA tissue types are not compatible for transplant. A kidney transplant from the donor would be rejected by the candidate's antibodies.

Interprovincial transplant

Transplants in which the donor is from a different province from the recipient of their organ donation. Living kidney donors will most commonly travel to the province in which the recipient is located for their surgery, but in some cases the kidney may be shipped after being removed from the donor.

Intraprovincial transplants

Transplants in which the donor is from the same province as recipient of their organ donation.

Interquartile Range (IQR)

The interquartile range represents the inner two quartiles of the distribution.

Human Leucocyte Antigen (HLA)

The antigens on the donor's cell surface that may cause the recipient's immune system to react and reject a transplanted organ. See also antigen, above. HLA antigens are named in groups, or loci, and identified as: A, B, Cw, DR, DRw, DQA, DQ, DPA, and DP.

Kidney Paired Donation (KPD) Program

A registry operated and managed by Canadian Blood Services in collaboration with the provincial living kidney donation and transplantation programs. The KPD program matches pairs and NDADs into chains of donor exchanges and works with their living kidney donation and transplant programs to facilitate the completion of all the donations and transplants in the chain.

Matching Algorithm

See Algorithm.

Match

See Proposed Pair/Match.

Match Cycle (MC)

A period of time beginning on the date the matching algorithm is run to identify a group of mutually exclusive chains from a set group of donor-candidate pairs and NDADs, and ending on the date the last transplant in the last chain is completed. Match Cycles can overlap one another in time.

Match Run

The running of the KPD matching algorithm to identify chains of proposed exchanges. Each Match Cycle will have a main run and may have additional runs (re-runs) using the same group of pairs and NDADs, if required.

Non-Directed Anonymous Donor (NDAD)

A donor who wishes to donate a kidney to anyone in need and is registered in the KPD program without a paired registered candidate. NDADs allow for domino chains to be proposed.

Pair (or Registered Pair)

A kidney transplant candidate and donor who are registered together in the KPD registry, with the goal of finding a suitable match for the transplant candidate through a donor exchange.

Paired Exchange (PE)

A KPD donor exchange between two registered pairs wherein each recipient receives a kidney from the donor in the other pair. This is equivalent to a 2-way exchange or a closed chain involving only two pairs.

Proposed Pair/Match

A potentially compatible donor and candidate who are matched for transplant by the matching algorithm.

Proposed Chain

A set of transplants between donors and recipients participating in the KPD program who have been identified as compatible and potentially able to proceed to transplant.

Recipient (or Transplant Recipient)

A patient who received a kidney transplant through the KPD program. This includes those who received a transplant as part of a pair participating in the KPD program (registered recipients) and those who received a transplant without participating in a KPD pair.

Registered Pair

See "Pair"

Appendix A: (cont.)

Registered Recipient

A patient who received a kidney transplant through the KPD program as part of a pair.

Repaired Chain

When one or more matched donors or candidates in a chain can no longer proceed to transplant, the KPD program may attempt to repair the chain to allow the rest of the matches to continue to transplantation. Repairs are generally done by substituting in one or more pairs for the pair that cannot proceed or by shortening the chain to allow at least some of the transplants to proceed.

Rejection

An immunological response to the transplanted organ in which the recipient's immune system (antibodies) attempts to destroy the graft, resulting in decreased function. A rejection episode does not necessarily result in graft loss.

Transplant Recipient

See Recipient.

Virtual Crossmatch (VXM)

A comparison between candidate antibodies and donor antigens. A positive VXM means that the candidate has antibody(ies) to the donor's antigen(s) and could result in injury or rejection of the transplanted organ. A negative VXM means that the candidate's antigens match the donor's antigens with a corresponding lower risk of organ injury and rejection.

Waitlist

A list of patients who are qualified and registered by a transplant program and who are waiting to receive an organ transplant.

Waitlist Recipient

A patient who received a transplant through the KPD program without having participated in the KPD program as part of a registered pair. The transplant is received from the donor at the end of a domino chain.

Appendix B: Matching algorithm and guiding principles for KPD program

Matching algorithm points

Match points are assigned to matches between donor and candidate records with the following characteristics:

Attribute	Points
Compatible Donor-Candidate match (using ABO, HLA, filters)	100
Highly Sensitized (cPRA ≥ 95%)	125
ABO Match: blood group O to blood group O	75
Pediatric Candidate (<19 years of age)	75
Candidate is a Prior Living Donor	75
ABDR 0/6 Mismatch	75
Dialysis Wait Time (starting at initiation of dialysis)	Days/30
Geography: Same City	25
Donor/Candidate age difference of ≤30 years	5
ABO Match: A to A, B to B, AB to AB	5
EBV Negative to Negative Match	5

Guiding principles for Kidney Paired Donation program

1. **Maximize Transplants** – primary goal should be to find the greatest number of high quality matches between living donors and candidates.
2. **Minimize Logistics** – to the extent possible, the need for donors or recipients to travel should be minimized.
3. **Equity for High Need Patient Groups** – candidates who are disadvantaged due to medical or demographic factors should receive additional priority (e.g., highly sensitized, blood group O, pediatrics, lengthy time on dialysis, etc.).
4. **Priority for Higher Quality Matches** – transplants that are zero mismatch HLA-A, B, DR or other clinical criteria considered to be “more ideal” should receive special priority.
5. **Evidence-Based Decision Making** – all principles adopted and algorithm decisions made should be based on the most current and best quality peer-reviewed evidence available.