

Original article

Predictors of waiting time for deceased donor kidney transplantation in Thailand: a competing risks analysis

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Abstract:

Introduction: Management of patients on the waiting list for deceased donor kidney transplantation (DDKT) remains a major challenge in organ transplantation. Understanding the factors that influence access to transplantation is essential for optimizing allocation systems. **Objective:** This study aimed to evaluate the cumulative incidence of DDKT and identify independent predictors of transplant probability among patients with end-stage kidney disease (ESKD). **Materials and Methods:** This study analyzed a cohort of 5,276 ESKD patients registered at the Organ Donation Centre, Thai Red Cross Society (ODC-TRCS), between January 1, 2010 and December 31, 2020. Demographic characteristics, ABO blood groups, human leukocyte antigen (HLA) sensitization and HLA-A, -B, -DR haplotypes were analyzed. Transplantation was assessed by using cumulative incidence functions, with death treated as a competing risk. Significant factors were identified by using descriptive statistics and multivariate Fine-Gray sub-distribution hazard models. **Results:** A total of 1,996 patients (37.83%) underwent transplantation. The median follow-up time for kidney transplantation was 3.5 years. The probability of receiving a DDKT was 15% within the first year and increased to 45% by year 3. Older age was strongly associated with increased transplant likelihood, particularly among patients aged ≥ 60 years [subdistribution hazard ratio (SHR): 5.63, 95% confidence interval (95%CI): 4.12-7.70; $p < 0.001$]. Intermediate (50-80% PRA) and high (81-100% PRA) sensitization were associated with modestly higher transplant probability compared with low sensitization (SHR 1.37; 95%CI: 1.02-1.84; $p = 0.037$ and SHR 1.41, 95%CI: 1.01-1.99; $p = 0.045$). Each additional year of dialysis reduced the likelihood of transplant by 29% (SHR 0.71, 95%CI: 0.67-0.75; $p < 0.001$). ABO blood group and HLA haplotype were not significant. **Conclusion:** Age, HLA sensitization and dialysis duration significantly influence the probability of DDKT. These findings provide a framework for refining organ allocation policy and may serve as one consideration in its improvement.

Keywords : ● Kidney transplantation ● Deceased donors ● Competing risks analysis ● Survival analysis
● Dialysis duration

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นิพนธ์ต้นฉบับ

ปัจจัยทำนายระยะเวลารอดคอยการปลูกถ่ายไตจากผู้บริจาคสมองตายในประเทศไทย: การวิเคราะห์ความเสี่ยงที่แข่งขันกัน

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บทคัดย่อ

บทนำ การบริหารจัดการผู้ป่วยในบัญชีรายชื่อรอรับการปลูกถ่ายไตจากผู้บริจาคสมองตาย ยังคงเป็นความท้าทายหลักในด้านการปลูกถ่ายอวัยวะ การทำความเข้าใจปัจจัยที่มีอิทธิพลต่อการเข้าถึงการปลูกถ่ายไตจึงมีความสำคัญยิ่งต่อการพัฒนาระบบจัดสรรอวัยวะให้มีประสิทธิภาพสูงสุด **วัตถุประสงค์** เพื่อประเมินอุบัติการณ์สะสมของการปลูกถ่ายไตจากผู้บริจาคสมองตาย และระบุปัจจัยพยากรณ์อิสระที่มีผลต่อความน่าจะเป็นในการได้รับการปลูกถ่ายไตในผู้ป่วยโรคไตเรื้อรังระยะสุดท้าย **วัสดุและวิธีการ** ทำการศึกษาเชิงวิเคราะห์ในกลุ่มตัวอย่างผู้ป่วยโรคไตเรื้อรังระยะสุดท้ายจำนวน 5,276 ราย ที่ลงทะเบียน ณ ศูนย์รับบริจาคอวัยวะ สภากาชาดไทย ระหว่างวันที่ 1 มกราคม พ.ศ. 2553 ถึงวันที่ 31 ธันวาคม พ.ศ. 2563 โดยวิเคราะห์ข้อมูลลักษณะทางประชากร หมู่เลือดระบบ ABO ระดับภูมิคุ้มกันต่อระบบ HLA (HLA sensitization) และลักษณะทางพันธุกรรม HLA-A, -B และ -DR สถิติที่ใช้ประเมินการปลูกถ่ายไตคือฟังก์ชันอุบัติการณ์สะสม (cumulative incidence function) โดยกำหนดให้การเสียชีวิตเป็นเหตุการณ์ความเสี่ยงคู่แข่ง (competing risk) และวิเคราะห์ปัจจัยที่มีนัยสำคัญด้วยสถิติเชิงพรรณนาและแบบจำลองความเสี่ยงส่วนย่อยของ Fine-Gray (multivariate Fine-Gray sub-distribution hazard models) **ผลการศึกษา** มีผู้ป่วยได้รับการปลูกถ่ายไตทั้งหมด 1,996 ราย (ร้อยละ 37.83) ระยะเวลาพื้นฐานของการติดตามผลการปลูกถ่ายไตคือ 3.5 ปี โดยโอกาสที่จะได้รับการปลูกถ่ายไตจากผู้บริจาคสมองตาย คิดเป็นร้อยละ 15 ภายในปีแรก และเพิ่มขึ้นเป็นร้อยละ 45 เมื่อเข้าสู่ปีที่ 3 ปัจจัยด้านอายุที่มากขึ้นมีความสัมพันธ์อย่างมากกับโอกาสได้รับการปลูกถ่ายไตที่เพิ่มขึ้น โดยเฉพาะในกลุ่มผู้ป่วยอายุ ≥ 60 ปี [subdistribution hazard ratio (SHR) 5.63; 95%CI: 4.12-7.70; $p < 0.001$] สำหรับผู้ป่วยที่มีระดับภูมิคุ้มกันต่อระบบ HLA ระดับปานกลาง (PRA 50-80%) และระดับสูง (PRA 81-100%) มีความน่าจะเป็นในการได้รับการปลูกถ่ายไตเพิ่มขึ้นเล็กน้อยเมื่อเทียบกับกลุ่มที่มีระดับภูมิคุ้มกันต่ำ (SHR 1.37; 95%CI: 1.02-1.84; $p = 0.037$ และ SHR 1.41, 95%CI: 1.01-1.99; $p = 0.045$ ตามลำดับ) นอกจากนี้พบว่า ระยะเวลาการฟอกเลือดที่เพิ่มขึ้นทุก ๆ 1 ปี สัมพันธ์กับโอกาสได้รับการปลูกถ่ายไตที่ลดลงร้อยละ 29 (SHR 0.71, 95%CI: 0.67-0.75; $p < 0.001$) ในขณะที่หมู่เลือดระบบ ABO และลักษณะทางพันธุกรรม HLA ไม่พบความแตกต่างอย่างมีนัยสำคัญ **สรุป** อายุ ระดับภูมิคุ้มกันต่อระบบ HLA และระยะเวลาการฟอกเลือด เป็นปัจจัยสำคัญที่มีอิทธิพลต่อความน่าจะเป็นในการได้รับการปลูกถ่ายไตจากผู้บริจาคสมองตาย ข้อมูลที่ค้นพบนี้สามารถใช้เป็นกรอบแนวทางในการปรับปรุงนโยบายการจัดสรรอวัยวะและเป็นข้อพิจารณาสำคัญในการพัฒนาระบบให้ดียิ่งขึ้นในอนาคต

คำสำคัญ: ● การปลูกถ่ายไต ● ผู้บริจาคไตสมองตาย ● การวิเคราะห์ความเสี่ยงที่แข่งขันกัน ● การวิเคราะห์ระยะการรอดชีวิต ● ระยะเวลาการล้างไต

วารสารโลหิตวิทยาและเวชศาสตร์บริการโลหิต. 2569;36:251-62.

Introduction

Kidney transplantation is a definitive treatment for patients with end-stage kidney disease (ESKD), demonstrating clear clinical superiority over chronic dialysis in terms of both long-term prognosis and patient-reported outcome.¹⁻⁴ Despite these benefits, the global shortage of deceased donor organs continues to be a major barrier, resulting in prolonged waiting time and significant mortality among candidates on the transplant waiting list.^{5,6} Understanding the dynamics of organ allocation and the factors that influence the likelihood of receiving a graft is therefore crucial for optimizing clinical outcomes and ensuring equitable access to kidney transplantation.⁷⁻⁹

The likelihood of securing a deceased donor kidney graft is determined by a combination between recipient demographics, clinical status and immunological profiles.¹⁰⁻¹² Beyond the foundational requirements of blood group compatibility and histocompatibility, organ allocation systems are increasingly shaped by a broader range of variables, including age-related eligibility criteria,^{5,13,14} immunological HLA sensitization levels,^{15,16} and dialysis vintage,^{6,17,18} all of which critically modulate the likelihood of graft acquisition. Moreover, the significance of histocompatibility often diminishes when confounding variables are adjusted for. Although univariate analysis showed that recipient age, ethnicity, BMI, and HLA mismatching were associated with post-transplant kidney function, clinical outcomes are ultimately influenced by multiple factors simultaneously. To account for this complexity, a multivariate analysis was conducted. The resulting multivariable-adjusted model revealed that only recipient gender, ethnicity, BMI, and donor age remained significantly associated with post-transplant kidney function,¹⁹ while the initial effect of HLA mismatching was attenuated. Consequently, histocompatibility should not be evaluated in isolation. Instead, it must be considered in conjunction with recipient demographics and clinical characteristics, as its independent impact often diminishes after adjusting for these variables. However, analyzing these factors

in a wait-listed population presents a unique statistical challenge; standard survival estimates are frequently compromised by competing risk events, most notably pre-transplant mortality, which can lead to a statistical overestimation of the probability of transplantation if not appropriately addressed through sub-distribution hazard modeling.²⁰ This study analyzed a decade of patient data to estimate the cumulative incidence of kidney transplantation using a competing risks model and to identify key clinical and immunological predictors of transplantation.

Materials and Methods

Study populations

This retrospective cohort study was conducted under the research exemption category and was approved by the Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University, Bangkok, Thailand (Approved No. MUPH 45/2023).

The study population included 5,276 patients with end stage kidney disease (ESKD) who underwent renal dialysis and were registered on the deceased donor kidney transplantation (DDKT) waiting list at the Organ Donation Centre, Thai Red Cross Society (ODC-TRCS), between January 1, 2010 and December 31, 2020. All patients were followed up from the date of registration until the occurrence of the event of interest or the end of the study period (December 31, 2021). Eligible participants were adults aged at least 18 years who were listed for their first single kidney transplantation. Patients were excluded if they: (1) were registered before initiation of dialysis, (2) had inactive status on the waitlist or (3) had incomplete data on the study variables.

HLA antibody testing and HLA typing classification

HLA antibody screening was performed using LAB-Screen™ PRA Class I and Class II assays (One Lambda, Inc., CA, USA). Patients were classified according to panel reactive antibody (%PRA) levels as follows: low sensitization (0-50%), intermediate sensitization (51-80%) and high sensitization (> 80%).²¹

Patients' HLA types were classified based on HLA-A, -B and -DR haplotype frequencies derived from the Thai Stem Cell Donor Registry (TSCDR).²² Haplotypes with a frequency of at least 0.01% were categorized as common, whereas those with a frequency less than 0.01% were classified as rare.²³

Data collection

Demographic and clinical data were extracted from the ODC-TRCS patient registry database. The retrieved variables included sex, age, ABO blood group, HLA antibody status, HLA antigens, waiting list status, and mortality status. Following extraction, the dataset underwent a thorough data cleaning process to resolve inconsistencies and manage missing values prior to statistical analysis.

Haplotype frequency and estimated haplotype counts

HLA-A, -B, -DR haplotype frequency (HF%) using the following formula: $HF\% = (n/N) \times 100$, where n was the sum of the haplotype and N was the total number of chromosomes analyzed in the group.²⁴

The estimated haplotype counts for the Thai National Stem Cell Donor Registry (TSCDR) donors were calculated using the EM algorithm, with the formula: $\text{Count} = (HF/100) \times 2n$, where n represents the total number of individuals in the study.²⁵

Statistical analysis

All categorical variables were described as frequency (percentage). The distribution of estimated haplotype frequencies was compared between groups by using a global Pearson's Chi-square test to evaluate overall significance. For post-hoc comparisons, the frequency of each haplotype was compared between the recipient and donor groups. Odds Ratios (ORs) and 95% confidence intervals (95%CI) were calculated. To account for multiple testing across 16 haplotypes and control Type I error inflation, the Bonferroni correction was applied. The threshold for statistical significance was adjusted to $p < 0.0031$ (calculated as $\alpha = 0.05/16$).

The primary outcome was time to kidney transplantation, with death while on the waiting list for

DDKT treated as a competitive risk. The probability of receiving a kidney transplant was estimated by using the cumulative incidence function (CIF). To identify factors influencing the waiting time for DDKT, a multi-variate sub-distribution hazard model (Fine-Gray model) was employed. The model was adjusted for potential confounders, including sex, age, ABO blood group, HLA antibody and the patient's HLA type. All statistical analyses were performed using Stata/SE version 19.5 (StataCorp LLC, College Station, TX, USA).

Results

Among 5,276 wait-listed patients during the 10-year of follow-up period, 1,996 patients (37.83%) underwent transplantation. The remaining 3,280 patients (62.17%) did not receive a transplant during the study period. This group included both patients who remained active on the waiting list and those who died while awaiting a DDKT, the latter being treated as a competitive risk event in the analysis. Regarding demographic characteristics, males had more transplants than females (22.74% vs. 15.09%). The age distribution was relatively balanced among the 30-39, 40-49 and 50-59 age groups, with the 40-49 age group being the most represented ($n = 1,532$, 29.04%). Interestingly, patients aged ≥ 60 years had a notably higher transplantation rate compared to those remaining on the list (4.13% vs. 2.24%), as shown in Table 1.

The comparison of HLA-A, -B and -DR haplotype frequencies between wait-listed kidney recipients ($n = 5,276$) and TSCDR donors ($n = 16,807$) is summarized in Table 2. The overall comparison of haplotype frequency between the two groups was significant ($p < 0.001$). Among the top 15 haplotypes identified, A2-B46-DR9 was the most frequent in both groups, accounting for 3.55% of recipients and 4.11% of donors (OR 0.86, 95%CI: 0.76-0.97, $p = 0.011$). Several haplotypes showed significant differences in distribution after multiple-testing adjustment. The A2-B13-DR15 haplotype was significantly more prevalent in the recipient group compared

Table 1 Overall end-stage kidney disease (ESKD) patient's characteristics with transplantation while waiting for deceased donor kidney transplantation (DDKT)

Characteristics	Total	Transplant		Without transplant	
		Number	%	Number	%
Overall	5,276	1,996	37.83	3,280	62.17
Demographic characteristics					
Sex					
Male	3,102	1,200	22.74	1,902	36.05
Female	2,174	796	15.09	1,378	26.12
Age (years)					
≤ 29	781	231	4.38	550	10.42
30-39	1,433	496	9.40	937	17.76
40-49	1,532	562	10.65	970	18.39
50-59	1,194	489	9.27	705	13.36
≥ 60	336	218	4.13	118	2.24
Clinical characteristics					
ABO blood group					
O	2,157	792	15.01	1,365	25.87
B	1,702	671	12.72	1,031	19.54
A	1,089	388	7.35	701	13.29
AB	328	145	2.75	183	3.47
HLA sensitization					
low-sensitized (0-49%)	4,688	1,797	34.06	2,891	54.80
intermediately sensitized (50-80%)	273	109	2.07	164	3.11
highly sensitized (81-100%)	315	90	1.71	255	4.26
HLA type of patients					
Rare type	193	64	1.21	129	2.45
Common type	5,083	1,932	36.62	3,151	59.72

HLA = human leukocyte antigen

to donors (1.63% vs. 0.83%; OR 1.99, 95%CI: 1.64-2.42, $p < 0.001$). Conversely, five haplotypes were significantly less frequent among recipients, including A33-B58-DR17 (2.11% vs. 4.54%; OR 0.45, 95%CI: 0.39-0.52), A33-B44-DR7 (2.11% vs. 2.85%; OR 0.73, 95%CI: 0.63-0.85), A33-B58-DR13 (0.79% vs. 1.40%; OR 0.56, 95%CI: 0.44-0.71), A30-B13-DR7 (0.57% vs. 1.56%; OR 0.36, 95%CI: 0.28-0.47) and A1-B57-DR7 (0.35% vs. 0.82%; OR 0.43, 95%CI: 0.30-0.60), respectively, all with $p < 0.001$.

The bar chart illustrates the frequencies (%) of common HLA haplotypes in kidney transplant candidates

(black bars, $n = 5,276$) compared to donors from the TSCDR (hatched bars, $n = 16,807$). The A2-B46-DR9 haplotype was the most prevalent in both cohorts. Significant differences in frequency were observed for several haplotypes, including A33-B58-DR17, A33-B44-DR7 and A2-B13-DR15 (Figure 1).

The cumulative incidence of transplantation increased steadily over a 10-year follow-up period. The analysis accounts for the competing risk of death while on the waiting list. At the first year, the cumulative incidence was approximately 15%, rising to 35% at the second year

Table 2 Comparison of the top 15 HLA-A, -B and -DR haplotype frequencies between wait-listed kidney recipients and the Thai National Stem Cell Donor Registry (TSCDR) donors²²

Haplotype	Recipients (n = 5,276) n (%)	TSCDR Donors ²² (n = 16,807) n (%)	Odds Ratio (95%CI)	p-value
Overall comparison			$\chi^2 = 413.61, df = 16$	< 0.001
A2-B46-DR9	375 (3.55)	1,381 (4.11)	0.86 (0.76–0.96)	0.009
A33-B58-DR17	223 (2.11)	1,526 (4.54)	0.44 (0.38–0.51)	< 0.001*
A33-B44-DR7	223 (2.11)	958 (2.85)	0.73 (0.63–0.85)	< 0.001*
A11-B75-DR12	211 (2.00)	672 (2.00)	1.00 (0.85–1.17)	0.999
A2-B46-DR14	206 (1.95)	527 (1.57)	1.25 (1.07–1.48)	0.007
A2-B13-DR15	172 (1.63)	279 (0.83)	2.00 (1.65–2.42)	< 0.001*
A11-B13-DR15	140 (1.33)	352 (1.05)	1.27 (1.05–1.55)	0.016
A2-B46-DR12	135 (1.28)	379 (1.13)	1.14 (0.93–1.39)	0.202
A11-B46-DR9	100 (0.95)	406 (1.21)	0.78 (0.63–0.97)	0.028
A11-B60-DR4	92 (0.87)	279 (0.83)	1.05 (0.83–1.33)	0.680
A33-B58-DR13	83 (0.79)	470 (1.40)	0.56 (0.44–0.71)	< 0.001*
A24-B35-DR12	78 (0.74)	289 (0.86)	0.86 (0.67–1.10)	0.232
A24-B75-DR15	73 (0.69)	329 (0.98)	0.70 (0.54–0.91)	0.007
A2-B46-DR4	65 (0.62)	272 (0.81)	0.76 (0.58–1.00)	0.046
A30-B13-DR7	60 (0.57)	524 (1.56)	0.36 (0.27–0.47)	< 0.001*
A1-B57-DR7	37 (0.35)	275 (0.82)	0.43 (0.30–0.60)	< 0.001*

Note: global comparison of haplotype frequencies between groups was performed using Chi-square test

n (%): number of haplotypes (estimated counts based on 2n total haplotypes) and their corresponding percentage frequencies.

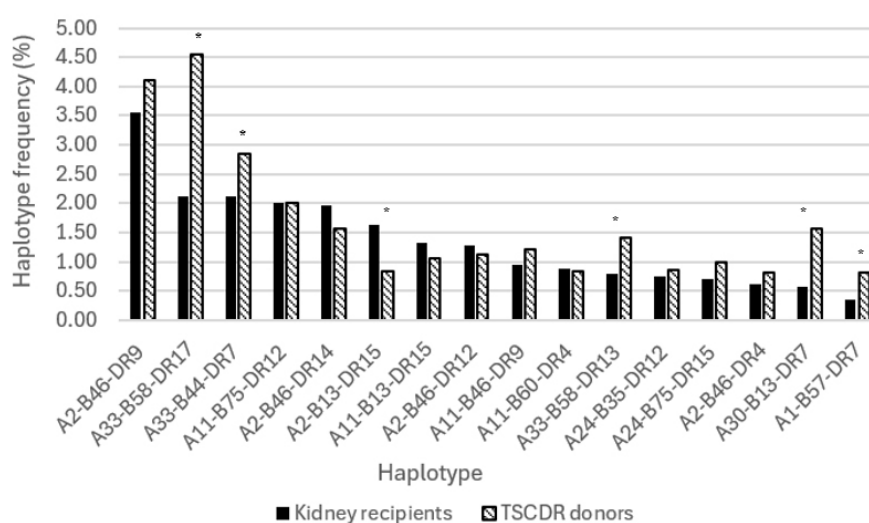
Odds Ratio (OR): calculated using 2x2 crosstabulation for individual haplotype comparisons, with TSCDR donors serving as the reference group.

95%CI: 95% confidence interval for the Odds Ratio.

p-value: determined by Pearson's Chi-square test.

*Statistically significant after Bonferroni correction ($p < 0.0031$, adjusted for 16 multiple comparisons).

HLA, human leukocyte antigen; TSCDR, Thai National Stem Cell Donor Registry

**Figure 1** Comparison of the most HLA-A, -B and -DR haplotype between in kidney recipients and TSCDR donors (*p-value < 0.001)

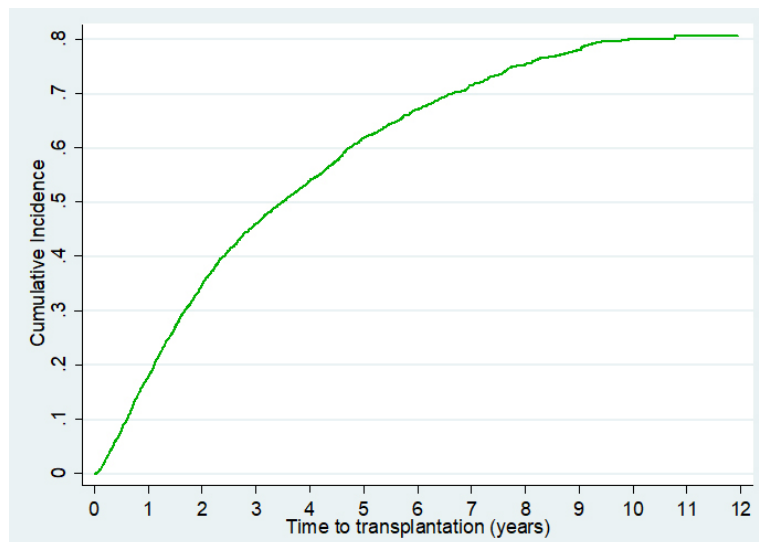


Figure 2 Cumulative incidence of kidney transplantation among wait-listed patients. The x-axis represents the time duration (in years) from the date of initial registration on the transplant waiting list until the occurrence of kidney transplantation

and 45% at the third year, respectively. The median time to transplantation was estimated at approximately 3.5 years after registration. At the end of the tenth year, the cumulative incidence reached approximately 80%, after which the curve reached a plateau (Figure 2).

The univariate analysis identified age, ABO blood group (A and O), HLA type and dialysis duration as potential predictors of transplantation (Table 3). However, in the multivariate model, only age, HLA sensitization and duration of dialysis remained significantly associated with the probability of receiving a deceased donor kidney transplant.

Age was a strong independent predictor, with a significant increasing trend in the likelihood of transplantation with advancing age (≤ 29 years as the reference group). Patients aged ≥ 60 years had the highest probability of transplantation (SHR 5.63, 95%CI: 4.12-7.70, $p < 0.001$), followed by those aged 50-59 (SHR 2.55, 95%CI: 1.97-3.30, $p < 0.001$).

Regarding HLA sensitization, patients in the intermediately sensitized (50-80% PRA) and highly sensitized groups (81-100% PRA) showed a slightly higher sub-distribution hazard of transplantation compared to the low-sensitized group (SHR 1.37, 95%CI: 1.02-1.84, $p = 0.037$ and SHR 1.41, 95%CI: 1.01-1.99, $p = 0.045$).

Conversely, the duration of dialysis was negatively significant associated with the chance of transplantation. Each year increase in dialysis duration resulted in a 29% reduction in the sub-distribution hazard of receiving a transplant (SHR 0.71, 95%CI: 0.67-0.75, $p < 0.001$).

Notably, while ABO blood group (specifically groups A and O) and common HLA type were found to be significantly associated with the probability of transplantation in the univariate analysis (all $p < 0.05$), these associations lost statistical significance after adjusting for other covariates in the multivariate model.

Discussion

A steady increase in the cumulative incidence of transplantation, reaching 45% at the third year. The median time to receive a transplant was approximately 3.5 years. While these overall numbers appear positive, the Fine-Gray model identifies a major challenge with waiting time. Specifically, the length of time spent on dialysis was strongly linked to a lower chance of getting a transplant. This result means that for every extra year a patient stays on dialysis, their chance of transplantation drops by 29%. Dialysis vintage was found to have a significant impact on transplant likelihood. This result is consistent with a previous study in Scotland, which

Table 3 Sub-distribution hazard ratio (SHR) estimation of transplantation by Fine-Gray model

Variables	Univariate		Multivariate	
	SHR (95%CI)	p-value	SHR (95%CI)	p-value
Demographic Characteristics				
Sex (ref: female)				
Male	1.10 (0.96-1.26)	0.185	1.04 (0.90-1.19)	0.596
Age (years) (ref: ≤ 29 years)				
30-39	1.39 (1.07-1.81)	0.014	1.49 (1.15-1.92)	0.002
40-49	1.82 (1.40-2.36)	< 0.001	1.84 (1.43-2.37)	< 0.001
50-59	2.66 (2.04-3.47)	< 0.001	2.55 (1.97-3.30)	< 0.001
≥ 60	8.93 (6.48-12.30)	< 0.001	5.63 (4.12-7.70)	< 0.001
Clinical characteristics				
ABO blood group (ref: AB)				
A	0.70 (0.53-0.94)	0.018	0.84 (0.63-1.11)	0.218
B	0.78 (0.59-1.03)	0.076	0.96 (0.73-1.26)	0.789
O	0.62 (0.48-0.82)	0.001	0.79 (0.60-1.03)	0.078
HLA sensitization date (ref: low-sensitized group (0-49%))				
Intermediately sensitized group (50-80%)	1.00 (0.84-1.20)	0.986	1.37 (1.02-1.84)	0.037
Highly sensitized group (81-100%)	1.00 (0.68-1.49)	0.983	1.41 (1.01-1.99)	0.045
HLA type of patients (ref: rare type)				
Common type	1.40 (1.20-1.64)	< 0.001	1.43 (0.97-2.12)	0.068
Duration of dialysis	0.68 (0.65-0.72)	< 0.001	0.71 (0.67-0.75)	< 0.001

HLA = human leukocyte antigen

reported that the probability of receiving a transplant decreased by 4% for each additional year on dialysis ($p < 0.0001$).²⁶ Hemodialysis patients often require blood transfusions for anemia, which can trigger HLA sensitization and complicate finding a compatible donor.²⁷ Longer duration on dialysis increase the risk of health complications including cardiovascular disease,²⁸ infection,²⁹ or nutritional decline³⁰ which can make patients less fit for surgery.^{26,31} Furthermore, comorbidities such as hypertension and diabetes may adversely affect both physical and mental health,³¹ potentially limiting patient access to transplantation. However, waiting times vary according to different allocation criteria. For example, some systems integrate HLA mismatch levels with the patient's antibody profile and the center credit difference.³² This credit system balances organ exchange between regions by prioritizing centers that have contributed more

donors. Such multi-factor approaches ensure regional equity and directly influence how quickly a patient receives a transplant.

Similar to international frameworks, the deceased donor kidney allocation system in Thailand incorporates waiting time as a key allocation criterion. However, the weighting assigned to waiting time within the Thai scoring system is considerably lower than that seen in many global models, such as the United Network for Organ Sharing (UNOS) system,³³ thereby diminishing its impact on overall transplant opportunities. For instance, while several Eurotransplant programs award an additional point for each year spent on the waiting list,³⁴ the Thai Red Cross Organ Donation Center criteria restrict the annual score increment to less than one point. This disparity critically disadvantages highly sensitized patients and those with donor-specific antibodies (DSA).

To address this issue, various international programs have implemented specialized allocation strategies for highly sensitized recipients with complex HLA profiles, including paired kidney donor exchanges and altruistic donor programs.³⁵ These strategies have significantly enhanced access to transplantation for immunologically complex patients; however, Thailand currently lacks specific legislation or a dedicated legal framework to support and formalize these alternative allocation approaches.

Unlike previous studies in the United States that identified sex as a significant determinant of kidney transplant probability,^{13,36} our findings demonstrated no statistically significant difference between male and female candidates. This discrepancy may be attributed to differences in the donor pools and age criteria studied. While earlier data encompassed both living and deceased donor transplants, our cohort focused exclusively on deceased donor kidneys. Given that female candidates often face greater immunological barriers in securing living donors, isolating the deceased donor pool likely minimized sex-based disparities. Furthermore, prior research demonstrating a male advantage was restricted to candidates aged over 60 years, whereas our study included a broader adult population (aged 18 years), thereby mitigating age-specific physiological disadvantages.

ABO blood group distribution does not significantly influence the likelihood of kidney transplantation. This lack of impact stems from the parallel distribution of blood types between waitlisted candidates and the donor pool. Consistent with previous Thai blood donor population reports, the prevalence follows an O > B > A > AB pattern,³⁷ creating a natural equilibrium between supply and demand that maintains equity across all groups. This contrasts with the United States, where blood type B is less common in the general population, leading to significant disparities in access for type B candidates. To address this, the U.S. Organ Procurement and Transplantation Network (OPTN) implemented policy changes to reduce these inequities and improve

transplant rates for minority groups, such as allowing A₂/A₂B donor kidneys to be transplanted into type B recipients.^{38,39}

In addition to ABO compatibility, the distribution of HLA haplotypes plays a critical role in ensuring equitable organ allocation. Our findings indicate a high degree of HLA-A, -B and -DR haplotype similarity between kidney wait-listed recipients and the potential donor pool (represented by the TSCDR²²). Notably, 10 out of the 15 most frequent haplotypes showed no significant disparity in frequency between the two groups, as evidenced by the comparable proportions in Table 2. This genetic alignment suggests that most candidates face a similar probability of finding a well-matched donor within the domestic pool. HLA symmetry, combined with the balanced ABO distribution discussed earlier, reinforces the equity of the current system, where biological barriers do not disproportionately disadvantage specific patient subgroups in Thailand.

Age was found to have a significant impact on transplantation. The results indicated that older patients were more likely to receive kidney transplantation than younger patients. This finding is likely explained by factors similar to those observed with dialysis duration, as older individuals in this cohort tend to have longer dialysis exposure, extended waiting times, and higher levels of HLA antibodies. These factors can lead to higher scores on the Thailand kidney allocation criteria, ultimately increasing their chances of receiving a transplant.²¹ However, receiving a kidney transplantation with advancing age is associated with higher comorbidity rates, which impact survival among elderly recipients.^{40,41}

For HLA sensitization, intermediate and highly sensitized patients have a higher likelihood of transplantation than low-sensitized patients, reflecting the distribution of kidney allocation, resulting in longer waiting times for some groups. The current kidney allocation criteria in Thailand assign additional points to intermediate and highly sensitized patients. Patients with PRA of 81-100% and 50-80% receive four and two points,

respectively, whereas those with PRA below 50% do not receive additional allocation points.²¹ In addition, using the calculated PRA (cPRA) score for kidney allocation rather than the PRA will result in higher scores for patients with antibodies of high frequency in the Thai population.⁴²

This study has several limitations. First, the analysis focused exclusively on patient-related data, excluding donor-side factors such as the timing of organ donation stimulation and the availability of specialized retrieval teams. Second, the retrospective design may affect data accuracy; for instance, the lack of specific causes of death in the database precluded distinguishing between kidney disease-related mortality and other causes. Additionally, since HLA antibody levels can fluctuate during the waiting period, this study only captured variations between initial and current results. Finally, while histocompatibility in this cohort was assessed using complement-dependent cytotoxicity (CDC), current practice has shifted toward flow cytometry. Consequently, these findings serve as a critical baseline for future research incorporating modern crossmatching techniques.

Conclusion

This study provides a comprehensive longitudinal perspective on DDKT access by analyzing a large national cohort over 11 years, specifically focusing on the interplay between patient demographics, HLA sensitization and clinical duration on dialysis. The results of the study revealed that while the cumulative incidence of transplantation increases steadily over a decade, the likelihood of receiving a graft is not uniform across the wait-listed population. The probability of transplantation is primarily driven by a complex interplay between patient demographics, immunological profiles and clinical history. Notably, advancing age and HLA sensitization emerged as positive predictors, whereas a prolonged duration on dialysis significantly hindered transplant access. The observation that initial associations with

blood groups and HLA commonality were confounded by these factors underscores the necessity of considering multi-variable clinical contexts. Ultimately, these insights highlight the need for refined organ allocation strategies and targeted wait-list management to ensure more equitable and predictable access to transplantation for ESKD patients.

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