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Educational interventions improve disparities in patient access to kidney transplantation: a network meta-analysis of randomized controlled trials

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Background: Transplantation significantly improves the quality of life for patients with chronic kidney disease. Despite various educational strategies being assessed, the optimal approach to overcome barriers to kidney transplantation remains unclear.
Materials and Methods: The authors conducted a systematic review and network meta-analysis (NMA) of randomized controlled trials (RCTs) comparing educational interventions to improve kidney transplantation access. The authors searched Medline, Embase, Cochrane Central, and Clinicaltrials.gov up until June 2024. Outcomes included rate of transplantation, living donor inquiries, waitlisting, evaluation, and knowledge level. Frequentist random-effects models and p-scores were used to rank strategies. The protocol was registered in PROSPERO.
Results: The authors included 24 RCTs with a total of 116 054 patients. Of these, 57 996 (49.97%) received educational interventions and 58 058 (50.03%) received standard-care. Educator-guided and home-based strategies were associated with a higher rate of transplantation to multilevel interventions (RR 1.63; 95% CI: 1.07–2.48; $P=0.023$ I RR 1.85; 95% CI: 1.11–3.08; $P=0.019$) and standard-care (RR 1.56; 95% CI: 1.00–2.45; $P=0.049$ I RR 1.78; 95% CI: 1.17–2.70; $P=0.007$). According to the P-scores ranking, home-based interventions were the most likely strategy to improve transplantation access.
Conclusion: In this NMA of 24 RCTs, home-based and educator-guided interventions were the most beneficial for improving access to kidney transplantation. Future studies should focus on their applicability for minority populations with challenges in health literacy and transplant access.

Keywords: end stage kidney disease, healthcare disparities, kidney transplantation, patient education, systematic review

Introduction

Renal transplantation is established as the treatment of choice for suitable patients with end-stage kidney disease (ESKD) as it significantly improves the quality of life, is more cost-effective and prolongs survival in comparison to the alternative renal replacement therapy (RRT) of dialysis[1–3]. Despite the substantial benefits offered by kidney transplantation, a significant proportion of eligible patients do not undergo this procedure[4]. The reasons for this gap in care are complex and multifaceted, involving barriers at various levels: patient and family concerns, stigma or lack of awareness about transplant options; challenges for healthcare professionals in appropriate referrals, managing

HIGHLIGHTS

- Our systematic review and network meta-analysis of 24 randomized controlled trials involving 110 352 patients is the first to compare various educational strategies in improving access to kidney transplantation.
- Home-based and educator-guided interventions significantly increased transplantation rates compared to multilevel interventions and standard care.
- Home-based approaches ranked highest for improving access, while educator-guided methods also provided notable benefits in the transplantation process.
- Findings indicate that targeted educational interventions can enhance transplantation rates and patient evaluation.
- Since most studies were conducted in the United States and developed countries, further research is needed in diverse settings to ensure these strategies can be effectively applied worldwide.

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comorbidities that affect transplant eligibility, or providing adequate patient education and support; disparities in access to transplantation services; and broader systemic issues such as funding limitations, and regulatory barriers[5,6].

Addressing these barriers requires a coordinated effort among healthcare professionals, transplant centers, policymakers, and patient advocacy groups to ensure equitable care for all eligible patients. Limited health literacy has been previously described as a significant factor contributing to poorer clinical outcomes for patients with chronic kidney disease (CKD), with the disproportionate impact of limited health literacy on individuals from lower socioeconomic backgrounds and nonwhite ethnicities[7]. Several educational initiatives have been launched worldwide to improve patient's health literacy and improve barriers associated with receiving a transplant[8]. However, data on the efficacy of such strategies is conflicting. While some studies show that the use of educational programs significantly improves evaluations, knowledge, and rate of living donor kidney transplants (LDKT)[9,10], others show no impact[11–13].

Given the discrepancy in the published efficacy of such interventions, the diverse range of educational strategies assessed, and the lack of previous meta-analyses focused on kidney transplantation[14], we aimed to perform a systematic review and network meta-analysis (NMA) assessing simultaneous comparisons of multiple educational interventions and standard of care in patients with ESKD eligible for kidney transplantation. We focused on evidence from randomized controlled trials (RCTs) assessing the efficacy of these strategies in access to transplantation at multiple stages of the process, including patients' health literacy during the journey to receive a kidney transplant.

Methods

Study design and reporting guidelines

This systematic review and NMA was performed and reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Supplemental Digital Content 1, http://links.lww.com/JS9/D569) Statement[15], Assessing the Methodological Quality of Systematic Reviews (AMSTAR) (Supplemental Digital Content 2, http://links.lww.com/JS9/D570) guidelines[16], and recommendations of the Cochrane Collaboration Handbook for Systematic Reviews of Interventions[17]. We prospectively registered the protocol with a prespecified methodology on the International Prospective Register for Systematic Reviews (PROSPERO).

Search strategy and eligibility criteria

We systematically searched Medline (OVID), Embase, Cochrane Central Register of Controlled Trials, and ClinicalTrials.gov databases up to June 2024 using the keyword terms 'kidney', 'transplant', 'education', and 'random'. The complete search strategy is available in the supplementary Appendix A (Supplemental Digital Content 3, http://links.lww.com/JS9/D571). Only articles published in the English language were applied. We also searched for additional eligible studies through a review of references from prior publications, including the included studies and related systematic reviews.

Two authors performed the literature search and screened studies independently following predefined search criteria. Eventual conflicts were resolved by consensus among the authors. Full-text screening was also performed independently using a standardized spreadsheet by the authors.

We restricted inclusion in this meta-analysis to studies that met the following criteria: 1) RCTs; 2) comparing different educational interventions and standard care in transplant clinics; 3) enrolling adult (> 18 years) patients with 4) chronic or end-stage kidney disease; and 5) eligible for transplantation. We excluded studies with 1) no control or intervention group of interest; 2) overlapping patient populations; 3) including patients' post-transplantation; or 4) under 18 years old; and 5) nonrandomized design. Additionally, when crossover studies were identified, they were included only if data prior to group crossover was available. We also excluded any post-hoc analyses of RCTs included.

Intervention and control groups

The interventions assessed in this meta-analysis were defined as educational approaches with a focus on improving patients' health literacy and access to kidney transplantation. Given the expected heterogeneity in the educational interventions applied in each included trial, these were classified into major educational categories:

1. 'Educator-guided' interventions, where trained staff provided education through group sessions and/or counseling in transplant clinics.
2. 'Patient-guided' interventions, where patients were provided with an educational package (e.g. video) guided by the user in transplant clinics or at home.
3. 'Home-based' interventions, where educational programs occurred through sessions in patients' own homes.
4. 'App-based' interventions, where computer-assisted algorithms provided tailored and interactive education to patients on App-based phone tools.
5. 'Web-based' interventions, where patients accessed specific educational websites with written and video information.
6. 'Mentoring' interventions, where social workers or kidney transplant recipients acted as navigators, counseling patients on a one-to-one basis.
7. 'Multilevel' interventions, where a range of the previously described interventions were utilized.

A full description of the categories of educational interventions assessed in our study are presented on Table S1 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571). Furthermore, control groups were individual to each trial, which could be comparing two or more educational interventions, or using 'standard care' as a control (see Supplementary material for definitions, Supplemental Digital Content 3, http://links.lww.com/JS9/D571). We defined 'standard care' as the usual consultation with multidisciplinary team members in transplant clinics, which could involve the use of written materials.

Outcome measures

Our primary outcome of interest was 1) the rate of transplantation (either deceased donor kidney transplant (DDKT) or LDKT) events at the end of each trial. Secondary outcomes included 2) evaluations for transplantation; 3) living donor inquiries or identification of living donors; 4) waitlisting; and 5) knowledge of transplantation. We limited our outcome analysis to post-intervention endpoints where studies reported data throughout intervention periods. For studies where data was collected at multiple follow-up periods, we used the follow-up specified in the primary outcome or the longest follow-up available to assess the long-term impact of the intervention.

We systematically identified knowledge scales used across studies. These included the Rotterdam Renal Replacement Knowledge-Test (R3K-T) scale[18], the Kidney Transplant Understanding Tool (K-TUT), the Knowledge about Living Donation Questionnaire[19], and the Kidney Donor Profile Index/Increased Risk Donor (KDPI/IRD) knowledge survey[20]. Other scales used were comprised of locally developed knowledge indexes which varied slightly across studies. A full description of knowledge assessment measures can be found in Table S2 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571).

Subgroup and sensitivity analyses

We performed prespecified analyses according to the level of income, education, and ethnic background of patients included in the trial to analyze the impact of specific disparities in transplantation outcomes. We also performed sensitivity analyses according to the geographical location of trials.

Quality assessment

Each study included in the analysis was assessed using the Cochrane Risk of Bias Assessment Tool (RoB-2) for RCTs, which rates studies as ‘low risk’, ‘some concerns’, or ‘high risk’ of bias[21]. The assessment process was conducted and documented by a minimum of two independent investigators. Any disagreements in the quality assessment were resolved through consensus or by seeking advice from the senior author. Publication bias was assessed for the primary outcome through the generation of a funnel plot and Egger’s regression test, where a *P*-value less than 0.05 indicates the presence of publication bias[22]. Finally, the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) tool was employed to evaluate the level of certainty of the direct, indirect, and network comparisons within the outcome of transplantation, with categorizations ranging from high to very low[23,24].

Statistical analysis

A frequentist network meta-analysis with a random-effects model was used to estimate the effect size of each prespecified endpoint relative to each intervention arm. For binary endpoints, we summarized results using the Mantel–Haenszel method, presenting risk ratios (RRs) and 95% CIs. Knowledge scale endpoints were assessed using standardized mean differences (SMD) given the difference in assessment tools, alongside SD as a measure of data dispersion. As recommended by the Cochrane Collaboration[17], we used the formula proposed by Wan and colleagues[25] using medians and interquartile ranges for missing means data, as well as *P*-values and t-scores to calculate missing SDs. Furthermore, where data was only available in graphical format, Webplotdigitizer version 3.9 was used as a tool for data extraction.

To illustrate network structure and node interconnections, we created network plots for each endpoint. The probabilities of ranking using direct and indirect comparisons of educational interventions were determined using *P*-scores, which range from 0 (poorest performance) to 1 (optimal performance). Higher *P*-scores denote better overall efficacy of the educational intervention assessed. When two subnetworks were identified, the largest subnetwork was chosen for analysis. Pairwise comparisons were conducted as sensitivity analyses. Statistical significance was defined by a *P*-value of <0.05, with all statistical tests being two-tailed.

For each comparison, network heterogeneity across interventions was assessed using τ^2 and I^2 statistics, employing the restricted maximum likelihood method (REML). We evaluated the overall inconsistency within the network by comparing direct versus indirect evidence effects for each endpoint using χ^2 tests. Inconsistency was identified when *P*-values were below 0.05. RStudio version 4.1.2 ‘netmeta’ and ‘dmetar’ packages (R Foundation for Statistical Computing) were used for the statistical analysis.

Role of the funding source

There was no funding source for this study. Data extractors had full access to all the data in the study and all authors had responsibility for the final publication.

Results

Characteristics of included studies

Our initial search yielded a total of 2221 results. After the removal of duplicates, 1453 articles were reviewed according to title and abstract based on our predefined inclusion criteria, and 120 studies were fully screened for inclusion as illustrated in Figure 1.

We included 24 RCTs[9–13,26–45] in our analysis, comprising a total of 116 054 patients. Of these, 40 662 (35.04%) received ‘educator-guided’ interventions, 14 414 (12.42%) received ‘multilevel’ interventions, 1603 (1.38%) received ‘mentoring’ interventions, 549 (0.47%) received ‘patient-guided interventions’, 521 (0.45%) received ‘app-based’ or ‘web-based’ interventions, 247 (0.21%) received ‘home-based’ interventions, and 58 058 (50.03%) received ‘standard care’. Most studies assessed combinations rather than single interventions. A full description of educational interventions and controls used by individual studies can be found in Tables S3 and S4 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571), respectively. Patients were mostly identified from hemodialysis or transplant centers, and some studies focused mainly on minority populations. Table S5 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571) describes the patient population in each study in more detail.

In the pooled population, the mean age was 59.1 years, and the percentages of included females ranged from 20 to 60%. Regarding the socioeconomic background of patients, the mean percentage of African American patients across trials was 55.8%, with 39.7% of patients having a ‘high-school education’ level and 42.8% being classified as ‘low income’ (most studies used an annual income of less than 20 000 dollars as a benchmark). The majority of studies were conducted in the United States (US), with two studies being conducted in Canada[12,37], and other two in the Netherlands[9,35]. Five of the RCTs were cluster-randomized trials[12,26,39,42,44]. The duration of follow-up ranged from 1 week to 36 months. Further details can be found on Table 1.

Pooled analysis: transplantation

For the primary outcome, a network was utilized in each endpoint analysis for individual interventions as described previously. Each

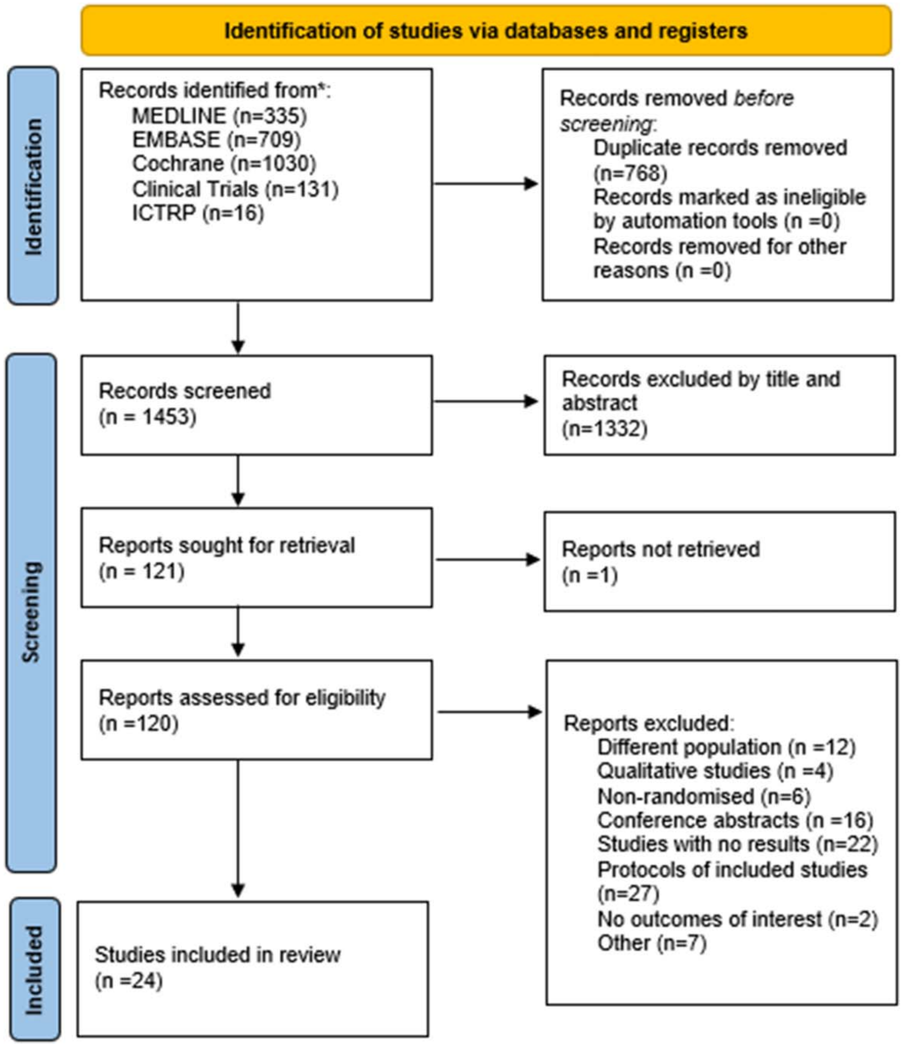

Figure 1. PRISMA 2020 flow of included studies.

educational strategy was directly compared with at least one other intervention. Within this network, it was assumed that all strategies within each educational class exhibited similar efficacy. 'Standard care' was used as the reference comparator.

Across 11 studies involving a total of 24 821 patients, transplantation events were reported for 2,923 (11.8%). As seen in Figure 2, educator-guided strategies had significantly improved rates of transplantation compared to multilevel (RR 1.63; 95% CI: 1.07–2.48; $P=0.023$) and standard care (RR 1.56; 95% CI: 1.00–2.45; $P=0.049$) approaches. Similar effects were observed in home-based strategies compared with multilevel interventions (RR 1.85; 95% CI: 1.11–3.08; $P=0.019$) and standard care (RR 1.78; 95% CI: 1.17–2.70; $P=0.007$) approaches. No significant differences were found between other pairwise comparisons.

Pooled analysis: transplantation-related endpoints

In a pooled analysis of 12 studies with 32 968 evaluation events, interventions based at home were significantly favored compared to financial assistance (RR 4.82; 95% CI: 1.01–22.82; $P=0.047$), mentoring (RR 2.16; 95% CI: 1.04–4.47; $P=0.039$), patient-guided approaches (RR 3.44; 95% CI: 1.16–10.19; $P=0.026$), and standard care (RR 1.2.73; 95% CI: 1.26–5.95; $P=0.011$). Furthermore, 10 studies involving a total of 22 115 patients assessed the rate of living donor inquiries or identification of a living donor. Home-based strategies significantly enhanced rates of inquiries or identifications of living donors compared with those guided by educators (RR 1.69; 95% CI: 1.19–2.40; $P=0.003$), patients (RR 1.92; 95% CI: 1.27–2.91; $P=0.002$), and standard care (RR 1.45; 95% CI: 1.14–1.83; $P=0.002$). No significant differences emerged from other pairwise comparisons between the educational strategies. Finally, the endpoint of waitlisting did not showed significant differences in network comparisons. Network plots and league tables for the endpoints of evaluation, inquiry, and waitlisting can be found in Supplementary Figures S1, S2 and S3, respectively (Supplemental Digital Content 3, http://links.lww.com/JS9/D571).

Pooled analysis: knowledge

A total of 3926 patients were analyzed across 14 studies for knowledge levels using multiple scales (Table S2, Supplemental

Table 1

Baseline characteristics of included studies.

Study	Registry	Country	Intervention	Control	Patient no, I/C	Follow-up, months	Age, years, I/C	Female %, I/C
ASCENT, Patzer 2017[39]a	NCT02879812	USA	Educator-guided education	Standard care	39977/39978	12	64.0/64.0	43.0/44.0
Barnieh 2011[27]	NA	USA	Educator-guided education	Standard care	49/59	3	41–60[b]	29.0/34.0
Basu 2018[28]	NCT01776073	USA	Mentoring	Standard care	196/205	28.8	54.0/54.0[c]	55.0/43.0
ELITE, Weng 2017[29]	NCT01261910	USA	Educator-guided education	Standard care	249/250	0.2	53.8/53.6	31.3/38.0
EnAKT LDK, Garg 2023[12]a	NCT03329521	Canada	Multilevel intervention	Standard care	9780/10595	3	61.0/61.0[c]	38.1/38.3
Explore Transplant @ Home, Waterman 2019[31]	NCT02268682	USA	Patient-guided education Mentoring	Standard care	185/189/187[d]	8	54.0/54.0/53.0[d]	48.0/51.0/48.0[d]
Explore Transplant, Waterman 2018[30]	NA	USA	Educator-guided education	Standard care	133/120	1	55.8/51.1	58.0/49.0
House Calls, Rodrigue 2014[32]	NCT00785265	USA	Home-based education Mentoring	Educator-guided education	54/49/49[d]	24	50.9/51.4/51.8[d]	23/20/22[d]
iChoose Kidney, Patzer 2018[11]	NCT02235571	USA	App-based education	Standard care	226/217	0	51.1/50.1	36.7/38.2
Inform Me, Gordon 2016[33]	NCT01859884	USA	App-based education	Standard care	133/155	0.2	51.2/50.5	47.4/41.4
Informate, Gordon 2016[33]	NA	USA	Web-based education	Educator-guided education	162/120	0.8	< 45[b]	51.8/50.0
Kidney Team at Home, Ismail, 2014[9]	NTR2730	Netherlands	Home-based education	Patient-guided education	84/79	6	54.9/54.5	45.2/40.5
Kidney Team at Home, Massey 2016[35]e	NTR2733	Netherlands	Home-based education	Standard care	40/40	24	59.4/56.7	40.0/50.0
Living ACTS, Arriola 2014[36]	NA	USA	Patient-guided education	Standard care	136/132	6	50.9/52.5	48.5/41.7
LOVED, Sieverdes 2021[13]f	NCT03599102	USA	Multilevel	Educator-guided education	24/24	12	50.9/47.9	50.0/50.0
Mansell 2021[37]	NCT03633136	Canada	Patient-guided education	Standard care	64/68	1	50.3/52.1	39.1/42.6
PREPARED, Boulware 2018[38]	NCT01439516	USA	Educator-guided education	Standard care	61/31	6	54.0/52.0	58.0/42.0
RADIANT, Patzer 2017[39]a	NCT02092727	USA	Multilevel intervention	Standard care	4203/4817	12	60.2/62.3	NA
Rodrigue 2007[40]	NA	USA	Home-based education	Standard care	69/63	36	50.7/53.4	46.0/50.7
simplifyKDPI / IRD-1-2-3, Kayser 2020	NA	USA	Patient-guided education	Standard care	42/38	0	61.1/58.7	33.3/30.6
Sullivan 2018[42]a	NCT01981603	USA	Mentoring	Standard care	1026/959	12	62.0/63.0	44.0/42.0
TALK, Boulware 2013[10]	NCT00932334	USA	Patient-guided education Mentoring	Standard care	43/43/44[d]	6	60.0/59.0/60.0[d]	60.0/60.0/59.0[d]
TALKS, Boulware 2021[43]	NCT02369354	USA	Mentoring Financial assistance	Standard care	100/100/100[d]	12	52.3/52.4/51.7[d]	46.0/46.0/47.0[d]
Your Path to Transplant, Waterman 2014	NCT02181114	USA	Multilevel intervention	Educator-guided education	407/395	18	52.7/53/2	41.3/37.5

Data are presented as means unless otherwise stated.

I/C, Intervention/Control; NA, not available; USA, United States of America.

[a]Cluster trial.

[b]Age provided as binary data. The majority of participants were in the age range reported.

[c]Data reported as median.

[d]Intervention groups had two different educational approaches. The first two values refer to the intervention groups.

[e]Crossover trial.

[f]Single blinded: statistician/outcome-assessor blinded to the analysis.

A League Table: Transplantation

App-based							
0.68 (0.34 - 1.39)	**Educator Guided**						
1.56 (0.15 - 16.30)	2.29 (0.23 - 23.26)	**Financial Assistance**					
0.60 (0.30 - 1.20)	0.88 (0.51 - 1.51)	0.38 (0.04 - 3.86)	**Home Based**				
0.84 (0.42 - 1.68)	1.24 (0.72 - 2.14)	0.54 (0.05 - 5.33)	1.41 (0.86 - 2.31)	**Mentoring**			
1.11 (0.58 - 2.12)	**1.63 (1.07 - 2.48)**	0.71 (0.07 - 7.08)	**1.85 (1.11 - 3.08)**	1.31 (0.79 - 2.19)	**Multilevel**		
0.75 (0.32- 1.73)	1.10 (0.54 - 2.25)	0.48 (0.05 - 5.05)	1.25 (0.78 - 2.00)	0.89 (0.45 - 1.76)	0.67 (0.34 - 1.36)	**Patient Guided**	
1.07 (0.61 - 1.85)	**1.56 (1.00 - 2.45)**	0.68 (0.07 - 6.65)	**1.78 (1.17 - 2.70)**	1.26 (0.84 - 1.90)	0.96 (0.68 - 1.35)	1.43 (0.76 - 2.68)	**Standard Care**

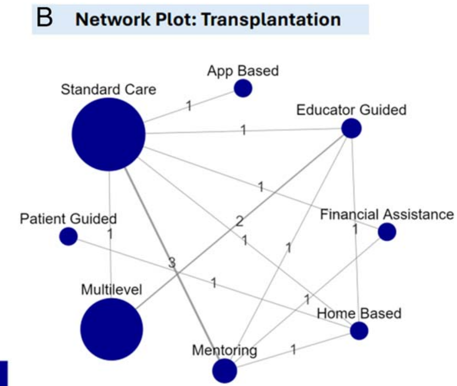

Figure 2. (A) League tables and (B) network plots of transplantation endpoint comparing educational interventions to improve patient access to kidney transplants. League Tables – Educational interventions are arranged alphabetically, displaying relative risks (RRs) and 95% CIs between the column-defined and row-defined treatments. RRs greater than 1 favor the treatment defined by the column. Statistically significant results are highlighted in bold. Network Plot – Nodes symbolize the different educational interventions, while edges depict direct comparisons from the included trials. The size of each node reflects the number of patients assigned to that educational method, and the thickness of each edge corresponds to the frequency of direct comparisons between the strategies.

Digital Content 3, http://links.lww.com/JS9/D571). As illustrated in Figure 3, strategies using multilevel components showed a substantial increase in the knowledge level of participants regarding transplantation rates when compared to all other approaches ($P<0.001$). Additionally, home-based strategies yielded similar positive outcomes over patient-guided (SMD 1.26; 95% CI: 0.35–2.17 $P=0.006$) and app-based interventions (SMD 1.92; 95% CI: 0.65–3.19; $P=0.003$) as well as standard care (SMD 1.54; 95% CI: 0.70–2.38; $P<0.001$) methods. Other pairwise comparisons between the educational strategies did not reveal significant differences.

Ranking of educational strategies

The P-score values and ranking probabilities for the efficacy of different educational strategies are presented on Tables 1, 2 and Supplementary Figure S4 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571). For the primary outcome, the highest P-score was observed for home-based education, with a score of 0.87, 0.97, and 0.96 for transplantation, evaluation, and LDKT inquiry endpoints, respectively. These were followed by educator-guided strategies for the outcomes of transplantation ($P=0.75$) and evaluation ($P=0.71$), while app-based strategies were ranked second for inquiries ($P=0.65$). For the endpoint of waitlisting, educator-guided interventions had the highest P-score ranking ($P=0.72$), followed by mentoring ($P=0.72$). Finally, multilevel interventions were the highest ranked for the endpoint of knowledge about transplantation ($P=0.99$), followed by home-based strategies ($P=0.81$). These results suggest that educational interventions based at home tend to offer better overall performance across clinical and health-literacy endpoints.

Network consistency and heterogeneity

Fitted models showed good convergence, and no statistical evidence of inconsistency was found in our NMAs for transplantation ($I^2=9.9\%$, $P=0.35$), inquiries ($I^2=28\%$, $P=0.21$), and waitlisting ($I^2=9.9\%$, $P=0.35$). However, significant heterogeneity was found in the NMA for the endpoint of evaluation ($I^2=79.8\%$, $P=0.008$) consistent across all studies, and the endpoint of knowledge ($I^2=95.3\%$, $P<0.001$) mainly due to comparisons between app-based, home-based, and standard care approaches. The proportions of direct evidence for each comparison are provided in Figure S5–S10 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571). Comparisons of direct versus indirect evidence for each network are presented in Supplemental Figures S11–S15 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571).

Sensitivity analyses and subgroups

Sensitivity analyses were conducted for the primary outcome and health literacy outcome of knowledge according to ethnicity, education level, and geographic location of trials. The overall results were consistent with the primary analyses in the NMA favoring home-based, educator-guided, and multilevel interventions, which assessed outcomes in a variety of settings. Detailed results of the sensitivity analyses can be found in Supplementary Tables S6–S10 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571).

Quality assessment

The risk of bias assessment for each RCT is detailed in Supplementary Figure S16 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571). Given the nature of interventions, all RCTs included were nonblinded but employed adequate methods for participant allocation and objective measurements of clinical outcomes. Six studies were considered to have ‘some concerns’ in bias assessment due to disparities in baseline characteristics[26,33,34] and adherence to interventions[27,31]. All remaining studies were considered to have a ‘low risk’ of bias. It is important to note that given the nonblinded nature of studies, assessment of health literacy through the knowledge endpoint

A **League Table: Knowledge**

App-based							
-0.75 (-2.09; 0.60)	**Educator Guided**						
-1.92 (-3.19; -0.65)	-1.17 (2.44; 0.10)	**Home Based**					
-0.62 (-2.16; 0.92)	0.13 (-1.41; 1.67)	1.30 (-0.12; 2.72)	**Mentoring**				
-3.99 (-5.68; -2.30)	**-3.24 (-4.26; -2.23)**	**-2.07 (-3.70; -0.45)**	**-3.37 (-5.22; -1.53)**	**Multilevel**			
-0.66 (-1.80; 0.49)	0.09 (-1.05; 1.23)	**1.26 (0.35; 2.17)**	-0.04 (-1.24; 1.17)	**3.34 (1.80; 4.87)**	**Patient Guided**		
-0.38 (-1.33; 0.57)	0.37 (-0.58; 1.32)	**1.54 (0.70; 2.38)**	0.24 (-0.97; 1.45)	**3.61 (2.22; 5.01)**	0.28 (-0.35; 0.91)	**Standard Care**	
-1.32 (-3.23; 0.58)	-0.58 (-1.92; 0.77)	0.60 (-1.25; 2.45)	-0.70 (-2.75; 1.34)	**2.67 (0.98; 4.36)**	-0.67 (-2.43; 1.10)	-0.95 (-2.60; 0.70)	**Web-based**

B **Network Plot: Knowledge**

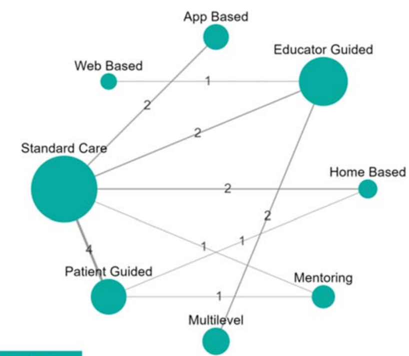

Figure 3. (A) League tables and (B) network plots of knowledge endpoint comparing educational interventions to improve patient access to kidney transplants. League Tables – Educational interventions are arranged alphabetically, displaying standardized mean differences (SMDs) and 95% CIs between the column-defined and row-defined treatments. SMDs greater than 1 favor the treatment defined by the column. Statistically significant results are highlighted in bold. Network Plot – Nodes symbolize the different educational interventions, while edges depict direct comparisons from the included trials. The size of each node reflects the number of patients assigned to that educational method, and the thickness of each edge corresponds to the frequency of direct comparisons between the strategies.

implicates most RCTs would be considered as 'some concerns' for bias assessment. Nonetheless, our quality assessment of studies was primarily driven by the primary clinical outcome of transplantation rates. Funnel plots for the primary outcome showed no visual indication of publication bias (Figure S17, Supplemental Digital Content 3, http://links.lww.com/JS9/D571) or based on Egger's regression test ($P = 0.709$). GRADE assessment of direct, indirect and network evidences is presented on Supplementary Tables 11–13 (Supplemental Digital Content 3, http://links.lww.com/JS9/D571), respectively, where most of the studies were classed as moderate certainty of evidence[22].

Discussion

In this systematic review and meta-analysis of 24 RCTs involving 116 054 transplant-eligible patients with ESKD, we showed that educational interventions can significantly improve access to transplantation. Importantly, 'home-based' approaches were associated with the highest rates of transplantation, evaluation, and inquiry. Other key findings were that 'multilevel' interventions were most effective for improving patients' health literacy, and educator-guided resources, mentoring, and app-based education also showed benefit in improving efficacy for transplantation-related events.

Achieving an optimal balance between the need for patient education and the constraints of time and resources in the healthcare system presents a significant challenge for the management of patients being assessed for transplantation. Consequently, there is substantial variability in the strategies used by transplant assessment clinics and hemodialysis centers to educate patients, and the evolving characteristics of patients and donors call for novel strategies in organ listing and acceptance practices[46]. A previous systematic review evaluating the benefits of interventions aimed at improving health literacy in people with CKD has suggested a potential benefit for the knowledge of patients when educational and self-management strategies are implemented[14]. However, this data was pooled based on limited patient-reported outcomes, with no insights into transplantation practices.

This is the first systematic review and NMA to compare multiple educational approaches for patients with the aim of improving access to transplantation. Given the recent priorities and aspirations established to increase kidney transplantation rates across countries[8], this NMA provides insightful suggestions that home-based and educator-guided programs warrant future research and investment given the likely superior efficacy compared to other approaches. Furthermore, our findings raise the question of whether multicomponent interventions deserve special attention in future trials. Multilevel strategies have been recently advocated to be preferred given that they target diverse stakeholders which may act as barriers in transplantation. Although we have seen maximum benefit for patient's health literacy with the use of multilevel interventions, this has not directly translated into better transplantation-related outcomes. The reasons for this may be diverse, and further studies should explore not only their efficacy across the transplantation process, but also patients' perspectives and struggles[47]. The implementation of these strategies should help both staff and patients to apply the knowledge into decision-making and steps towards transplantation[48].

Moreover, several trials included in our analysis reported struggles with adherence and feasibility of interventions[12,13,26,44], especially multilevel approaches. Our findings highlight that simplifying approaches to educate patients may translate into more favorable clinical outcomes while focusing on the inclusion of patients' families and colleagues in the decision-making process. An individual's behavior, such as engaging in educational

Table 2

P-Scores for each educational strategy and respective endpoints assessed.

Educational strategy	Transplantation	Evaluation	Inquiry	Waitlisting	Knowledge
Educator-guided	0.75	0.71	0.18	**0.72**	0.43
Patient-guided	0.63	0.22	0.09	NA	0.41
Home-based	**0.87**	**0.97**	**0.96**	0.51	0.81
App-based	0.37	NA	0.65	0.40	0.11
Web-based	NA	NA	NA	NA	0.62
Mentoring	0.54	0.54	0.64	0.72	0.38
Financial assistance	0.30	0.15	0.60	NA	NA
Multilevel	0.24	0.61	0.54	0.38	**0.99**
Standard care	0.27	0.29	0.34	0.27	0.24

The strategies with the highest P-score for each endpoint are in bold.

interventions or sharing information about living donation, is influenced by normative beliefs and perceived social norms[49,50]. Findings favoring home-based approaches highlight the significant role family and friends may play in the decision-making process regarding donation and acceptance of LDKTs[51], reinforcing the need to engage with them even if they are not direct donors.

Future trials must include process evaluations to assess the capacity to deliver these interventions without negatively impacting other services[52]. Centers that wish to utilize such strategies, especially technology based, should ensure optimal user interface, detailed guidance to patients and staff who struggle with technology[46,52], and clear action plans to be implemented in busy healthcare environments[47]. Cost-effectiveness evaluations are essential to ensure that effective interventions receive appropriate healthcare funding, and addressing these concerns will help balance the need for effective patient education with the practicalities of resource allocation and cost-effectiveness[53]. Finally, the inclusion of more diverse patient populations assessed in future trials is highly recommended, as this has been limited to patients with selected ethnic backgrounds, income levels, English-reading and writing abilities, and geographical regions.

Our study has important limitations. The nature of the interventions and consequent lack of blinding in the studies reduced the certainty of evidence for our findings, which was moderate, especially for patient-reported outcomes. There were considerable differences across educational strategies and standard-of-care approaches between trials. However, we attempted to mitigate this by classifying interventions differently from individual trials and finding common strategies for patient education to minimize and interpret such heterogeneities. The population sample for app-based strategies was limited, and its findings should be interpreted with caution. Unfortunately, there was a lack of use of endpoints such as mortality or graft-related function across trials, which could have been useful to assess the efficacy of these interventions throughout a patient's management journey. Our analysis combined LDKT and DDKT into an overall outcome due to limited data for separate comparisons, though most studies focused on living donor education. Although supplementary analysis of LDKT inquiries showed significant benefits for educational approaches, future studies should further explore the distinct impacts of educational interventions on DDKT and LDKT, especially considering time-to-transplant for deceased organs. Finally, multiple recent trials were found to be underway and were not included in this NMA as the data was not yet available. As more advanced approaches emerge, updated analyses should be carried out to ensure that optimal measures to improve kidney transplantation access are kept up to date.

In conclusion, this NMA showed that educational interventions can significantly improve access to transplantation, with 'home-based' approaches delivering the greatest improvement in recipient evaluation and transplantation rates. Moreover, patients receiving 'educator-guided strategies' had significant benefits for steps in the process of transplantation over multicomponent interventions or standard care. Knowledge levels were most favored by multilevel interventions, while steps towards transplantation did not differ significantly among other educational strategies. Importantly, these findings primarily derive from the US and developed countries, suggesting that although promising, such strategies should be assessed in a range of geopolitical situations and socioeconomic backgrounds to improve global access to transplantation across multiple healthcare systems.

Ethical approval

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Consent

Not applicable.

Source of funding

Not applicable.

Author contribution

A.G., N.F., and G.K.: wrote the study protocol and designed the statistical analyses; A.G., N.F., and G.K.: assessed the eligibility of studies for inclusion in this analysis; A.G. and A. G.S.: assessed the risk of bias, and performed the study quality assessment; A.G. and M.M.R.M.: had access to, and verified, the underlying data from all original research articles, and conducted statistical analyses; A.G.: wrote the first draft of the report. All authors were involved in data interpretation, manuscript writing, and manuscript editing. U.K.: provided senior supervision. All authors critically revised the report for important intellectual content, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflicts of interest disclosure

The authors declare no conflicts of interest.

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Data availability statement

All data are publicly available in the relevant primary and secondary papers from relevant trials as listed in the references.

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Disclosures

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