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Review article

Trends and outcomes in dual kidney transplantation- A narrative review

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ABSTRACT

Dual kidney transplantation (DKT) is a viable option to increase the donor pool and improve access equity to kidney transplantation. Dual kidneys are procured from carefully selected marginal donors that are not generally acceptable to most transplant centers. This is a narrative review of literature focusing on donor kidney allocation systems and selection of the ideal recipient for DKT. We also discussed surgical approaches for DKTs as well as patient and allograft outcomes. We found that most studies to date showed that DKTs has similar graft survival and delayed graft function rates when compared to single kidney transplants (SKTs). DKT is technically feasible with outcomes that are comparable to expanded criteria donor kidneys (ECD); and has substantial potential in expanding the donor pool. For allograft survival, most studies with strict allocation criteria showed that graft survival was similar in DKT as compared to SKT – ECD transplants.. Our review may encourage transplant centers to review their policies for donor and recipient selection leading to increase in DKT.

Contents

1. Introduction

Kidney transplantation is the modality of choice in patients with end stage renal disease (ESRD) [1,2]. There exists a widening disparity between organ donation and demand for kidneys for transplantation. Various strategies have been employed to overcome this disparity, including the use of expanded criteria donors (ECD) kidneys and implantation of both kidneys to a single recipient from a marginal donor, which would otherwise be discarded. The concept of dual kidney transplantation (DKT) harnesses the advantage of increasing the nephron mass and allowing for a higher glomerular filtration rate (GFR) compared to a single kidney. The disadvantage of transplanting higher nephron mass is an increased antigen load in the recipient [3]. This, along with longer anesthesia and surgery time, may lead to increased risk of post-operative complications.

There have been shifts in trends since the first report of DKT in 1996. This pilot study found that overall survival and graft function were

Abbreviations: DKT, Dual kidney transplantation; SKT, Single kidney transplantation; SCD, Standard criteria donor; ECD, expanded criteria donor; KDPI, Kidney donor profile index; EPTS, Estimated Post-Transplant Survival.

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comparable across DKT, single kidney transplantation (SKT) from donors <50 years and SKT from donors >60 years [4]. Donors over the age of 55 are now commonly accepted for transplantation, resulting in more elderly people in the donor pool. The increase in elderly donors accounts for approximately 20% in the total number of organ donors [5]. These developments can be attributed to better surgical outcomes and concomitant advances in immunosuppression and early detection of rejection.

We believe that DKTs are currently underutilized and this could be due to concerns regarding potential risk of increased postoperative complications [3]. Messina et al. retrospectively analyzed all ECD kidney transplants from a single center in Italy by donor age classes and upon comparison between SKT and DKT, the investigators found no significant difference in graft or recipient survival from donors between 60 and 79 years old; with DKT from donors older than 89 years old actually showing better overall graft survival ($P = .04$) [6]. In another Italian study involving 37 recipients of 1 or 2 histologically evaluated kidneys from donors older than 80 years that were compared with matched reference-recipients who received a single kidney transplant from donors aged 60 or younger, graft survival was similar between groups despite KDPI and KDRI being significantly higher for the octogenarian donors than for young donors of reference-recipients [7]. In the United States, only 625 DKT were performed between 2000 and 2005, which represented a mere 4% of kidney transplants from donors aged 50 years or older [8]. There is an opportunity to increase the donor pool and to reduce discard rates if there was a consensus for DKT allocation.

1.1. Donor allocation system and implications for DKT

The donor criteria used to allocate grafts for DKTs have undergone significant evolution, with some variability across different transplant centers. Early studies defined ECD kidneys as a donor ≥60 year or between ages 50–59 years with 2 out of 3 of the following criteria: cerebrovascular cause of death, hypertension or serum creatinine >1.5 mg/dL [9]. This has since been replaced by the Kidney Donor Risk/Profile Index (KDRI/KDPI) which is a cumulative percentage scale that combines 10 donor factors into a single number that summarizes the potential risk of graft failure after kidney transplant and has been shown to be a more precise quantitation of graft loss compared to the ECD [10,11].

A less-stringent allocation criteria will have the obvious effect of increasing the donor pool size at the expense of good outcomes. On the other hand, a more stringent allocation process that leads to comparable outcomes with SKT may raise the question if these organs could have been used as SKT in the first place. The allocation of kidneys is dependent upon donor and recipient characteristics to include the waiting-list time. These are illustrated through the KDPI as well as the Estimated Post Transplant Survival (EPTS) scoring system that depicts expected post-transplant survival time based on recipient's age, time on dialysis, the presence of diabetes and prior solid organ transplant [2]. Current practice allocates kidneys with a KDPI score of 20% or less to recipients with an EPTS of 20% or less [2]. The EPTS score is only used in kidney allocation when the donor has a KDPI of 20% or less and its tandem use illustrates the concept of longevity matching, in that the patient expected to survive the longest receive a graft that functions the longest. On the opposite end of the spectrum, patients with EPTS score of >20% have poorer survival, and conceptual allocation system for these patients remains an unmet medical need. In a single-center study with a mean follow-up of 43 ± 67 months, Islam et al. found that patient and graft survivals were equivalent between the DKT and SKT cohorts. For DKT, they used either ECD kidneys or kidneys from standard criteria donors that were considered functionally compromised [12]. Over the years, there have been efforts to promulgate a standard allocation criterion for DKT.

1.2. Role of pre-implantation biopsy in decision making

In 1999, Remuzzi et al. described the use of preimplantation biopsy in a prospective pilot study designed to evaluate the short-term outcomes of DKTs [13]. In a retrospective study, Karpinski et al. utilized the calculated donor creatinine clearance and a pre-implantation scoring system based on chronic changes within the glomerular, tubular, interstitial and vascular compartments, each ranging from 0 to 3. The sum of these scores was defined as the global kidney score, which could range from 0 to 12. Kidneys with a global score ranging from 0 to 3 were considered for use as single transplants and those with a score from 4 to 6 for use as DKT; those with a score of 7 or greater were discarded [14]. Remuzzi et al. subsequently showed that protocolized preimplantation biopsy was useful in allocating kidneys for DKT with greatest potential for long-term survival [15]. In an analysis of 97 DKTs in comparison with a SKT control group whose donors were older than 60 years, Impedovo et al. showed that although the mean Remuzzi-Karpinski score for SKT was significantly better than DKT, patient and graft survivals were similar, suggesting that the use of a biopsy to allocate expanded criteria donor kidneys may be too restrictive [16]. Nevertheless, there have been widely disparate results between different transplant centers in the application of the Remuzzi-Karpinski scoring system [15,17].

Gill et al. analyzed DKTs from the United Network for Organ Sharing (UNOS) database and found that the rates of delayed graft function (DGF) were lower compared to single kidney ECD transplants (29.3% vs. 33.6%, $p = .03$). Further, despite the use of organs from higher risk donors, DKT had similar three-year graft survival compared with single kidney ECD transplants (79.8% vs.78.3%, respectively) [8]. In an analysis of UNOS data, Tanriover et al. found: 1) significant overlap in KDPI between utilized DKTs and discarded duals; 2) high discard rates of ECD kidneys at highest KDPI (which could be used for DKT rather than discarding one kidney and using the other as a single ECD transplant); 3) inconsistent application of DKT criteria among centers that perform DKTs; and 4) histopathology was the most common reason for discard despite the lack of evidence-based data to validate this practice [18]. Di Laudo et al. presented an intriguing cohort of patients who underwent combined liver-kidney transplantation vs. those who underwent liver-dual kidney transplantation based on a histological-based algorithm (Remuzzi scoring system) and found no difference in overall survival (91% vs. 100%, respectively, $p > .99$) [19]. In a registry analysis of 287 DKT recipients, where the kidneys used for DKT had been refused as SKTs by local and regional centers, the overall incidence of DGF was 27%; the 1- and 5-year graft survivals were 86% and 69%, respectively. When the patients were grouped on the basis of whether or not they had DGF, the authors found that the only significant difference was the cold ischemia time, 22 ± 9 h (prompt graft function) versus 29 ± 10 h (DGF), $p < .001$) [20].

Preimplantation biopsy; as with kidney biopsy for non-transplant diagnostic indication, has several caveats; with wedge biopsies being superior to the more commonly performed needle core biopsies [21]; although they may underestimate the extent of vascular intimal thickening and overestimate percentage of glomerulosclerosis, drawbacks that may be ameliorated by skin punch biopsies, as reviewed by Naesens [22]., The reliability of pretransplant donor biopsy is also dependent upon whether the specimen was frozen or formalin-fixed. In a retrospective evaluation, Azancot et al. found that donor histology and graft outcome were correlated when the biopsy was evaluated by a renal pathologist who was blinded to the clinical outcome, but not when they were evaluated by on-call pathologists [23]. More recently, a single center study reported that procurement biopsies are poorly reproducible and do not correlate with paraffin-embedded reperfusion biopsies, and are not significantly associated with transplant outcomes [24].

It is noteworthy that pre-analytical and analytical factors influence the value of preimplantation biopsy. In an Italian study as described

by Gandolfini et al., pre-transplant donor biopsies are formalin-fixed and stained with hematoxylin and eosin, periodic acid-Schiff, Masson's trichrome and periodic acid-methenamine Silver and read within 4 h upon arrival by dedicated pathologists at a central laboratory [25].

In addition, a systematic review of studies published between 1994 and 2014 that examined the utility of both procurement and implantation biopsies for predicting posttransplant outcomes ($n = 47$) concluded that the overall data on the value of biopsy in consistently predicting posttransplant outcomes is poor across studies. [21,26].

1.3. Current guidelines for DKT

Current Organ Procurement and Transplantation Network (OPTN)/United Network for Organ Sharing (UNOS) policy dictates that DKTs could only be considered if at least two of the following criteria are met: donor age >60 years, estimated donor creatinine clearance <65 mL/min, rising serum creatinine (>2.5 mg/dL) at time of retrieval, history of longstanding hypertension or diabetes mellitus or adverse donor kidney histology (defined as moderate to severe glomerulosclerosis, > 15% and < 50%) [2]. This policy has been criticized for being ambiguous, out-of-date and failed to identify and allocate dual kidneys in a timely manner thus increasing cold ischemia times. It is expected to undergo revisions with the goal of streamlining the dual kidney allocation process [27].

In 2000, Andres et al. described an allocation criterion that protocolized donor age and degree of glomerulosclerosis. In this study, SKT would be performed if the glomerulosclerosis rate was <15% in kidneys from donors between 60 and 74 years. DKT was performed if donor age was ≥75 years or when the donors between 60 and 74 years had >15% glomerulosclerosis. Based on this protocol, 21 out of 181 patients underwent DKT and there were no significant differences in one-year patient or graft survival rates among patients with DKT vs. those who received single kidney transplants. These findings suggest that DKT provides comparable clinical outcomes, utilizing kidneys from elderly donors (≥ 75 years) or those donors who had >15% glomerulosclerosis [28].

When the 3 allocation criteria (Remuzzi et al., Andres et al., UNOS) were tested in a simulation protocol on a single center database, no improvement in 12-month estimated glomerular filtration rate (eGFR) was observed compared to allocation based on donor eGFR except for the UNOS criteria [29].

Worldwide, there are slight variations in criteria adoption. For example, in Italy, preimplantation is performed in all donors>60 years and eligibility for DKT as described by Remuzzi et al. [15]. In France, DKT is performed if donor age is more 65 years and estimated creatinine clearance is 30–69 ml/min. In Canada, DKT is performed when glomerulosclerosis is between 15 and 50% and terminal creatine is <1.7 mg/dl [30].

The proportion of deceased donors aged above 65 years is above 50% in countries such as Spain [31] and Italy. In comparison, this donor demographic is only 5% in the US. Therefore, the main role of DKT in the US may be to recover kidney from elderly donors (where KDPI >85 is largely driven by old donor age).

1.4. Surgical approaches

Until 1998, when Masson et al. described transplantation of both adult donor kidneys unilaterally (monolateral or ipsilateral) into the same iliac fossa, most DKTs were performed bilaterally, described by Lee et al. [32]. It is noteworthy, however, that transplantation of both kidneys en-bloc using the donor aorta and vena cava in instances when both donor kidneys were small with minimal aortic atherosclerosis have also been described [33].

The unilateral approach was devised with the notion that a single incision would reduce surgical trauma and thus facilitate postoperative recovery, with the additional advantage of leaving the contralateral iliac fossa intact for further transplantation in the event of graft failure [34]. However, this approach is not without its own risk profile, such as the need for more extensive vessel dissection and a higher risk of renal vein thrombosis due to compression by two kidneys. Nevertheless, a survey of existing literature (Table 1), implies that the unilateral approach is an increasingly favored option over the bilateral approach [35]. Ekser et al. retrospectively compared the outcomes between the two surgical approaches in a single center study and found significant reduction in operating time and cold ischemia time using the unilateral approach [36].

With the unilateral approach firmly entrenched in many transplant centers, variations of the method have been described in recognition of the increased vascular calcifications that DKT candidates usually have. Indeed, some have recommended that a pre-operative abdominal computed tomography scan be performed in DKT recipients [3]. Veroux et al. described a joined monolateral DKT where the procured kidneys were joined at the bench at the inferior vena cava above and below the opening of the renal vein. This technique was used in 10 patients and was found to reduce cold ischemia time and surgical trauma [37]. Haider et al. described 11 DKT patients whose grafts were implanted in the extraperitoneal space via a lower abdominal midline incision. The authors found this approach to afford less graft mobility and easier access to the iliac vessels than the transabdominal approach with resultant less postoperative bowel ileus and no adhesion complications. However, higher amount of drain output was also noted [38]. Salifu et al. described a single center experience of 300 deceased kidney donor transplants that included 44 DKTs. In this report, an ipsilateral retroperitoneal approach was employed for all DKTs [39]. The use of robot-assisted surgery is promising and may further decrease surgical morbidity, immobilization, and time to recovery, as described in a case report where both grafts were introduced through a single upper midline incision [40].

Despite apparent theoretical differences between the various surgical approaches, surgical outcomes are heavily operator-dependent and randomized trials to compare techniques are nearly impossible to perform (Fig. 1). Cocco et al. reviewed 15 reports of DKT surgical techniques involving 434 DKT and compared three techniques: bilateral placement, unilateral placement with separate anastomoses, and unilateral placement with patch anastomoses. Graft and patient survival were found to be comparable across all 3 techniques. However, the investigators also iterated analyses pitfalls such as missing data and lack of consistent outcome reporting [41].

Table 1
Summary of studies examining surgical approaches.

Studies	Design	Outcomes
[24]	Retrospective analysis of 150 unilateral vs 50 bilateral approaches	No significant difference between groups in terms of renal vein thrombosis, wound dehiscence, lymphocele, hematoma, incisional hernia, stenosis of ureteroneocystoanastomoses
[25]	Retrospective comparison of bilateral and monolateral approaches	DGF was recorded in 15 (52%) patients in group I and three (10%) patients in group II, lasting 11.0 ± 7.9 and 6.0 ± 1.0 days respectively
[42]	Retrospective analysis of DKT compared with SKT	DGF rate was not significantly different between the two groups, the duration of DGF was longer the SKT group. Incidence of acute rejection, steroid-resistant acute rejection, and hospital stay with or without DGF, were comparable between the two groups. DKT recipients required more blood transfusions in comparison to SKT recipients. Incidence of surgical complications was not significantly different between the two groups

DGF; Delayed graft function, DKT; Dual kidney transplantation, SKT; single kidney transplantations.

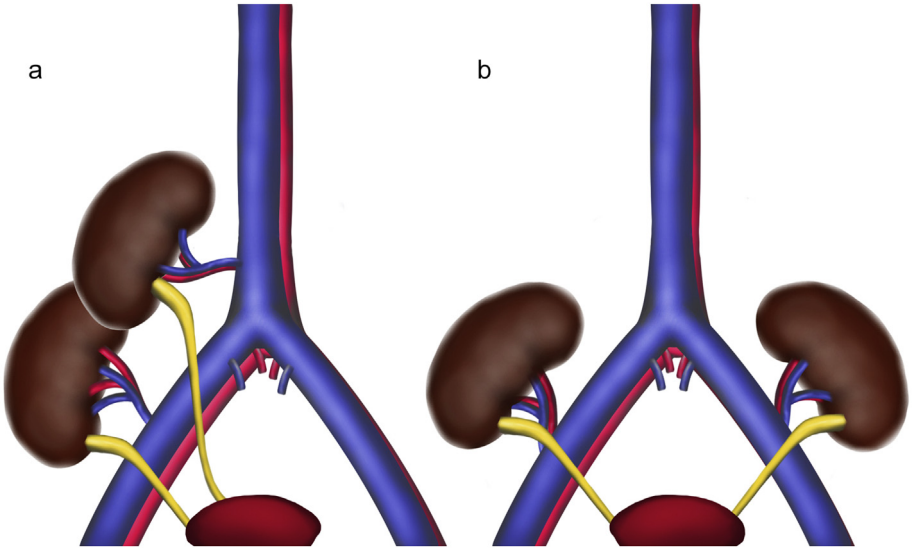

Fig. 1. Surgical approaches in DKT.

1.5. Renal allograft and patient outcomes

Table 2 represents summaries of studies of DKT with outcomes. Johnson et al. published the first report of dual kidneys transplanted into nine adult recipients [4]. The same investigators subsequently reported that the DUAL policy has significantly increased the utilization of older donor kidneys (actual number of kidneys transplanted = 52 vs hypothetical number of kidneys transplanted without a policy of DUAL transplantation: $n = 36$, $P = .01$). The actuarial 1-year graft survival rate of the dual kidneys was 100% with mean follow –up of 11.1 ± 2.9 months. Mean 6-months and 1-year serum creatinine levels were 1.76 ± 0.4 and 1.63 ± 0.6 mg /dl respectively [42].

Bunnapradist et al. using UNOS database compared the outcomes of 403 DKT to single kidney transplantations from 1997 to 2000 and reported a 7% lower graft survival rate at one year and a 15% lower graft survival at 3 years in DKT patients compared with SKT patients. However, DKT resulted in similar graft survival outcomes when compared with SKT with donor age over 55 years [43]. Gill et al. using UNOS/OPTN data from 2000 to 2005 compared the outcomes in DKT vs SKT ECD from donors aged >50 years and found similar three-year allograft survival (79.8% vs 78.3%, $p = .77$) [8]. In a single center study of DKT with a longer follow-up period of 56 months, patient or graft survival was similar in DKT vs ECD vs standard criteria donor (SCD) recipients [44].

Remuzzi et al. in a prospective study of 54 DKT and donor >60-year-old with preimplantation biopsy had similar graft outcomes as compared to SKT who did not undergo preimplantation biopsy [15]. In another prospective study, 81 DKTs were compared to 70 SKT-ECD donors aged >65 years; patient and graft survival were similar in the two groups [29].

Using Scientific Registry of Transplant Recipients (SRTR) data, Klair et al. examined outcomes of SKT and DKT stratified by KDRI and observed that DKT of kidneys with KDRI >2.2 was associated with significantly better overall graft survival compared to single kidneys with KDRI >2.2 [45]. Tanirover et al. using OPTN/UNOS data reported that kidneys with KDPI>90% were associated with increased odds of discard and emphasized the potential to improve the DKT policy and minimize discard rates. DKT from KDPI >90% were associated with lower graft failure (HR = 0.74, 95% CI 0.62–0.89) and better patient survival (HR = 0.79, 95% CI 0.64–0.98) compared to single ECD kidneys with KDPI>90% [18]. Hanf et al. reported for the first time four DKT from donation after circulatory death (DCD) donors with 100% graft survival at 1 year [46]. In a United Kingdom based single center study, outcome for DKT ($n = 12$) as compared to SKT ($n = 43$) from DCD donors over 70 years old, using preimplantation biopsy, showed comparable death-censored graft survival at 3 years. Also, the rate of DGF was lower in the DKT group as compared to SKT (25% vs 65%) [47]. Salifu et al. in a single center retrospective study of primarily African American recipients reported similar renal allograft survival and patient survival in SCD, ECD and DKT kidneys [39]. However, using UNOS data, Bunnapradist et al. reported a greater percentage of African-American recipients and donors in the DKT group. Using multivariate analysis, the investigators found that re-transplantation, recipient age, graft from diabetic donors, and African-American recipient were risk factors for graft loss in DKTs, with re-transplantation presenting as the strongest risk [43]. Taken together, this observation may be a reflection of known risk factors for allograft rejection in general and should be interpreted with caution before precluding use of DKT in African Americans.

For allograft survival, most studies with strict allocation criteria showed that graft survival was similar in DKT as compared to SKT ECD transplants [8,16,20,25,29,45,48–50]. Two studies showed better allograft survival in DKT as compared to SKT ECD [18,44]. Patient survival was also similar in studies comparing DKT to SKT ECD [17,18,20,25,45,48]. Two studies showed better patient survival in DKT compared to SKT ECD [32,51].

1.6. Delayed graft function

Andres et al. found lower rates of DGF in DKT ($n = 21$) compared to SKT ECD (24% vs. 57%, respectively) [28]. Gill et al. in a study using OPTN/UNOS data from 2000 to 2005, showed significantly lower rates of DGF in 625 DKT as compared to SKT ECD transplants (29.3% vs. 33.6%, $p = .03$) [8]. These authors postulated that the general increased risk of DGF attributed to longer cold ischemic time in DKT is offset by an increase in the transplanted nephron mass. Lower rates of DGF in DKT as compared to SKT ECD were also reported in other studies [15,29,48]. Gandolfini et al. showed similar rates of DGF as compared to SKT ECD kidneys [25]. Klair et al. and Tanirover et al. evaluated outcomes of SKT and DKT stratified by KDRI and KDPI respectively and showed similar rates of DGF in DKT and SKT [18,45]. In conclusion, most studies showed either lower or comparable rates of DGF in DKT as compared to SKT ECD transplants.

A limitation in our review is the lack of reported outcomes of DKT recipients who experienced graft loss and if they needed to be placed

Table 2
Summary of studies involving DKTs.

Reference	Design	N	Donor criteria for DKT		Outcomes		
				Preimplantation biopsy (Y/N)	Delayed graft function	Graft and patient survival	Complications
[12]	Prospective cohort of DKT with preimplantation biopsy against matched SKT controls without preimplantation biopsy	62	Donors age > 60 years and underwent biopsy: ranging from 0 to 3. Kidneys with a global score ranging from 0 to 3➔ SKT 4–6 ➔ DKT >7➔ discard	Y		Graft survival at three years similar to that among SKT <60 years and was 21% greater compared to SKTs >60 years	
[13]	Retrospective	97	UNOS criteria plus prolonged cold ischemia times or a history of drug abuse regardless of age	Y	Delayed graft function in 127 (33.5%) 39 (40.2%) 0.5	No significant difference in graft or patient survival between the two groups, although SKT 60 years showed a mean Karpinski score considerably lower than that for DKT.	1 patient underwent monolateral transplant nephrectomy secondary to an abscess near the right graft and 2, dual transplant nephrectomies due to massive iliac vessel thrombosis
[19]	Analysis of planned protocol comparing 3 groups: DKT (I), SKT from 60- to 74-year old donors (II) and SKT from <60-year-old donors (III)	21	Donor age > 75 years or when the donors between 60 and 74 years old with a glomerulosclerosis rate > 15%.	Y	Significant differences in creatinine level between groups I and II (1.6±0.3 vs. 1.9±0.6 mg/dl, P < .05), II and III (1.9±0.6 vs. 1.4±0.4 mg/dl, P < .001), and I and III ($P < .05$). No statistical difference in primary graft failure in the three groups. Significantly greater percentage of patients from group I (76%) presented immediate renal graft function as compared with group II and III.	No significant differences between the different groups for 1-year actuarial patient survival (100, 95, and 98%, respectively) or graft survival rates (95, 90, and 93%, respectively).	
[20]	Prospective	80	Donors aged >65 years, with either: hypertension, diabetes mellitus, atherosclerotic disease or death from a cardiovascular cause. eGFR between 30 and 60 mL/min.	Y	Incidence of DGF was significantly lower in the DKT group	Patient and graft survival were similar in the two groups at 3 months, 1, 2 and 3 years	Except for vascular thrombosis, the incidence of other complications was similar between the two groups.
[22]	Retrospective database analysis comparing outcomes in recipients of dual ECD kidneys with single younger kidneys (control) and single ECD kidneys.	50	Severe donor instability, a long history of hypertension, or creatinine clearance was 1.50 mL/s (90 mL/min	N	No significant difference in delayed graft function	The mean number of rejections per patient was significantly lower in DKT vs SKT.	No difference in the number of technical complications. But recipients of dual kidneys had significantly more overall complications vs recipients of single control kidneys
[24]	Retrospective analysis	200	Donors ≥70-year-old, or > 60 with: creatinine clearance ≤60 mL/min; hypertension treated with at least two drugs; proteinuria, diabetes mellitus type 1 or history of cardiovascular complications	Y	DGF was reported in 63 patients (31.5%) and lasted a median five (3–9) days	The 5-year patient survival rate was significantly lower in the ECD-SKT group (82%, p = .04), and significantly higher in the Standard-SKT group (96%, p = .03) than in the DKT group	The most frequent complications were lymphocele requiring laparoscopic treatment with intraperitoneal drainage (11 patients)
[33]	Single center retrospective analyses with ECD SKT and ideal donor SKTs as control groups	63	All donors younger than 75 years refused by all centers for single transplantation, and kidneys from donors aged 75 years or older	Y	DGF and initial length of hospitalization were similar between DKT and ECD	After a median follow-up of 56 months, patient survival was similar between the groups. Graft survival was not significantly different between groups	The surgery for DKT was longer than for ECD, higher transfusion rate The proportion of renal endarterectomy for DKT was comparable with ECD. No difference between groups for wound-related and urologic complications. There was a nonstatistically significant but 2-fold increase in graft thrombosis in DKT
[40]	Retrospective analysis	28	Donor age > 55 years, or	Y (54%of DKT)	Differences in primary	No significant difference	

Table 2 (*continued*)

Reference	Design	N	Donor criteria for DKT	Preimplantation biopsy (Y/N)	Outcomes		
					Delayed graft function	Graft and patient survival	Complications
	with SKT as control group		had diabetes mellitus, hypertension, >15% glomerulosclerosis, increasing creatinine or intrinsic renal parenchymal disease.		nonfunction (1 group 1 versus 5 group 2 patients) and delayed graft function (6 versus 7) were not statistically significant	between groups in 1 and 2-year graft survival rates	
[43]	Retrospective comparison between DKT and SKT	41	calculated donor admission creatinine clearance <90 mL/min and the donor age > 60 years, or if the donor had an elevated terminal serum creatinine	N	No significant difference in delayed graft function and 3-month posttransplant creatinine clearance	No significant difference in one-year patient and graft survival (97% and 90%, respectively for SKT; 98% and 89% for DKT)	
[44]	Retrospective case-control study	40	Donor age > 60 and biopsy score > 5 or age > 75 with biopsy score ≤ 6. All donor-recipient age difference < 20 years	Y	No difference in graft survival between groups (90% at 3 years)	no differences between groups with regard to glomerular filtration rate or proteinuria. DKT recipients achieved better creatinine clearance	2 DKT patients each lost 1 kidney due to thrombosis and ureteral necrosis

DKT; dual kidney transplantation, SKT; Single kidney transplantation, UNOS; United network for organ sharing,
DGF; Delayed graft function.

back on hemodialysis. We acknowledge this insight will be important in crafting patient selection criteria going forward.

In this narrative review, our interpretation of the current data indicates that DKT is a feasible and efficient procedure that expands the donor pool and decrease discard rates of marginal kidneys without significant adverse impact on graft function. A recent work that examined this issue was a meta-analysis that did not yield any randomized controlled trials. Subsequent analysis of observational data from which the evidence base was described as weak, the investigators did not find differences in graft survival or patient survival, except for 5-year patient survival in DKT recipients and a slightly better 1-year graft function [52].

2. Conclusion

Careful donor selection is crucial and prospective data in examining current practices remains an unmet medical need. Existing studies that compared unilateral and bilateral surgical approaches have shown that these two surgical techniques have comparable outcomes. Advancements such as robotic-assisted techniques will need to be assessed further in clinical studies.

Conflict of interest

None reported by all authors.

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