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ORIGINAL ARTICLE

Vascular access for chronic hemodialysis in children: arteriovenous fistula or central venous catheter?

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Abstract
Background The choice of vascular access (VA) for hemodialysis (HD) in end-stage renal disease (ESRD) is arteriovenous fistula (AVF) or central venous catheter (CVC). Whereas clinical practice guidelines suggest AVF to preserve the vascular bed, pediatric nephrologists tend to favor CVC for shorter-term dialysis. Our objective was to determine whether pediatric priority allocation policies for deceased-donor kidneys affect VA planning.
Methods Pediatric priority for deceased-donor kidneys was instituted in Quebec in 2004. We retrospectively compared clinical practice on AVF, CVC, wait time on transplant list, HD duration in pre-policy (group A) and post-policy (group B) from 1997–2011.
Results We identified 78 patients with a median age of 14.7 years (range, 0.7–20.5 years) and weight of 46 kg (12.5–95 kg); AVF decreased from 76 % in group A to 41 % in group B (p=0.002). Wait times on transplant list were significantly reduced: median 413.5 days (range, 2–1,910 days) in group A vs. 89 days (range, 18–692 days) in group B (p=0.003). Time on HD for deceased-donor recipients was shorter: 705 (range, 51–1,965 days) group A vs. 349.5 days (range, 158–1,060 days) group B (p=0.01).
Conclusions This is the first study to document VA changes related to pediatric priority allocation policy. Our fistula-first center saw a shift toward CVC-first.

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Introduction

Transplantation is the renal replacement therapy of choice for children with end-stage renal disease (ESRD) [1]. The most commonly used modality while awaiting a kidney transplant is hemodialysis, rather than peritoneal dialysis, according to the United States Renal Data System [2, 3]. As per European and North American guidelines for pediatric ESRD, early planning is recommended if patients are not anticipated to undergo peritoneal dialysis or receive a transplant within 6 months. Patients are referred to a vascular surgeon, where the choice of appropriate vascular access (VA) for hemodialysis, whether arteriovenous fistula (AVF) or central venous catheter (CVC), becomes crucial [4–8].

Benefits of AVF vs. CVC include lower rates of infection and thrombosis, superior dialysis adequacy, greater freedom for activities such as bathing and swimming, and longevity of access site. Disadvantages are delays in maturation (up to 2–6 months), needle pain, arm immobilization during hemodialysis, and risk of dysfunction with eventual compromise of the vascular network. Advantages of CVC include immediate delay-free access, needle-free dialysis, and greater freedom of movement during dialysis. Disadvantages are high infection rates, dysfunction, poor flow, damage to VA, stenosis, and thrombosis [9]. In adults as well as in children, the National Kidney Foundation - Kidney Disease Outcomes Quality Initiative (NKF-KDOQI) clinical practice guidelines [10] and other initiatives [11] have promoted AVF over CVC, as AVF has been associated with a better quality of life and improved outcomes. Nonetheless, in practice, pediatric nephrologists

still favor CVCs for shorter-term dialysis, resulting in increased morbidity when used longer term [12].

Priority allocation policies [13] for deceased-donor kidneys have been set up in various countries to minimize time on dialysis for children, as long-term dialysis may lead to both growth and neurodevelopmental delays. With expected wait times and corresponding dialysis durations potentially shortened, there may likely be a shift toward CVCs and away from AVFs. To date, no studies have reported on the impact of pediatric priority allocation policies on the choice of VA for hemodialysis. In Quebec, Canada, the priority allocation policy changed in 2004. Previously, pediatric patients aged less than 18 years at the time of listing were given priority for a deceased-donor kidney only if a potential pediatric recipient and adult recipient had equal HLA matching. After August 1, 2004, priority for one kidney from all deceased donors aged 5–45 years was given to ABO-compatible pediatric patients with a negative crossmatch, regardless of HLA matching or wait time on the list. Our objective was to determine whether the new pediatric priority allocation policy affected clinical practice in VA planning and to what extent it changed the choice from AVF to CVC.

Methods

Participants and study design

We conducted a 14-year retrospective chart review of all pediatric patients started on chronic hemodialysis from 1997 to 2011 at Sainte Justine Hospital (CHU Sainte-Justine) in Montreal, Quebec, Canada. Data were extracted from a local database registry containing information on all consecutive patients in the hemodialysis program, including demographics, VA type, listing for renal transplant, and wait time to transplant. The study was approved by the Sainte-Justine Research Ethics Board.

Sainte-Justine is a tertiary care pediatric teaching hospital affiliated with the University of Montreal and a major referral center for Quebec. Since 1971, our pediatric dialysis and renal transplantation program has treated 339 patients on hemodialysis and 111 patients on peritoneal dialysis and performed 321 kidney transplants [14]. In 2000, a chronic kidney disease and predialysis clinic was added to the program; the clinic has followed 150 patients to date [15]. The program is staffed by a dedicated vascular and transplant surgeon and a multidisciplinary team including nephrologists, renal nurses, psychologist, social worker, and dietician.

We reported on the first chronic VA used for initiating hemodialysis. The choice of VA is determined for each patient after discussion with the family and multidisciplinary team with a view to long-term preservation of the vascular network. Whenever possible, the transition from chronic kidney disease care to ESRD care is facilitated with parents and patients educated early on, transplant candidates listed, pre-emptive renal transplant promoted, living kidney donors identified, and orchestration between recipients and donor teams, all coincident with VA creation.

The study was divided into two periods, corresponding to the change in Quebec pediatric priority allocation policy: group A, January 1, 1997 to August 1, 2004; and group B, August 2, 2004 to December 31, 2011. Participants were allocated to group A or group B based on date of first chronic hemodialysis. Since 1997, all VA procedures have been performed by the same vascular and transplant surgeon.

Statistical analysis

Descriptive analysis was used for information on demographic data and first VA. Statistics were calculated for median range and frequency. We used Student's t test, Chi-square tests, and nonparametric Mann–Whitney test for comparison between groups. p values <0.05 were considered statistically significant. Statistical analysis was performed using SPSS, version 19 (IBM Corp, Armonk, NY, USA).

Results

Participants

We identified 78 children and adolescents with ESRD on chronic hemodialysis (41 initiated in period A and 37 in period B) (Table 1). The median age was 14.7 years (range, 0.7–20.5 years) and median weight was 46 kg (range, 12.5–95 kg). Most (62 %) patients were boys. ESRD was predominantly due to uropathy (32 %). There were no significant differences between group A and B. In our experience, 111 patients received treatment with peritoneal dialysis; of these, almost half ($n=59$) were included in the database as they were also on the hemodialysis program. When comparing period A and period B, there was a statistically lower peritoneal dialysis use before transferal to hemodialysis between the two eras, with 17.9 % of patients on PD after 2004 versus 45.2 % on PD before 2004 ($p=0.025$).

Vascular access

Of the 78 patients in our cohort, 46 (59 %) had an AVF and 32 (41 %) had a CVC (Table 2). The choice of VA changed significantly once the new priority allocation policy came into effect; AVF decreased from 76 % of patients to 41 % ($p=0.002$). We observed a similar pattern when analyzing deceased-donor transplant recipients alone; AVF decreased from 83 to 40 % of patients ($p=0.002$). Only two of the nine

Table 1 Participant characteristics

	Total (n=78)	Group A, Jan 1, 1997 to Aug 1, 2004 (n=41)	Group B, Aug 2, 2004 to Dec 31, 2011 (n=37)	p value
Gender, male	49 (62 %)	24 (58 %)	25 (67 %)	0.41
Age (years)				
Median (min, max)	14.7 (0.7–20.5)	14.7 (0.7–20.2)	13.7 (1.5–20.5)	0.49
Weight (kg)				
Median (min, max)	46 (12–95)	44.5 (12–79)	46 (13–95)	0.75
Cause of end-stage renal disease				
Uropathy	25 (32 %)	11 (27 %)	14 (38 %)	0.83
Glomerulopathy	19 (24 %)	10 (24 %)	9 (24 %)	
Hereditary nephritis	20 (26 %)	11 (27 %)	9 (24 %)	
Various	9 (12 %)	6 (15 %)	3 (8 %)	
Unknown	5 (6 %)	3 (7 %)	2 (5 %)	

living donor recipients (22 %) received an AVF. Also, we analyzed VA breakdown based on weight during period A and B with a cut-off of 12.5 kg for the creation of an AVF in our hospital (Fig. 1).

Living vs. deceased-donor transplants

Kidney transplants were obtained for all the patients in our unit, except for the 18 adolescents who were transferred to adult care and one child who died after 3 months on hemodialysis. Most (85 %) of the 59 transplant recipients received a deceased-donor kidney: 30/31 (97 %) in Group A, and 20/28 (71 %) in Group B (Table 2). Of the 9 living donor transplants, 8 were performed in Group B. Fisher's exact test demonstrated a significant difference in outcomes between Group A and B (deceased-donor transplant, living donor transplant, transferred, deceased), with more living donor transplants in Group B (P=0.025).

Patients who received a deceased-donor transplant were not significantly different in age and weight in Group B as compared to Group A (Table 2). Living donor recipients were difficult to compare as there were so few.

Wait times and hemodialysis duration

Delay to list was determined from the date of first hemodialysis. Patients were sometimes registered onto the transplant list before that date, in which case negative values were reported. During the study period, the median time to be listed from hemodialysis initiation was 178 days (range, −363 to 793 days) with no statistically significant difference between groups (102 days (−363 to 793) for group A and 275 days (range, −63 to 507) for group B; p=0.06).

The wait time once registered on the transplant list for a deceased-donor kidney was significantly reduced in group B, a median of 89 days (range, 18–692 days) as compared to 413.5 days (range, 2–1,910 days) in group A; p=0.003. Hemodialysis duration for deceased-donor recipients was significantly shorter in group B as well (349.5 days (range, 158–1,060) vs. 705 (range, 51–1,965) in group A; p=0.001). There were no statistically significant differences between groups A and B when considering AVF alone or CVC alone (Table 2). However, when comparing duration of hemodialysis in group B, patients who received a CVC tended to spend less time on hemodialysis than those with an AVF (median time of 294.5 days (range, 158–1,060 days) vs. 547 days (range, 324–1,018 days, respectively; p=0.06).

When analyzed all 59 patients who ultimately received a renal transplant in our unit, regardless of whether they obtained a deceased-donor or living donor transplant, the median duration of hemodialysis was significantly shorter in group B (median time of 330.5 days (range, 60–1,060 days) as compared to group A (median time of 685 days (51–1,965 days) (p=0.003).

Discussion

In this 14-year retrospective cohort study of children and adolescents with ESRD, we found that the pediatric priority allocation policy instituted in August 2004 did indeed affect the choice of hemodialysis VA. Patients initiated on hemodialysis after the new policy came into effect were more likely than previously to have a CVC as opposed to an AVF (CVC: AVF ratio 60:40 as compared to 25:75 previously). Hemodialysis duration, as envisioned by the policy change, shortened considerably. Also, there were more living donor transplants in the period following the policy change than before.

Renal transplantation remains the treatment of choice for pediatric patients with ESRD to avoid increased morbidity (including developmental and growth delays) and mortality

Table 2 Patient outcomes

	Total (n=78)	Group A, Jan 1, 1997 to Aug 1, 2004 (n=41)	Group B, Aug 2, 2004 to Dec 31, 2011 (n=37)	p value
Vascular access for hemodialysis – no. (%)				
Arteriovenous fistula	46 (59 %)	31 (76 %)	15 (41 %)	0.002
Central venous catheter	32 (41 %)	10 (24 %)	22 (59 %)	
Deceased-donor transplant	50 (64 %)	30 (73 %)	20 (54 %)	0.025
Living donor transplant	9 (12 %)	1 (2 %)	8 (22 %)	
Transferred before transplant	18 (23 %)	9 (22 %)	9 (24 %)	
Deceased	1 (1 %)	1 (2 %)	0	
Deceased-donor transplant recipients	(n=50)	(n=30)	(n=20)	
Age, years – median (min, max)	13.0 (0.7–17.5)	13.7 (0.7–17.5)	12.5 (1.5–17)	0.44
Weight, kg–median (min, max)	45 (12.5–79)	47 (12.5–79)	42.5 (13–75)	0.75
Vascular access for hemodialysis – no. (%)				
Arteriovenous fistula	33 (66 %)	25 (83 %)	8 (40 %)	0.002
Central venous catheter	17 (34 %)	5 (17 %)	12 (60 %)	
Delay to list, days – median (min, max)	178 (−363, 793)	102 (−363, 793)	275.5 (−63, 507)	0.06
Wait time on transplant list, days				
Median (min, max)	253 (2, 1,910)	413.5 (2, 1,910)	89 (18, 692)	0.003
Hemodialysis duration, days – median (min, max)				
Regardless of venous access type	539 (51–1,965)	705 (51–1,965)	349.5 (158–1,060)	0.01
Arteriovenous fistula	567 (98–1,901)	685 (98–1,901)	547 (324–1,018)	0.27
Central venous catheter	336 (51–1,965)	881 (51–1,965)	294.5 (158–1,060)	0.22
Living-donor transplant recipients	(n=9)	(n=1)	(n=8)	
Age, years – median (min, max)	15.4 (4.6–19.1)	15.4	13.3 (4.6–19.1)	
Weight, kg – median (min, max)	41 (23–65)	46	40.5 (23–65)	
Vascular access for hemodialysis – no. (%)				
Arteriovenous fistula	2	1	1	0.22
Central venous catheter	7	0	7	
Hemodialysis duration, days – median (min, max)				
Regardless of venous access type	216 (60–763)	216	283 (60–763)	
Arteriovenous fistula	435 (216–654)	216	654	
Central venous catheter	208 (60–763)	0	208 (60–763)	
Hemodialysis duration list, days in all donors recipients	(n=59)	(n=31)	(n=28)	
Regardless of venous access type	482 (51–1,965)	685 (51–1,965)	346 (60–1,060)	0.006
Arteriovenous fistula	567 (98–1,901)	626 (98–1,901)	558 (324–1,965)	0.39
Central venous catheter	328 (51–1,965)	881 (51–1,965)	269 (60–1,060)	0.17

associated with dialysis [1, 16–18]. In 1997, North American Pediatric Renal Registries reported that in the last decade, 78 % of pediatric patients with ESRD received a renal transplant, while 22–32 % were on chronic dialysis, two-thirds of these on hemodialysis [10]. In our center, all children received a kidney transplant (except for one who died and older adolescents transferred to adult care institutions).

We observed that during the study period, 59 % of our ESRD patients initiated on hemodialysis while awaiting transplantation had an AVF. This is consistent with our vision of a fistula-first center, with 76 % of our patients initiated on AVF in the period before the policy change. However, after the policy change, this figure dropped to 41 %. Literature on VA is sparse, due to the low prevalence of ESRD in children [19], with 7.5–13.0 incident cases per million population in Canada [20]. The North American Pediatric Renal Transplant Cooperative Study (NAPRTCS) data registry [21] reported that 79 % of patients received a CVC, 12.5 % an AVF, and 8.5 % an arteriovenous graft. In some cases, CVC remains the best option, since pediatric priority allocation policies and the possibility of available living donors in the family allow children to be transplanted sooner than adults, with consequently shorter dialysis durations. However, in some cases, the short period is not so short, as illustrated by Fadrowski's

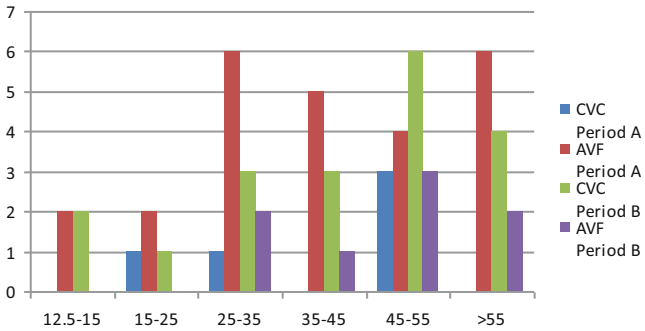

Fig. 1 Vascular access type and weight in period A and B

retrospective cohort study of 2001–2003 ESRD Clinical Performance Measures Projects included in the US Renal Data System transplant files [4, 22]. Of 1,284 pediatric patients identified in that study, 41 % had an AVF or arteriovenous graft, while 59 % had a CVC. Of the CVC patients, only 32.2 % underwent transplantation within 1 year, indicating the need to perhaps re-evaluate (viz. decrease) the administration of CVCs in light of the difficulty of predicting dialysis duration [4].

International variations on allocation policy, type of renal transplantation and waiting time exist among centers. Living donor transplantation is for example highly variable in European countries, from less than 10 % in France to 80 % in Scandinavia with a median of 43 % [23]. In some centers, the fact that children will get a favorable status while they are young will save family kidneys for later. In our hospital, we tend to favour the living donation for the first pediatric kidney transplantation and both the pediatric donor deceased policy and the living donation programs are discussed to facilitate access to renal transplantation at the pediatric age.

Pediatric priority allocation policies [13, 23–25] have resulted also in reduced overall wait times for a new kidney in many pediatric transplant centers across Europe (median waiting time of 11 months [23, 26]) and in US and Canada [27–29], including Quebec [30]. Consistent with these findings, we observed a median wait time on the transplant list shortened to only 89 days (with a range of up to 2 years) in the post-policy period from a median of 414 days (ranging to as long as 5 years) in the pre-policy period. The delay to list was quite variable, but statistical analysis indicated a trend to longer delays in the post-policy period, perhaps consistent with an expectation of shorter wait times. In those who received deceased-donor transplants, the median duration of hemodialysis was indeed reduced in the post-policy period, corresponding to shorter wait times on the transplant list: from 705 days in group A to 350 in group B, regardless of access type, and from 881 days to 295 days for those administered a CVC. However, it is noteworthy that this is still a median of over 9 months for those on CVC, a fairly long time. For those on AVF, the average hemodialysis duration changed only from a median of 685 to 547 days, a non-significant result confirming the appropriateness of having administered an AVF in these cases.

The choice of AVF vs. CVC is a complex issue [8]. While early planning for AVF is recommended for patients over 20 kg, a safe and lasting AVF is generally difficult to obtain in young children because of small vessels, except in specialized centers where AVF is possible even in babies weighing less than 10 kg [5, 31]. In our cohort, the age at first hemodialysis varied considerably, from infants to young adults, with a median age around 14 years (no significant differences between the two periods). Further, risk factors that affect VA development and longevity are also variable. The choice of VA is therefore individualized for each patient. Complicating clinical decision-making is the fact that the existing literature is hampered by small sample sizes or small centers, use of peritoneal dialysis, use of pre-emptive renal transplantation, and technical difficulties related to blood vessel sizes in children and availability of a vascular surgeon. To assist clinicians in the decision-making process, perhaps further research might be conducted with multisite studies to elucidate subgroups, risk factors and biomarkers, now that we have documented for the first time a crucial change in clinical practice influenced by clinicians' expectations of shorter wait times until transplantation. Importantly, it would be interesting to compare complications and vascular outcomes resulting from each of the two procedures, in a larger multisite study.

There were several limitations inherent in this study. For one, the reference date for this intent-to-treat analysis was the date of first hemodialysis, as the only available date consistent for all cases. However, the choice of VA type would have occurred sometime earlier, to allow for maturation time of the fistula. This should not, however, affect the validity of our results; if anything, there would have been even more CVCs in group B if decision-making was done at the cut-off date and influenced by expectations of shorter wait times. Hence, our findings are conservative. The second limitation of this study was its single-center aspect. The advantage of our single-center design, however, reflecting procedures and decision-making by the same vascular and transplant surgeon throughout, is standardization and consistency of findings between the two periods. Further, as our center is a major referral center for Quebec, we would have captured a large number of the ESRD cases occurring during the study time frame. The third limitation is that small subgroup sample sizes and large variations precluded further subgroup analysis, but ESRD is a rare condition in children, and we sampled a wide coverage in Quebec over a 14-year time span.

To summarize, this 14-year retrospective study is the first to document and analyze the choice of VA following a change in pediatric kidney transplantation priority allocation policy. We observed a change in clinical practice: for hemodialysis patients awaiting renal transplantation, our fistula-first center

saw a shift toward a CVC-first center. For the medical team, shorter expected wait times implied a more flexible approach to VA placement in children with ESRD.

Choice of VA represents a challenge in the organization of care for these patients, from determining how long the patient will be receiving hemodialysis, to choosing the type of VA best suited to preserve the vascular bed, while avoiding AVF if short dialysis durations are envisaged. In our experience, we conclude that despite the policy change, which has shortened hemodialysis duration time considerably, the median duration on hemodialysis is still too long and AVF should still be first choice of VA in children with ESRD.

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