A national study of autogenous arteriovenous access use and patency in a contemporary hemodialysis population

Sokratis Stoumpos[1,2], Jamie P Traynor[2], Wendy Metcalfe[3], Ram Kasthuri[4], Karen Stevenson[2], Patrick B Mark[1,2], David B Kingsmore[2], Peter C Thomson[2]

1. Institute of Cardiovascular and Medical Sciences, BHF Glasgow Cardiovascular Research Centre, University of Glasgow, Glasgow, UK
2. Renal and Transplant Unit, Queen Elizabeth University Hospital, Glasgow, UK
3. Renal Unit, Edinburgh Royal Infirmary, Edinburgh, UK
4. Department of Radiology, Queen Elizabeth University Hospital, Glasgow, UK

Corresponding author:

Dr Sokratis Stoumpos MSc MRCP

Clinical Research Fellow

Institute of Cardiovascular and Medical Sciences, University of Glasgow, Glasgow G12 8TA

E-mail: sstoumpos@nhs.net

Tel: +44 141 330 2079, Mobile: +44 781 874 2133

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Objective: The predicted outcomes of autogenous arteriovenous (AV) hemodialysis access creation are predominantly based on historical data; however both the hemodialysis population and clinical practices have changed significantly over the last decade. This study examined contemporary AV access clinical use and patencies.

Methods: A multi-centre observational cohort study was performed of all new AV accesses created in Scotland in 2015. The primary endpoint was efficacy assessed by successful AV access use for a minimum of 30 days and primary, primary-assisted, and secondary patency at 1 year. Data obtained included all interventions to maintain or restore patency. Predictors of patency loss including demographics, comorbid conditions, dialysis status, AV access location, duplex surveillance, procedures, prior access, and antiplatelets were assessed. Kaplan-Meier and competing risks analyses were performed to estimate the probability of AV access failure. All patients were followed-up for at least 1 year, or had a censoring event.

Results: A total of 582 AV accesses were created in 537 patients (mean age 60 [SD 14] years; 60% men; 42% with diabetes) in nine adult renal centres. Mean follow-up was 11.8 (SD 7.6) months. By the end of the follow-up, 322 (55.3%) AV accesses were successfully used for dialysis. At 1 year, 48% (95% CI 44-52) of AV accesses had primary patency, 67% (95% CI 63-71) had primary-assisted patency, and 69% (95% CI 65-73) had secondary patency. The leading cause of primary patency loss was primary failure (30%). An average of 0.48 interventions per patient-year was required to maintain patency. On multivariable analysis, patency was better for an upper compared to forearm AV access (1-year secondary patency of upper vs. forearm AV accesses 74% vs. 58%, respectively). The cumulative hazard and incident functions for AV access failure were 31% (95% CI 27-35) and 23% (95% CI 20-27) at 1 year, respectively.

Conclusions: Despite advances in recent years with pre-operative vessel assessment and surveillance, patency rates have not improved with primary failure remaining the major

obstacle. Competing events should be taken into consideration otherwise biases may occur with overestimation of the probability of AV access failure.

Introduction

Autogenous arteriovenous (AV) accesses are widely recognized as the most reliable and durable AV access for hemodialysis (HD) treatment. In recent years, however, there have been significant changes in the demographics of the prevalent hemodialysis population with trends towards increasing age and comorbidity. These changes make successful creation and maintenance of AV accesses considerably more challenging.

A major problem with AV accesses is the high frequency of primary failure, either as a result of poor maturation or early thrombosis. Thereafter maintaining AV access patency may be compromised by emergent structural or functional problems that may develop during routine use[1-3]. As such, AV access dysfunction is one of the leading causes of morbidity and mortality among end stage renal disease patients[4-6]. Consequently there has been an increased focus on percutaneous and surgical interventions aimed at promoting AV access maturation and maintaining the long-term patency[7].

Reports of AV access patency and complications are limited by heterogeneous patency definitions, the exclusion of primary failures in the estimation of patencies, and the inclusion of AV accesses created in the era before the routine uptake of duplex ultrasound (US) for vascular mapping and surveillance, or before the shift towards current clinical practice patterns which involve more aggressive endovascular interventions. These features contribute to wide estimates of secondary patency reported in the literature with data ranging from 45-96% at 1 year[8, 9]. Obtaining accurate data that reflect on AV access performance using robust definitions is therefore required, and would serve to inform patient and clinician decision making, as well as provide benchmarking levels from which standards of care may be set.

The aim of this study was to assess the outcome of all AV access creation operations by determining subsequent successful use and patency in a contemporary non-selected population. The natural history of patients following AV access creation, access-related

complications, procedure burden, predictors of patency loss and the probability of AV access failure were also examined. Data were collected across a variety of centre sizes and population types without case-selection, thus these data reflect the outcomes of AV access in reality rather than a selected cohort.

Methods

Study design, participants and setting

This was a national multi-centre cohort study of all patients in Scotland who underwent autogenous arteriovenous (AV) access creation in 2015. All nine renal units in Scotland (estimated population of 5,373,000 in 2015) participated with an overall incident HD population of 8.1/100,000 between 2012 and 2016. On 31st December 2015 the prevalent HD population size was 1,873 with 43% and 75% of the incident and prevalent HD patients, respectively, dialysing via AV access[10]. All adult (aged over 18 years) patients who had undergone autogenous AV access creation were identified by cross referencing unitary electronic patient records, surgical logbooks, theatre lists and vascular access coordinators diaries. Nonautogenous AV accesses and autogenous AV accesses placed anywhere other than the arm were excluded. Pre-operative US vascular mapping is routinely used in all units aided by venography in patients at high risk for central vein stenosis, however vessel selection is not based on strict minimum diameter criteria and the decision ultimately resides with the operating surgeon. Patients were followed from the time of AV access placement and up until 31st December 2016 thus allowing a minimum 1 year of follow-up. Data on AV access use, patency, complications and procedures were determined through analysis of unitary electronic patient records or scrutiny of the clinical case records. The study was conducted under the auspices of the Scottish Renal Registry (SRR). The SRR is registered with the information commissioner under the terms of the data protection act via National

Service Scotland. As part of a national audit representing an ongoing quality improvement work-stream undertaken by SRR, formal ethics approval was not required. Information regarding the use of SRR data for quality improvement is displayed in all dialysis units in Scotland (http://www.srr.scot.nhs.uk/About/Patient-Confidentiality.pdf).

Outcomes

Patencies and other outcomes of interest were reported using recommended standards for AV hemodialysis accesses[11]. The primary endpoint was efficacy as assessed by a) successful AV access use and b) primary, primary-assisted, and secondary patencies at 1 year. Successful AV access use was defined as the ability of the AV access to be cannulated with 2 needles and achieve the prescribed dialysis for at least 75% of dialysis sessions over a minimum period of 30 days[12]. In the remaining patients, non-use was defined as AV access abandonment prior to use or less than 30 days of use. Patients not defined as having use or non-use (e.g. never initiated hemodialysis) were considered indeterminate. Primary patency was defined as the interval from the time of access placement until any type of intervention to maintain or restore patency, access thrombosis, or the time of measurement of patency; primary-assisted patency was defined as the interval from the time of access placement until access thrombosis, or the time of measurement of patency; and secondary patency was defined as the interval from the time of access placement until access abandonment, thrombosis, or the time of measurement of patency including preceding successful interventional or surgical procedures to maintain or re-establish patency[11]. Secondary endpoints were patency at 6 months, the natural history of patients following AV access creation and interventions by the end of the observation period. An AV access was defined as functional if it fulfilled the criteria for successful use and was still in use at the end of the follow-up. AV accesses were categorizes as being abandoned due to primary failure (i.e.

never used for dialysis or failed within 90 days of use) or late failure (i.e. failed after at least 90 days of normal use). The time of abandonment was verified by the electronic patient record and it was the first time that an AV access was reported as 'failed' or 'abandoned'. In pre-dialysis patients, AV access maturation and patency were defined on the basis of physical examination findings, flow measurements, or duplex US.

Statistical analysis

Key parameters were summarised descriptively. Time to loss of patency was demonstrated using the Kaplan-Meier method[11] with separate assessments for primary, primary-assisted, and secondary patency. Patients were censored at death, kidney transplantation, switch to peritoneal dialysis (PD), or loss to follow-up. Additional analyses were conducted with access stratified by location (upper vs. forearm and use of cephalic vs. basilic vein). A Cox proportional hazards model was created with time to final failure or access abandonment as the dependent variable. The complement of the Kaplan-Meier estimate (1-KM) was used to estimate the cumulative hazard function for AV access failure. Additional competing risk regression using the subdistribution hazard model[13] was performed and the cumulative incidence competing risk (CICR) method[14] was applied to estimate the cumulative incidence function for AV access failure. Competing events were death, kidney transplantation, or switch to PD.

For all analyses, a $p<0.05$ was considered significant. The Stata Statistics Package (Stata/SE, version 15.0; StataCorp LLC, USA) was used for all analyses.

Results

There were 582 autogenous AV accesses created in 537 patients (Table 1). This was a predominantly Caucasian population, 60.1% were males and mean age at the time of AV

access creation was 60 (SD 14) years. Diabetes and vascular disease were common (more than 40% each) and significant comorbidity was present with a Charlson comorbidity index of ≥3 in 69.8% of the patients. 164 (28.2%) patients had previous AV access for hemodialysis, with a range of 1 to 5 procedures, and almost half of the patients had previous central venous catheterisation (CVC), with a range of 1 to 8. Mean follow-up was 11.8 (SD 7.6) months, with a cumulative follow-up of 571 patient-years.

During follow-up, 322 (55.3%) AV accesses were successfully used for hemodialysis and 166 (28.5%) were not. For 94 (16.2%) AV accesses functional status could not be determined as the patients never initiated dialysis, died or were transplanted with a patent AV access (Table 2). The average time to AV access use was 96 (IQR 57-197) days. At the end of the follow-up, 287 (49.3%) AV accesses were patent (either functional or not yet used as patients were pre-dialysis) and 196 (33.7%) were abandoned mainly due to primary failure. Of these, 48 (8.2%) AV accesses were abandoned in the first week after creation. During follow-up, 99 patients (17.0%) were censored (including 48 who died, 44 transplanted, 5 switched to PD, and 2 lost to follow-up) while the AV access was patent (Table 2). From the 363 patients that were on hemodialysis at the end of the follow-up, 303 (83.5%) were dialysing via an AV access (autogenous or prosthetic) and 60 (16.5%) via CVC. A graph chart displaying the natural history of patients from the time of AV access creation and up to 1 year of follow-up is shown in Figure 1. In the pre-dialysis group, 116 (37.3%) patients were dialysing via the index AV access 1 year after creation compared with 131 (48.3%) patients in the dialysis-dependent group.

Interventions to maintain or restore patency were performed at a rate of 0.48 per patient-year (Table 2). Most interventions were angioplasties (67.6%) with only a small number of AV accesses requiring thrombectomy (4.4%). Stents were placed in AV accesses with recurrent stenoses resistant to angioplasty (4.0%), and in one case a stent was inserted following

thrombectomy. Of the 186 angioplasties, 116 (62.4%) were performed in outflow veins, 44 (23.7%) in swing-points (39 juxta-anastomotic and 5 in cephalic arch), 14 (7.5%) in central veins and 12 (6.4%) in inflow arteries. All 11 stents were placed in outflow circuit [8 (72.7%) in outflow veins and 3 (27.3%) in central veins)]. Twenty nine (10.5%) AV accesses required surgical revision, mainly juxta-anastomotic reconstructions, and 37 (13.5%) required ligation of venous tributaries. The outflow vein was the predominant location of intervention with a total of 181 (63.1%) procedures followed by the anastomotic or juxta-anastomotic parts of the AV access with 53 (18.5%) procedures. From the 132 AV accesses requiring at least one intervention to promote maturation, 101 (76.5%) were ultimately successfully used for dialysis.

At 1 year, the pooled primary patency was 48% (95% CI 44-52, n=234/582), primary-assisted patency was 67% (95% CI 63-71, n=322/582), and secondary patency was 69% (95% CI 65-73, n=331/582). At 6 months, the primary patency was 62% (95% CI 58-66), primary-assisted patency was 74% (95% CI 70-77), and secondary patency was 76% (95% CI 72-79) (Table 3, Figure 2a). In subgroup analyses of upper vs. forearm AV accesses, the primary, primary-assisted and secondary patency at 1 year was 51% (95% CI 45-56), 73% (95% CI 68-77) and 74% (95% CI 70-79) for upper arm vs. 43% (95% CI 35-50), 55% (95% CI 48-62) and 58% (95% CI 51-65) for forearm AV accesses, respectively (Table 3, Figure 2b-d). In subgroup analyses of brachial-cephalic vs. brachial-basilic AV accesses, the primary, primary-assisted and secondary patency at 1 year was 57% (95% CI 51-63), 77% (95% CI 72-82) and 80% (95% CI 75-85) for brachial-cephalic vs. 35% (95% CI 26-45), 62% (95% CI 52-71) and 65% (95% CI 55-73) for brachial-basilic AV accesses, respectively (Table 3).

On univariable analyses, upper arm AV access (HR 0.54; 95% CI 0.41 to 0.72) was associated with prolonged secondary patency whilst previous AV access (HR 1.50; 95% CI

1.11 to 2.01) and previous ipsilateral CVC (HR 1.44; 95% CI 1.02 to 2.03) were associated with poorer secondary patency (Table 4). On multivariable analysis, upper arm AV access (HR 0.48; 95% CI 0.36 to 0.65) was an independent predictor of prolonged secondary patency whilst previous AV access (HR 1.49; 95% CI 1.06 to 2.07) was an independent predictor of poorer secondary patency. These associations remained unchanged when competing risks were taken into account in multivariable analysis (Table 4).

The probability of AV access failure was 24% (95% CI 21-28) at 6 months and 31% (95% CI 27-35) at 1 year when traditional survival analysis was applied to estimate the cumulative hazard function (Figure 3a). When competing risks analysis was implemented to estimate the cumulative incident function, the probability of AV access failure was 18% (95% CI 16-21) at 6 months and 23% (95% CI 20-27) at 1 year (Figure 3b).

Discussion

This is a contemporary national cohort of all AV access creation operations in a calendar year showing that AV access outcomes in a changing HD population are similar to historical reports despite the increased use of imaging and targeted endovascular approaches. The volume of activity was relatively high with a total of 582 autogenous AV accesses formed across the country. Using the conventional definition for successful AV access use of reproducible cannulation for 1 month of dialysis, 55% of patients used their AV access within 1 year. A further 16% patients had a patent AV access when censored or at the end of the follow-up and were considered indeterminate. In an intention-to-treat analysis, where primary failures were included in estimation of patency, 69% (65-73) AV accesses were patent at 1 year and 52% failed or required at least one intervention. Primary-assisted and secondary patency rates were similar suggesting that when thrombosis occurs, this commonly represents

a non-remediable underlying problem. From the multiple factors tested, upper arm AV accesses had prolonged patency especially if they were the patient's first access.

Determining a meaningful definition of optimal outcome for a patient is not straightforward. For example, only 60–70% of patients with chronic kidney disease who undergo pre-dialysis AV access placement initiate dialysis within 1 year. Definitions of outcomes that are based on AV access use are thus not applicable in 30-40% of these patients. In this study 166 (53%) pre-dialysis patients initiated dialysis within 1 year, of whom 116 (70%) did so via the index AV access. In the dialysis-dependent group 221 patients were receiving HD at 1 year, of whom 131 (59%) did so via the index AV access.

As a consequence of high non-maturation rates ranging from 20-60%[15-17], a significant proportion of the AV accesses encounter primary failure during the first weeks after surgery[15, 18, 19] with more current data highlighting a higher risk of primary failure[17]. When patency rates are calculated starting at the day of first cannulation, primary failed AV accesses are not included introducing biases. In two meta-analyses of AV access patency reports covering >20 years of AV access creation, when primary failure was included in the calculation of patency rate, the primary and secondary patency rates were 60-64% and 71-79% at 1 year, respectively[17, 20]. Although primary patency as determined by our data is lower than that reported in previous studies, secondary patency rates are similar (76% and 69% at 6 and 12 months, respectively). In fact, an increased risk for primary patency loss can be expected in our population where routine monitoring programs are in place as adoption of AV access surveillance is known to result in increased intervention rates[21].

This study benefits from a comprehensive data collection system. In particular we had access to all radiological procedures and we were able to characterize the exact location and the intervention performed in all dysfunctional AV accesses. AV access thrombosis treatment success can range from 88 to 100%, with post-intervention primary patency rates ranging

from 9% to 49% at 1 year[22-24]. In our study, primary patency following treatment of thrombosis was 49% (22-71) at 1 year, however the difference between primary-assisted and secondary patency was only 2%. This indicates that interventions should be targeted to prolong the thrombosis-free access survival i.e. before a stenosis progresses to thrombosis. Undoubtedly this may translate to a more aggressive approach when a stenosis is identified. In AV accesses that fail to mature, early evaluation and aggressive treatment of correctable problems, mainly stenosis, resulted in 1-year primary patency from 68 to 74.7%[25, 26]. On the other hand, in functional AV accesses, although pre-emptive stenosis correction reduced the risk of thrombosis, it did not prolong the longevity of the access[27].

On multivariable analysis upper arm AV accesses and first attempt for an AV access creation were the only predictors of better cumulative patency. Indeed, there was a significant difference in patency rates between upper and forearm AV accesses, with 1-year patency of 74% versus 58%, respectively. This trend is echoed by others[18, 28-31] and has contributed in the shift from forearm to upper-arm AV accesses predominantly in the US[32]. Patients with previous failed AV access are susceptible to future AV access failure and this is conceivably related to the presence of pre-existing risk factors for failure or the occurrence of maladaptive vascular remodelling and neointimal hyperplasia following creation of the previous failed AV access[33].Brachial-cephalic AV accesses had better patency rates compared to brachial-basilic and this is opposed to previous studies which have shown less primary failures for basilic vein AV accesses and similar cumulative access survival[34-36]. This finding should be interpreted with caution and may merely represent the practice of rarely using the basilic vein as a first option and thus the majority of these AV accesses were created in patients with previous failed VA procedures or poor cephalic options hence were representative of a cohort of patients with difficulties in establishing permanent access. Although not statistically significant, poorer outcomes were found for several known risk factors: patients on

hemodialysis at the time of AV access creation, previous dialysis catheters ipsilateral to the AV access arm and patients that did not have duplex US as part of their routine surveillance. Many studies are challenging the utility of 'fistula first' strategies in the older dialysis patient population, however age was not a predictor of patency when analysed as continuous (Table 4) or binary variable (HR for patients ≥60 years 0.96; 95% CI 0.73 to 1.27 on univariable and 1.10; 95% CI 0.82 to 1.46 on multivariable analysis). Previous studies have also failed to show that older patients and women were at significantly increased risk for AV access abandonment[37, 38] suggesting that these are potential confounders.

One of the key findings of this study brings the accepted concept of competing risks that is widely applied in other fields to that of AV access. Standard survival analysis and Cox proportional hazards models that are used to describe outcomes other than all-cause mortality in the presence of a significant and related competing risk may generate misleading results and this has been acknowledged to represent a problem that deserves more attention in the field of nephrology[39]. Censored subjects will be considered "at risk" for the outcome of interest for the duration of the study, yet deceased patients for instance are no longer at risk for AV access failure. By failing to account for the competing risk of death, Kaplan-Meier estimates will overestimate the probability of AV access failure. In our study 17% patients had a competing event (died, transplanted or switched to PD) and this alters the estimated probability of AV access failure. The probability of AV access failure was 31% at 1 year when cumulative hazard function was used, which is significantly higher compared to the 23% probability of failure estimated with the cumulative incident function.

The results from this study challenge the current clinical practices and may pave the road for future clinical trials with definitive strategies to prevent early failure. Despite a number of 'negative trials' in HD (dose of dialysis[40], statins[41], cinacalcet[42]), we still have not conquered one of the single most important determinants of survival and quality of life: improving

technical and functional success of AV access in an increasingly comorbid population. We have demonstrated that in a non-selected population where 70% of patients had Charlson comorbidity index of 3 or more, the vast majority had previous access procedures and half of them required an intervention within 1 year of the index AV access creation, AV access outcomes were suboptimal. Nevertheless, these data clearly show that proximal versus distal AV access and avoidance of prior surgery are the key factors for success. This creates a case for an appropriately designed trial which will directly compare the outcomes of proximal versus distal AV access creation focusing on patient-specific factors rather than vessel selection or pharmacological interventions.

Although observational, this study benefits from high-quality granular data that were captured manually through the databases used allowing for accurate assessment of AV access use, abandonment and procedure rates. In addition, by tracking of the patients' dialysis career we achieved detailed profiling which was graphically plotted. We analysed data from nine centres with heterogeneity of available resources and implementation of different policies which allows generalisability of our results. Although several previous observational studies have been performed on this topic, there is a dearth of data derived from European populations. Survival of AV accesses has been shown to differ across continents[43]; hence this study expands our current knowledge.

Our study also has limitations. No unifying criteria between centres were applied to define AV access maturation and patency and duplex surveillance was routinely applied in four out of the nine renal units (n=230 AV accesses). We used an observational study design thus there is likely residual confounding due to patient characteristics (e.g., vessel size and quality, surgical experience) not available in the data sources used for this analysis. A centre-effect may have played a role in our observation as inclusion of dialysis centres with an insufficient number of AV access surgeries per year may have resulted in a lower number of functioning

AV accesses with a high failure to mature rate. However, all centres had a cohesive vascular access team in place and the value of this national dataset is that it reduces population specific, surgical skills specific and vessel selection specific variation that may be seen between individual units. Finally, access choice was not standardized, and although the majority of the patients had pre-operative duplex vessel assessment, the clinical or radiologic evaluation of patient suitability for an AV access may have varied by surgeon.

Conclusion

Creating and maintaining an autogenous arteriovenous access for hemodialysis is a complex process subject to patient-specific characteristics, surgical expertise and vascular access infrastructure. Despite significant technical and medical advances in vascular access and associated increases in healthcare costs, patency rates in a non-selected contemporary population have not improved significantly. This should be taken into account in future clinical trial design where a more holistic range of endpoints should be endorsed, and where variables such as AV access site and cannulation techniques are included.

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Conflict of interest statement

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Table 1. Baseline characteristics.

Patients	**N=537**
Male	323 (60.1%)
Race	
White Caucasian	514 (95.7%)
Asian	21 (3.9%)
African American	2 (0.4%)
Comorbidities	
Diabetes	223 (41.5%)
Cardiovascular disease	112 (20.9%)
Cerebrovascular disease	62 (11.5%)
Peripheral arterial disease	62 (11.5%)
Charlson comorbidity index	
2	162 (30.2%)
3-4	198 (36.9%)
>4	177 (32.9%)
AV access procedures	**N=582**
Mean age at AV access creation (years; SD)	60 (14)
≥60 years	301 (51.7%)
Mean duration of follow-up (months; SD)	11.8 (7.6)
≥12 months	331 (56.9%)
≥18 months	145 (24.9%)
Mean body mass index (kg/m^2; SD)	28.6 (6.9)
Hemodialysis at AV access creation	271 (46.6%)
Median hemodialysis vintage (months; IQR)	7.6 (2.6-27.5)
Antiplatelet use	266 (45.7%)
Anticoagulant use	45 (7.7%)
At least one previous arteriovenous access	164 (28.2%)
At least one previous central vein catheter	266 (45.7%)
Data are n (%) unless stated otherwise	

Table 2. Clinical outcomes and interventions after AV access creation.

	Total AV accesses (N=582)
Successful AV access use	
AV access use	322 (55.3%)
AV access non-use	166 (28.5%)
Indeterminate	94 (16.2%)
Natural history after AV access creation[a]	
AV access functional	244 (41.9%)
AV access patent	43 (7.4%)
AV access abandonment	196 (33.7%)
Primary failure	173 (29.7%)
Late failure	23 (4.0%)
Death	48 (8.2%)
Transplantation	44 (7.6%)
Peritoneal dialysis	5 (0.9%)
Lost to follow-up	2 (0.3%)
Interventions	
Total procedures	275
Angioplasty	186 (67.6%)
Stent insertion	11 (4.0%)
Thrombectomy	12 (4.4%)
Revision	29 (10.5%)
Ligation of tributaries	37 (13.5%)
Interventions per patient-year	0.48
Location of intervention	
Inflow artery	22 (7.7%)
Outflow vein	181 (63.1%)
Swing-point	60 (20.9%)
Juxta-anastomotic	53 (18.5%)
Cephalic arch	7 (2.4%)
Central vein	24 (8.3%)
Data are n (%) unless stated otherwise [a] By the end of the observation period	

Table 3. AV access patencies.

	Total AV accesses (N=582)	**Forearm AV accesses (N=196)**	**Upper arm AV accesses (N=386)**	**P-value[a]**	**Brachial-cephalic AV accesses (N=273)**	**Brachial-basilic AV accesses (N=107)**	**P-value[b]**
Patency (%, 95% CI)							
Primary patency							
6 months	62% (58-66)	55% (47-62)	66% (61-71)		72% (66-77)	51% (41-60)	
12 months	48% (44-52)	43% (35-50)	51% (46-56)	0.005	57% (51-63)	35% (26-45)	<0.001
Primary-assisted patency							
6 months	74% (70-77)	62% (55-69)	80% (76-84)		84% (79-88)	69% (59-76)	
12 months	67% (63-71)	55% (48-62)	73% (68-77)	<0.001	77% (72-82)	62% (52-71)	0.002
Secondary patency							
6 months	76% (72-79)	65% (58-71)	82% (77-85)		87% (82-90)	72% (63-80)	
12 months	69% (65-73)	58% (51-65)	74% (70-79)	<0.001	80% (75-85)	65% (55-73)	0.001

[a] Upper vs. Forearm

[b] Brachial-cephalic vs. brachial-basilic

Table 4. Factors associated with secondary patency.

	Univariable analysis		**Cox regression analysis**		**Competing risks analysis**	
	Hazard ratio (95% CI)	**P-value**	**Hazard ratio (95% CI)**	**P-value**	**Subdistribution hazard ratio (95% CI)**	**P-value**
Age, per year	0.99 (0.98 – 1.00)	0.25	1.00 (0.99 – 1.01)	0.94	1.00 (0.99 – 1.01)	0.99
Female sex	1.05 (0.79 – 1.39)	0.76	1.20 (0.89 – 1.62)	0.22	1.21 (0.90 – 1.62)	0.22
Diabetes	1.01 (0.76 – 1.34)	0.94	1.09 (0.82 – 1.46)	0.54	1.10 (0.82 – 1.48)	0.51
Predialysis vs. hemodialysis	0.77 (0.58 – 1.02)	0.07	0.92 (0.66 – 1.29)	0.65	0.94 (0.67 – 1.33)	0.74
Upper vs. forearm AV access	0.54 (0.41 – 0.72)	<0.001	0.48 (0.36 – 0.65)	<0.001	0.51 (0.38 – 0.69)	<0.001
Duplex surveillance[a]	0.76 (0.57 – 1.02)	0.07	0.77 (0.57 – 1.04)	0.09	0.78 (0.57 – 1.06)	0.11
Procedures[b]	1.00 (0.99 – 1.00)	0.11	1.00 (0.99 – 1.00)	0.16	1.00 (0.99 – 1.00)	0.38
Previous AV access	1.50 (1.11 – 2.01)	0.007	1.49 (1.06 – 2.07)	0.02	1.48 (1.04 – 2.10)	0.03
Previous ipsilateral CVC	1.44 (1.02 – 2.03)	0.03	1.30 (0.88 – 1.92)	0.19	1.23 (0.82 – 1.84)	0.31
Antiplatelet use	0.98 (0.74 – 1.30)	0.91	0.93 (0.69 – 1.24)	0.61	0.93 (0.70 – 1.24)	0.62

[a] Intention to treat (ITT) analysis
[b] Time-varying covariate

Figure 1. Changes in patients' status from the time of AV access creation and up to 1 year of follow-up divided by patients' status at time of AV access creation **a**. Pre-dialysis and **b.** dialysis-dependent patients.

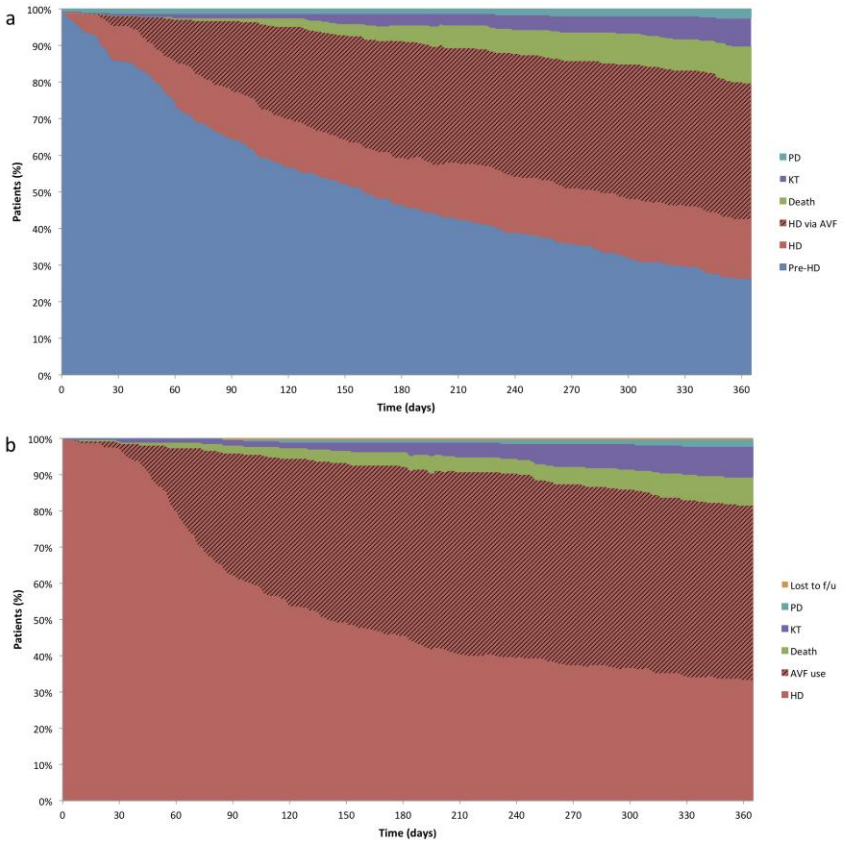

Figure 2. Kaplan-Meier curves for AV access patencies **a.** Primary, primary-assisted and secondary patencies of all AV accesses and **b.** primary, **c.** primary-assisted and **d.** secondary patency by AV access type (upper vs. forearm).

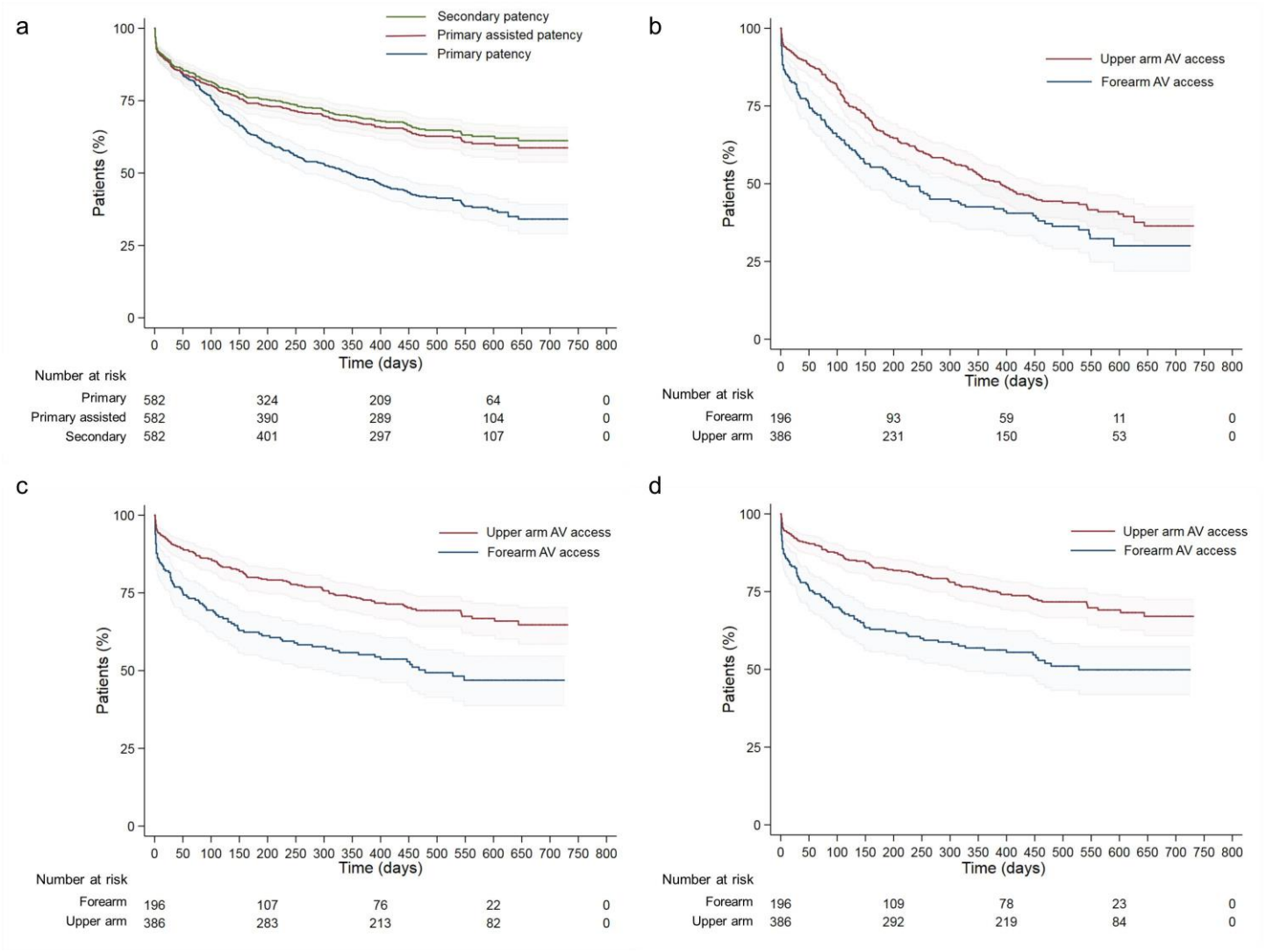

Figure 3. Cumulative probability of AV access failure over time estimated by **a.** the cumulative hazard function derived from the complement of the Kaplan-Meier estimate (1-KM) and **b.** the cumulative incidence function derived from the cumulative incidence competing risk (CICR) method accounting for the presence of competing risks.