Original Article

The Combination of Sonography and Physical Examination Improves the Patency and Suitability of Hemodialysis Arteriovenous Fistula in Vascular Access

Submitted: 13 Dec 2015
Accepted: 12 May 2016
Online: 30 June 2016

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To cite this article: Mat Said N, Musa KI, Mohamed Daud MA, Haron J. The combination of sonography and physical examination improves the patency and suitability of hemodialysis arteriovenous fistula in vascular access. *Malays J Med Sci.* 2016; **23(4)**: 26–32. doi: 10.21315/mjms2016.23.4.4

To link to this article: http://dx.doi.org/10.21315/mjms2016.23.4.4

Abstract

Purpose: **We compared the patency and the suitability of arteriovenous fistula (AVF) created for vascular access by two approaches: (a) physical examination with preoperative vascular mapping and (b) physical examination alone.**

Methods: **We compared the patency and the suitability of AVF created in patients for dialysis. There were two cohorts of patients of 79 patients each: (a) patients with AVF created based on the combination of physical examination and preoperative vascular mapping (PE+VM) and (b) patients with AVF created based on physical examination (PE) alone. Fistula patency is defined as clinical detection of thrill (or auscultation) of murmur over the fistula and coded as having thrills (patent) versus not having thrills (not patent). Suitability of fistula is defined as functioning AVF (AVF can be adequately used via 2-needle cannulation for dialysis) and coded as suitable versus not suitable.**

Results: **AVF created after the preoperative vascular mapping (PE+VM) has 5.70 (at six weeks) and 3.76 (at three months) times higher chance for patency, and 3.08 times higher chance for suitable AVF for dialysis than AVF created after the physical examination (PE) alone.**

Conclusion: **Physical examination with preoperative ultrasound mapping (PE+VM) significantly improves the short term patency and the suitability of AVF for dialysis.**

Keywords: *arteriovenous fistula, hemodialysis, ultrasound, sonography, vascular patency*

Introduction

A hemodialysis arteriovenous fistula (AVF) is a surgically created communication between a vein and an artery, usually in the forearm, allowing access to the vascular system for hemodialysis. Native AVF is created using the native vessels while prosthetic AVF uses materials such as polytetrafluoroethylene (PTFE), Dacron, polyurethane, bovine vessels or saphenous veins as medium to connect between the vein and the artery (1, 2) and a well-functioning vascular access is a mainstay to perform an efficient haemodialysis (3) .

One common disadvantage of native AVF is its failure caused by multiple factors. Common causes for its failure were technical errors, hypotension, difficulty at the site of insertion, small size of the vessels, diabetes and atherosclerosis (4).

To minimise failure, a multidisciplinary approach to hemodialysis access was emphasised and a prospective study demonstrated a decrease in access failure and an increase in successful AVF creation in patients from 33% to 69% following the approach (5).

At Hospital Universiti Sains Malaysia, Malaysia, the AVF is a standard procedure performed on end stage renal failure (ESRF) patients requiring long term hemodialysis. The selection of the suitable site for AVF was based on the physical examination only; and the pre-ultrasound mapping was not a standard practice until 2011 despite its benefit shown in other studies (6). During the physical examination the selected veins and arteries were examined clinically for their suitability. Therefore, a study that looks into the outcome of AVF formation in our own setting was important to examine the effectiveness of AVF formation based on the combination use of physical examination and pre-ultrasound mapping.

We carried out a study to compare the patency and the suitability of AVF after its creation between two approaches:(a) physical examination with pre-operative vascular mapping and (b) physical examination alone.

Materials and Methods

Study design

We performed a prospective cohort study at the Hospital Universiti Sains Malaysia (HUSM) Kota Bharu, Kelantan, Malaysia for a period of 18 months from April 2008 to September 2009. This was the period where the clinicians at our setting were trying to encourage the use vascular mapping using ultrasound. We recruited two cohorts of patients with 79 patients in each cohort: (a) patients undergoing AVF creation based on the combination of physical examination and pre-operative vascular mapping (PE+VM), and (b) patients undergoing AVF creation based on the physical examination (PE) alone.

Inclusion and exclusion criteria

We included all patients that required native arteriovenous fistula (AVF) in HUSM. The referring physician or nephrology team assessed them clinically prior to reference for fistula creation. At HUSM, the surgeons from the Urology Unit or the Plastic and Reconstructive Surgery Unit normally managed the patients for AVF creation.

Informed consent was taken from each of the patients and those who consented were enrolled.

We excluded patients with any of these conditions: difficult venous access, had undergone other than native fistula creation such as prosthetic hemodialysis access using arteriovenous grafts (AVGs) e.g. Polytetrafluoroethylene (PTFE) and other materials (Dacron, polyurethane or saphenous veins), had undergone refashioning of the poor functioning or failed existing fistula.

Sample size calculation

The success rate for AVF in patients with vascular mapping was reported at 58% (4). In this study, we expected that the success rate in the PE cohort was 28% (30 percent lower). Since the ratio of the two cohorts were one, the sample size calculated using two proportion formulas with 80% power and 5% type 1 error, required a sample size of 42 patients per cohort (inclusive of 10 percent of oversampling).

Research tools

To measure the diameter and Doppler study of the vessels, we used an ultrasound machine, Siemens Sonoline Elegra, version 6.0.200 and high resolution linear transducer VF 5.0–13.0 MHz (PVFL011972).

For reviewing the images, we used PACS System Workstation, a product of GE Healthcare, USA; model Centricity PACS – IW, version 3.7.1.1.

We collected patients' clinical data, their pre-operative sonographic parameter, post-operative physical examination parameters, operative information and post-operative outcomes and arterial and venous template. The vascular (ultrasound) mapping technique was adapted from the study by Nursal et al. and the examination were carried out by a single researcher whom had undergone a proper training on the preoperative ultrasound mapping (7).

Follow-up and outcomes

The surgeon who created the fistula confirmed the status of AVF fistula based on: a) patency and b) suitability for AVF. Each patient was followed up at day-1, six weeks, three months and six months after AVF creation. The suitability was assessed just before the hemodialysis.

Fistula patency is defined as clinical detection of thrill (or auscultation) of murmur over the fistula and coded as having thrills (patent) versus not having thrills (not patent). Suitability of fistula is defined as functioning AVF (AVF can be adequately used via 2-needle cannulation for dialysis) and coded as suitable versus not suitable.

Statistics

Data were entered, cleaned and analyzed using Statistical Package for Social Sciences (SPSS) version 18 software. We described the mean and standard deviation for numerical variables. We checked the distribution of the parameters to assess the normality of data using histogram. The frequency (n) and percentage (%) were reported for categorical independent variables.

The outcome variables were AVF status, recorded as patency of the fistula (patent or not patent) and its suitability (suitable or not suitable) for dialysis.

The adjusted variables were demographic profiles such as age and gender, underlying medical illnesses (diabetes mellitus, hypertension, hypercholesterolaemia and ischaemic heart disease), causes of renal failure, previous fistula creation and site of fistula.

We performed chi-square tests to examine the distribution of outcomes and distribution of categorical predictor variables between the two cohorts at univariable level. To compare each of the outcomes between the PE cohort versus PE+VM cohort, we performed separate binary logistic regression. In multiple logistic regression, we adjusted the model for age, gender, and history of diabetes mellitus, hypertension, hypercholesterolaemia and ischemic heart disease. We set the level of significance at p-value < 0.05 with 2-tail fashion.

Results

A total of 158 patients with end-stage renal disease or chronic renal failure approaching end-stage renal failure were included in this study: 79 in physical examination plus preoperative vascular mapping (PE+VM) cohort and 79 in physical examination alone (PE) cohort.

Table 1 shows that the demography and clinical characteristics of patient in PE+VM and PE cohort. The ages in both groups are not different. We checked the distribution of medical illnesses in both groups. The distribution of causes of renal failure is shown. In both groups, the main cause for renal failure was diabetic nephropathy. Lastly, we presented the distributions of the position of the fistulas. The left radiocephalic fistula was the most site for the creation of AVF.

Table 2 and Table 3 show the comparison of outcomes of AVF in the two cohorts. Of all, 98.7% (78/79) patients in preoperative ultrasound mapping (PE+VM) cohort had thrill after one day post operation compared to 93.7% (74/79) in PE cohort. A total of 92.2% (71/77) of patients in PE+VM cohort had functioning fistula at six weeks but only 72.0% (54/75) of patients in PE cohort had functioning fistula. Sixty-six out of 75 patients (88.0%) in PE+VM cohort in-contrast to 50/74 (67.6%) patients in PE cohort had functioning fistula at three months. However, there is no significant difference in the immediate thrill in patients of both study groups ($p = 0.210$).

Table 3 shows the results from the univariable logistic regression. The AVF created in the PE+VM cohort had significantly higher odds for the presence of thrills than those AVF created in the PE cohort – at day one ($p = 0.042$), at six weeks ($p = 0.002$) and at three months ($p = 0.004$). Generally, the chance for favourable patency decreases from immediate assessment until assessment at six months, with obvious benefit for PE+VM cohort at all measurement occasions.

AVF created in PE+VM cohort showed superior suitability (2.60 times more favorable outcome, $p = 0.008$) for dialysis (functioning fistula) than AVF created in the PE cohort.

Multiple logistic regressions in Table 4 show the outcomes of AVF after adjustment to other important clinical confounders in the model. The AVF created in the PE+VM cohort resulted in 5.70 times and 3.76 times higher chance for patent fistula at six weeks and three months, respectively in comparison to that of physical examination only (PE). The AVF created in the PE+VM cohort also led to higher chance of having suitable fistula for dialysis (functioning fistula); 3.08 times higher than PE cohort when adjusted for the similar confounders.

Table 1: Profile of patients in 'physical examination and preoperative vascular mapping' (PE+VM) cohort and 'physical examination' alone (PE) cohort

Profiles	PE+VM cohort	PE cohort
Age (years old)	52.9(14.8)*	52.5(16.2)†
Gender		
Male	36(45.5)	45(57.0)
Female	43(54.5)	34(43.0)
Medical illness		
Have diabetes mellitus	47(59.5)	44(55.7)
Have hypertension	72(91.1)	69(87.3)
Have hypercholesterolaemia	40(58.0)	32(40.5)
Have ischaemic heart disease	11(13.9)	21(26.6)
Causes of renal failure		
Diabetic nephropathy	47(59.5)	42(53.2)
Hypertension	28(35.4)	12(15.2)
Glomerulonephritis	0(0.0)	10(12.7)
Others	4(5.1)	15(19.0)
Type of fistula		
RightRCF (Radiocephalic)	17(21.5)	16(20.3)
LeftRCF (Radiocephalic)	39(49.4)	41(51.9)
Right BCF (Brachiocephalic)	3(3.8)	3(3.8)
Left BCF (Brachiocephalic)	14(17.7)	12(15.2)
Right BBF (Brachiobasilic)	3(3.8)	1(1.3)
Left BBF (Brachiobasilic)	1(1.3)	1(1.3)
Others	2(2.5)	5(6.3)

*† Mean (SD)

Table 2: Comparison of outcomes (patency and suitability for haemodialysis) between arteriovenous fistula (AVF) created using 'physical examination' alone (PE) cohort and the combination of using 'physical examination and preoperative vascular mapping' (PE+VM) cohort

Outcomes		PE cohort		PE+VM cohort		*P*-value
		Frequency	(%)	Frequency	%	
Patency*						
Immediately post-op	No	5	(6.3)	1	(1.3)	0.210**
	Yes	74	(93.7)	78	(98.7)	0.018†
At Day-1	No	8	(10.3)	1	(1.3)	0.018
	Yes	70	(89.7)	78	(98.3)	
At 6-week	No	21	(28.0)	6	(7.8)	0.001†
	Yes	54	(72.0)	71	(92.2)	
At 3-month	No	24	(32.4)	9	(12.0)	0.003†
	Yes	50	(67.6)	66	(88.0)	
At 6-month	No	26	(41.9)	15	(27.3)	0.097†
	Yes	36	(58.1)	40	(72.7)	
Suitable for hemodialysis	No	32	(43.2)	17	(22.7)	0.008†
	Yes	42	(56.8)	58	(77.3)	

** Fisher's Exact Test † Pearson Chi-Square * Patent or not, based on the presence of thrills

Table 3: The crude regression coefficients show the result of logistic regression analysis with the outcomes of arteriovenous fistula (AVF) creation: (a) patency and (b) suitability of arteriovenous fistula (AVF). The crude odds ratios were obtained by comparing each outcome between patients undergoing 'physical examination and preoperative ultrasound mapping' (PE+VM) against patients undergoing 'physical examination' (PE) alone

Outcome	Predictor	Crude OR (95% CI)	*P*-value
Patency:			
Immediate thrills	PE+VM	5.27 (0.60 , 46.18)	0.133
	PE	1.00	
Thrills at Day-1	PE+VM	8.91 (1.09 , 73.07)	0.042
	PE	1.00	
Thrills at 6-week	PE+VM	4.60 (1.74 , 12.19)	0.002
	PE	1.00	
Thrills at 3-month	PE+VM	3.52 (1.51 , 8.23)	0.003
	PE	1.00	
Thrills at 6-month	PE+VM	1.93 (0.88 , 4.20)	0.097
	PE	1.00	
Functioning:			
Suitable for dialysis	PE+VM	2.60 (1.28 , 5.29)	0.008
	PE	1.00	

*PE+VM = Physical examination and vascular mapping †PE = Physical examination alone

Table 4: The adjusted logistic regression models with the outcomes of arteriovenous fistula (AVF) creation: (a) patency and (b) suitability for haemodialysis. The adjusted odds ratios are based on comparing each outcomes in two predictors: between patients undergoing preoperative ultrasound examination (PE+VM) against patients undergoing physical examination (PE) alone, while controlling for important clinical confounders.

Outcome	Predictor	AdjustedOR (95% CI)†	*P*-value
Patency :			
Thrills at 6-week	PE+VM	5.70 (1.85, 17.55)	0.002
	PE	1.00	
Thrills at 3-month	PE+VM	3.76 (1.46 , 9.66)	0.006
	PE	1.00	
Thrills at 6-month	PE+VM	2.05 (0.84 , 4.97)	0.113
	PE	1.00	
Functioning:			
Suitable for dialysis	PE+VM	3.08 (1.39 , 6.85)	0.006
	PE	1.00	

† PE+VM cohort vs PE cohort (reference). Adjusted for age, sex, history of diabetes mellitus, history of hypertension, history of dyslipidemia and history of ischemic heart disease.

Discussion

In this study, we compared the outcome of AVF between two cohorts: a) AVF created based on physical examination only (PE cohort) and AVF created based on the combination of physical examination and vascular (ultrasound) mapping (PE+VM cohort). We have found a significant difference in fistula patency between the two cohorts at day one, sixweeks and at three months after the fistula creation. We also showed that the use of vascular (ultrasound) mapping on top of physical examination (PE+VM) led to 8.91 times higher chance for thrills detected on day-one post operation compared to physical examination (PE) alone. The adjusted model results show that the use of vascular mapping increased chances for fistula at six weeks and at three months post AVF creation. The findings from our study show that preoperative vascular mapping if done with physical examination offers significant benefit in the management of hemodialysis AVF.

The benefit of using preoperative vascular (ultrasound) mapping for fistula creation shown in our study is consistent with studies elsewhere (8–10). Silva et al. compared access outcome in 172 patients undergoing preoperative venous mapping with historical controls and showed that the routine preoperative ultrasound increased the prevalence of native access from 14 to 63% ($p < 0.05$) (10). Another prospective study evaluating the effect of preoperative ultrasound by Mihmanli et al. used randomised study design where 124 patients undergoing assessment for fistula into preoperative physical examination alone or evaluation with ultrasound alone showed benefit of using ultrasound during AV fistula creation – the rate of primary non-functioning was only 5.6 % in the ultrasound group compared with 25% in patients undergoing physical examination (8). A study by Allon et al. found that the proportion of fistulas placed increased from 34% during the historical control period to 64% with preoperative vascular mapping ($P < 0.001$) (11).

Our study also showed that by adding vascular (ultrasound) mapping, there will be higher success rate for functioning fistula for dialysis. The result revealed that 77.3% (58/75) patients in the PE+VM cohort had a suitable fistula for hemodialysis compared to only 56.8% (42/74) patients in the PE alone cohort. Multiple regression analysis done to adjust the effect of confounders shows that patients in the PE+VM cohort had 3.08 times higher chances for suitable fistula for dialysis. There was no significant difference in the presence of thrill at six months posts AVF creation that indicates no difference in long-term patency between the two cohorts. Our findings support the reports from Allon et al. showing the increased adequacy rate for dialysis from 46 to 54% with the use of mapping (11). A study by Grogan et al. also reported that that functional patency was approximately 60% in patients with adequate vein mapping (5). Perhaps vascular (ultrasound) mapping provided more objective assessment of the cephalic vein until the axillary vein. In our study, the ultrasound mapping not just the size of the vessels but also its depth and presence of stenosis similar to a report elsewhere (12).

In our study, the functioning fistula at six months did not differ in both groups ($p = 0.097$), which suggests that preoperative mapping is not a good predictor for long term patency. The inability to maintain the benefit of using preoperative ultrasound mapping could be due to failure caused by various factors such as thrombosis or stenosis of the venous limb due to multiple puncture or stenosis at the juxtaarterial anastomosis. Similar finding was reported by I. Mihmanli et al., where they concluded that preoperative duplex US scanning improved short-term AVF patency, from 75% to 94%, compared with physical examination alone (8).

Conclusion

The combination of preoperative vascular (ultrasound) mapping and physical examination during arteriovenous fistula (AVF) creation leads to higher success in its patency and its suitability for dialysis than by using only physical examination. Color Doppler ultrasonography is beneficial when used in combination with physical examination and should be a routine prior to the creation of hemodialysis arteriovenous fistula. The preliminary finding from this study has successfully encouraged the routine use of vascular mapping via ultrasound in our hospital setting.

Ethical Approval

The study was approved by the Research Ethics Committee (Human), Universiti Sains Malaysia (USMKK/PPSP/JEPem[199.4(2.3)]).

Acknowledgements

We are grateful to the Director, Hospital Universiti Sains Malaysia (HUSM) for approving this study to take place at HUSM'

Conflict of Interests

None

Funds

None

Authors' Contribution

Conception and design: JH, MAMD
Analysis and interpretation of the data: JH, KIM, NMS, MAMD
Drafting of the article: JH, NMS
Critical revision of the article for important intellectual content: JH, KIM, MAMD
Final approval of the article: JH, KIM
Provision of study materials or patents: JH, NMS
Statistical expertise: KIM
Administrative, technical, or logistic support: NMS
Collection and assembly of data: NMS, MAMD

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