

Outcome of Immediate Interventions in Acute Dysfunctional Hemodialysis Fistulas

Evaluation sofortiger Interventionen in akut dysfunktionellen Hämodialyseshunt

Authors

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Key words

- vascular
- interventional procedures
- efficacy studies
- hemodialysis fistula

Zusammenfassung

Ziel: Evaluation der interventionellen Revision akut dysfunktioneller Dialyseshunts bei sofortiger Intervention wie von European Best Practice Guidelines for Hemodialysis empfohlen.

Material und Methoden: Über 3 Jahre wurden alle (n=280) Patienten mit akut dysfunktionellem Dialyseshunt unabhängig von der Tageszeit zur Angiografie vorgestellt. Eine Angiografie und, falls möglich, interventionelle Revision wurden bei n=241 Fällen durchgeführt. Es wurden 3 Beobachtungsgruppen gebildet: Erfahrungsgrad des Interventionalisten (hoch/niedrig), Tageszeit (Routinearbeitszeit, 7–16 h; Notdienstzeit, 16–7 h), Läsionsart (Stenose/fibrosklerotischer Verschluss/thrombotischer Verschluss/kombiniert Stenose+Thrombose). Für die statistische Analyse wurden die korrespondierenden Erfolgsraten, Chi-Quadrat-Tests ($p < 0,025$) und eine logistische Regressionsanalyse ($p < 0,05$) berechnet.

Ergebnisse: Die Gesamterfolgsrate betrug 62% (149/241). Die Erfolgsraten waren nach Interventionalist für hohen/niedrigen Erfahrungsgrad 71% (79/111)/54% (70/130), $p = 0,022$; nach Tageszeit für Routinearbeitszeit/Notdienstzeit 68% (93/136)/53% (56/105), $p = 0,017$; nach Läsionsart für Stenose/fibrosklerotischen Verschluss/thrombotischen Verschluss/kombiniert Stenose+Thrombose 82% (94/104)/39% (13/33)/18% (6/33)/59% (36/61), $p < 0,001$. In der logistischen Regressionsanalyse waren relevante Variablen hoher Erfahrungsgrad und die Läsionsarten Stenose und kombiniert Stenose+Thrombose mit einer Odds Ratio von 2,300 ($p = 0,012$), 12,053 ($p < 0,001$), 3,189 ($p = 0,003$).

Schlussfolgerung: Eine uneingeschränkte Umsetzung sofortiger Interventionen bei akut dysfunktionellen Dialyseshunts erfordert die permanente Bereitschaft eines Interventionalisten mit hohem Erfahrungsgrad. Die Läsionsarten fibrosklerotischer und thrombotischer Verschluss bieten nur geringe Erfolgsraten bei interventioneller Revision.

Abstract

Purpose: To analyze the efficacy of interventions in acute dysfunctional hemodialysis fistulas, if intervention is performed immediately as recommended by European Best Practice Guidelines for Hemodialysis.

Materials and Methods: Over 3 years, all (n=280) patients with an acute dysfunctional hemodialysis fistula were immediately referred to angiography, irrespective of the time of day. Angiography and, if possible, interventional revision (n=241) were performed. Three groups of interest were established: interventionalist's experience (high/low), time of day (routine hours: 7 am–4 pm/emergency hours: 4 pm–7 am), lesion type (stenosis/fibrosclerotic occlusion/thrombotic occlusion/combined stenosis+thrombotic occlusion). For statistical analysis corresponding success rates, chi-square tests ($p < 0,025$) and logistic regression analysis ($p < 0,05$) were calculated.

Results: The total success rate was 62% (149/241). The success rates were: interventionalist experience high/low 71% (79/111)/54% (70/130), $p = 0,022$; time of day routine/emergency hours 68% (93/136)/53% (56/105), $p = 0,017$; lesion type stenosis/fibrosclerotic occlusion/thrombotic occlusion/combined stenosis+occlusion 82% (94/104)/39% (13/33)/18% (6/33)/59% (36/61), $p < 0,001$. Relevant variables due to logistic regression analysis were high experience and the lesion types stenosis and combined stenosis+occlusion with odds ratios 2.300 ($p = 0,012$), 12.053 ($p < 0,001$), 3.189 ($p = 0,003$).

Conclusion: Unrestricted implementation of immediate interventions in acute dysfunctional hemodialysis fistulas requires permanent availability of experienced interventionalists. The lesion types fibrosclerotic occlusion and thrombotic occlusion offer poor success rates for interventional revision.

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Bibliography

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Introduction

Although renal transplantation is considered the therapy of choice for patients with end-stage renal disease (ESRD), ESRD patients are often put on long-term hemodialysis [1, 2]. For permanent hemodialysis access surgically created native arteriovenous (AV) fistulas are commonly used [3–5]. Adequate care of an ESRD hemodialysis patient includes constant attention to the need to maintain vascular access patency. Hemodialysis access failure is a major cause of morbidity for ESRD patients on hemodialysis, resulting in an increased number of patient hospitalizations, prolonged hospitalizations and thus increasing costs [6]. Dysfunctional AV fistulas often result in thrombosis of the vascular access as the final complication. As recommended by the Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines of the American National Kidney Foundation, treatment of thrombosis should start as early as possible to maintain long-term patency of the vascular access [6]. The optimal timing of the treatment of the underlying causes for dysfunction, such as arterial, anastomotic and venous stenosis or fibrosclerotic occlusion of the vein, is not specified by the KDOQI guidelines and remains to be determined [7]. Due to the European Best Practice Guidelines (EBPG) for Hemodialysis of Nephrology Dialysis Transplantation Education, pre-emptive intervention should be performed immediately in the case of dysfunction [8]. Thus, there is a certain discrepancy among the available major guidelines, and, in our opinion, immediate interventional revision would be influenced by a setting on an emergency basis.

For a period of three years, we followed the EBPG: All ESRD hemodialysis patients with acute dysfunctional AV fistulas were immediately referred to the radiological intervention center, irrespective of the time of day, the available interventionalist and the lesion type. We analyzed our data to prove the efficacy of radiological interventions in this “emergency setting”.

Materials and Methods

Study Design and Patient Population

Following the EBPG for a period of three years, all ($n=280$) patients who presented in the local university hospital with an acute dysfunctional hemodialysis fistula were immediately referred to the radiological intervention center. Written informed consent was obtained from each patient. The patients were consecutively enrolled. The patients could reject the intervention at any time of the procedure. As soon as possible, angiography and, if deemed feasible, interventional treatment were performed, irrespective of the time of day, the interventionalist available, and the specific lesion type. In $n=241$ cases, an intervention was performed. Of the 280 patients, there were 141 men and 139 women. The mean age was 64 years (range: 26–91 years). Institutional Review Board approval was present for the data analysis.

Angiography and Interventional Techniques

All procedures were performed under local anesthesia. It was attempted to puncture the failing hemodialysis fistula initially with retrograde/ antegrade placement of an 18-G catheter. If necessary for sufficient angiography, the brachial artery was punctured or catheterized via groin access in selected cases. Successive angiographies were conducted to obtain diagnostic image data covering the afferent arterial inflow, the perfusion of the hemo-

dialysis fistula, and the efferent venous outflow up to the right heart ventricle. All patients were given an antithrombosis regimen with preinterventional injection of a 5000-IU intravenous heparin bolus.

Depending on the profile of the utilized interventional equipment, the sizes of the inserted sheaths ranged from 4-F to 8-F. Considering the location of the target lesion, an antegrade/retrograde approach via the hemodialysis fistula, an antegrade approach via the brachial artery or a transinguinal venous approach in selected cases of occlusion was chosen. Stenoses and occlusions were crossed with a hydrophilic 0.035-inch or 0.018-inch guide wire. Stenoses and fibrosclerotic occlusions were primarily dilated by plain balloon angioplasty. If that was insufficient with a residual stenosis of 30% or greater, cutting balloons were used. Thrombotic occlusions were aspirated manually, and aspiration was performed using 7-F and 8-F aspiration catheters and a 60-mL syringe. If necessary in long thrombotic occlusions, two sheaths were placed in “criss-cross” technique. No stents were deployed in the AV fistulas, and no thrombolytic agents were administered. The fistula puncture sites were sealed using a double U-shaped suture with interposition of a tapered plastic introducer [9], and the arterial puncture sites were manually compressed until complete hemostasis. Futile interventional revisions of dysfunctional hemodialysis fistulas were immediately referred to surgical revision.

Study Objectives

Three groups of interest were set as the primary objectives for statistical analysis:

- Time of day when the intervention was performed with the subgroups: routine working hours from 07:00 a.m. to 04:00 p.m. Monday through Friday and emergency working hours from 04:00 p.m. to 07:00 a.m. including the entire weekend (● Table 1).
- Interventionalist's level of experience with the subgroups: low level and high level. The level definitions were based on the number of interventions in dysfunctional hemodialysis fistulas per interventionalist during a two-year period before study onset (● Table 1).
- Specific lesion type with the subgroups: stenosis, fibrosclerotic occlusion, thrombotic occlusion, and combination of stenosis and additional thrombotic occlusion (● Table 1).

Statistical Analysis

Success was defined as a combination of initial technical success by angiographic evidence of a patent hemodialysis fistula and clinical success by at least one sufficient hemodialysis following intervention. For stenosis and fibrosclerotic occlusion, technical success was defined as residual stenosis of less than 30%. For each subgroup of the three groups of interest, the corresponding success rates were calculated. Cross tables were established for each group of interest, and Pearson's chi-square tests were calculated to search for significant differences among the subgroups (two-sided asymptotic significance with $p < 0.05$). A logistic regression analysis was performed to detect the variables with considerable impact on the success rate, providing the corresponding odds ratios of the relevant subgroups. As the statistical software, SPSS (Version January 2010; Chicago, IL, USA) was used.

Table 1 Definition of the three groups of interest with the specific subgroups.¹**Tab. 1** Definition der 3 Beobachtungsgruppen mit den spezifischen Untergruppen.²

group of interest	subgroup	definition
time of day	routine working hours	07:00a. m. to 04:00 p. m. Monday through Friday
	emergency working hours	04:00 p. m. to 07:00a. m. Monday through Friday and entire weekend
interventionalist's level of experience	low	≤ 30 interventions
	high	> 30 interventions
lesion type	stenosis	stenosis ≥ 50 % at arteriovenous anastomosis, fistula or central venous outflow
	fibrosclerotic occlusion	occlusion by fibrosclerosis in fistula or central venous outflow
	thrombotic occlusion	occlusion by thrombosis in fistula
	combined stenosis/thrombotic occlusion	combination of any stenosis and additional thrombotic occlusion of fistula

¹ Note: The ranges for the level of experience represent the number of interventions in acute dysfunctional hemodialysis fistulas performed during a two-year period before study onset.

² Anmerkung: Zur Festlegung des Erfahrungsgrads wurde die Anzahl an Interventionen in akut dysfunktionellen Hämodialyseshunt in den 2 Jahren vor Studienbeginn herangezogen.

Table 2 Distribution of interventions for each subgroup in the three groups of interest.**Tab. 2** Verteilung der Interventionen je Untergruppe in den 3 Beobachtungsgruppen.

group of interest	subgroup	intervention rate
time of day	routine working hours	56 % (136/241)
	emergency working hours	44 % (105/241)
interventionalist's level of experience	low	54 % (130/241)
	high	46 % (111/241)
lesion type	stenosis	47 % (114/241)
	fibrosclerotic occlusion	14 % (33/241)
	thrombotic occlusion	14 % (33/241)
	combined stenosis/thrombotic occlusion	25 % (61/241)

Table 3 Success rates for each subgroup in the three groups of interest.**Tab. 3** Erfolgsrate je Untergruppe in den 3 Beobachtungsgruppen.

group of interest	subgroup	success rate	Pearson's Chi-square
time of day	routine working hours	68 % (93/136)	
interventionalist's level of experience	emergency working hours	53 % (56/105)	
			p = 0.017
time of day	low	54 % (70/130)	
	high	71 % (79/111)	
			p = 0.022
	stenosis	82 % (94/114)	
	fibrosclerotic occlusion	39 % (13/33)	
	thrombotic occlusion	18 % (6/33)	
	combined stenosis/thrombotic occlusion	59 % (36/61)	
			p < 0.001

Results

Intervention and Success Rates

The distribution of the total n = 241 interventions by the time of day group was 56 % (136/241) for routine working hours versus 44 % (105/241) for emergency working hours (Table 2). For the level of experience group, 46 % (111/241) of the interventions were performed by interventionalists with a high level of experience and 54 % (130/241) by ones with less experience (Table 2). Concerning lesion type, most of the lesions treated were stenoses with 47 % (114/241) of the cases, followed by the combination of stenosis and additional thrombotic occlusion (Fig. 1) with 25 % (61/241) of the cases (Table 2).

The success rate for interventions conducted during routine working hours was 68 % (93/136) versus 53 % (56/105) for those conducted during emergency working hours, with p = 0.017 (Table 3). Depending on the level of the interventionalist's experience, the highest success rate was found for a high level of experience with 71 % (79/111) versus 54 % (70/130) for a low level of experience, with p = 0.022 (Table 3). In the lesion type group, stenoses were very likely to be treated successfully with 82 % (94/114) of the cases. The combination of stenosis and additional thrombotic occlusion had a success rate of 59 % (36/61), while

fibrosclerotic occlusions and especially thrombotic occlusions had low success rates of 39 % (13/33) and 18 % (6/33), respectively. The differences reached level of significance with p < 0.001 (Table 3).

The specific success rates were significantly better for stenoses treated during routine working hours by experienced interventionalists with 94 % (34/36) versus 74 % (31/42) (Table 4), with p < 0.001. During emergency working hours, the success rates for stenoses were similar with 80 % versus 81 %. The specific success rates were also significantly better for the combination of stenosis and additional thrombotic occlusion treated during routine working hours by experienced interventionalists with 84 % (16/19) versus 60 % (3/5) (Table 4), with p < 0.001. The corresponding success rates during emergency working hours were similar with 44 % versus 48 %. However, the success rate decreased significantly for that lesion type from 84 % during routine working hours to 44 % during emergency working hours, if treated by experienced interventionalists (Table 4). The majority of 5/6 successfully treated thrombotic occlusions were treated by experienced interventionalists, independent of the time of day (Table 4).

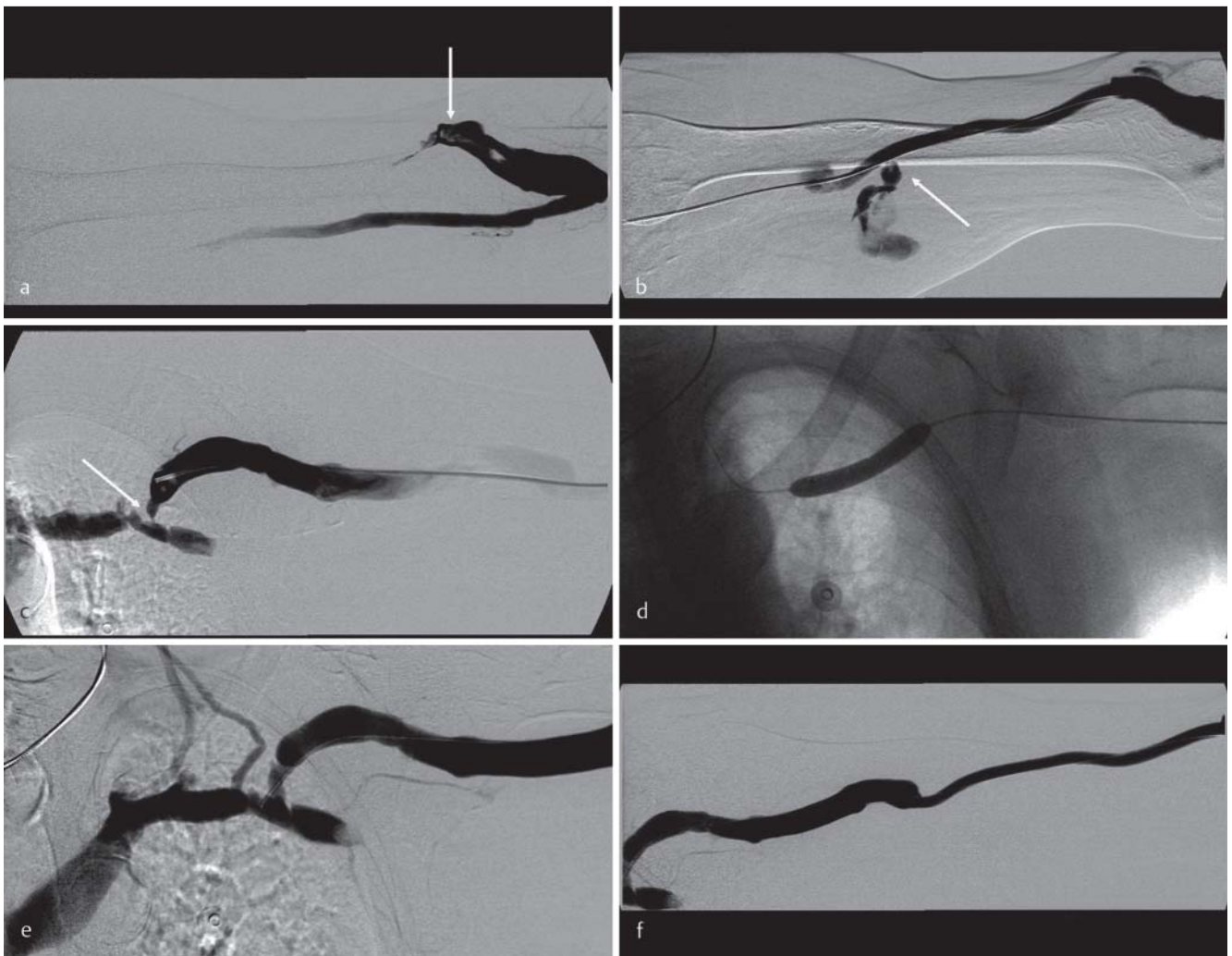


Fig. 1 64-year-old male ESRD patient with an interposed PTFE segment in a dysfunctional cephalic arteriovenous fistula on the left upper arm and a moderate hematoma after futile puncture for hemodialysis. Time of day, emergency working hours; interventionalist's level of experience, high; lesion type, combined stenosis and thrombotic occlusion. **a** The first angiogram confirms occlusion by thrombosis (white arrow), with the segment distal to the arteriovenous anastomosis patent. **b** After manual aspiration of thrombus, the control angiogram reveals active bleeding (white arrow) due to the futile puncture for hemodialysis. **c** Further manual aspiration reopens the fistula, and a severe stenosis at the conjunction of the cephalic into the subclavian vein (white arrow) can be detected as the underlying cause. **d** Dilation of the stenosis using an 8-mm balloon at an inflation pressure of 8 atm. **e, f** After gentle compression of the bleeding site, the final angiograms demonstrate restored patency of the fistula.

Abb. 1 64-jähriger dialysepflichtiger Mann mit interponiertem PTFE-Graft in einem dysfunktionellen Cephalicashunt am linken Oberarm und einem mäßigen Hämatom nach frustrierender Punktion zur Hämodialyse. Tageszeit: Notdienstzeit; Erfahrungsgrad Interventionalist: hoch; Läsionsart: kombinierte Stenose und thrombotischer Verschluss. **a** Die erste Angiografie zeigt einen thrombotischen Verschluss (weißer Pfeil) mit distal der arteriovenösen Anastomose offenem Segment. **b** Nach manueller Thrombusaspiration offenbart die Kontrollangiographie eine aktive Blutung (weißer Pfeil), entstanden nach frustrierender Punktion zur Hämodialyse. **c** Weitere manuelle Aspiration eröffnet den Shunt wieder, und eine hochgradige Stenose am Eintritt der V. cephalica in die V. subclavia (weißer Pfeil) stellt sich als zugrunde liegende Ursache heraus. **d** Dilatation der Stenose mit einem 8mm-Ballon bei 8 atm Inflationsdruck. **e, f** Nach sorgfältiger Kompression der Blutungsquelle zeigt die Abschlussangiografie einen wiedereröffneten Shunt.

	routine working hours		emergency working hours	
	high level of experience	low level of experience	high level of experience	low level of experience
stenosis	94 % (34/36)	74 % (31/42)	80 % (12/15)	81 % (17/21)
fibrosclerotic occlusion	38 % (3/8)	36 % (4/11)	57 % (4/7)	29 % (2/7)
thrombotic occlusion	50 % (2/4)	0 % (0/11)	50 % (3/6)	8 % (1/12)
stenosis + thrombotic occlusion	84 % (16/19)	60 % (3/5)	44 % (7/16)	48 % (10/21)

Table 4 Cross table providing the distribution of the specific success rates for each subgroup.

Tab. 4 Kreuztabelle mit Verteilung der einzelnen Erfolgsraten der jeweiligen Untergruppen.

Table 5 Logistic regression analysis providing the subgroups with relevant impact on the success rate.**Tab. 5** Darstellung der Untergruppen mit relevantem Einfluss auf die Erfolgsrate gemäß logistischer Regressionsanalyse.

subgroup	regression coefficient	standard deviation	p-value	odds ratio	lower bound 95 % CI	upper bound 95 % CI
high level of experience	0.833	0.332	0.012	2.300	1.199	4.410
stenosis	2.489	0.375	<0.001	12.053	5.774	25.158
combined stenosis/thrombotic occlusion	1.160	0.386	0.003	3.189	1.495	6.802

Specific Findings for Lesion Types

Fibrosclerotic occlusion

20/33 lesions were located on the upper arm and 13/33 lesions on the forearm, with success rates of 45 % (9/20) and 31 % (4/13), respectively. Among the 20 failed interventions, 3 cases were discontinued due to periinterventional perforation, strong pain, and wound healing deficit along the target lesion, respectively. 7/20 cases were occlusions of 10 cm or longer with additional extensive collaterals, 4/20 extending to the central venous outflow, 3/20 hemodialysis fistulas having not matured, and 2/20 sustained recoiling even not responding to cutting balloons. One case failed due to an additional occlusion of the brachial artery, which could not be crossed.

Thrombotic occlusion

17/33 lesions were located on the upper arm with 3/17 successful interventions, and 16/33 lesions were located on the forearm with 3/16 successful interventions. Three interventions were discontinued and referred to surgical revision due to periinterventional complications, with two cases of embolism of thrombotic material in the arterial vasculature and with one case of persistent bleeding at a puncture site. In 24 cases, the dysfunction was rated as early failure with occurrence of thrombosis within 60 days of creation, and the corresponding success rate was 17 % (4/24). Of these 24 cases, 10 cases had a thrombosis age of one week or older and failed, 8 cases had an unclear thrombosis age and failed, and 6 cases had a thrombosis age of up to one week with four successful interventions. Six cases of thrombotic occlusion were mature hemodialysis fistulas, with a success rate of 33 % (2/6). Of these six cases, three cases had a thrombus age of one week or older and failed, two cases had an unclear thrombus age with one successful intervention, and one case had a thrombus age of less than one week with successful intervention.

Combination of stenosis and additional thrombotic occlusion

36/61 lesions were located on the upper arm and 25/61 lesions on the forearm, with success rates of 64 % (23/36) and 52 % (13/25), respectively. Among the 25 failed interventions 4 cases were discontinued due to periinterventional perforation, embolism of thrombotic material in the arterial vasculature, arterial vasospasm of the afferent radial artery, and strong pain, respectively. 10/25 cases had a thrombus age of one week or older, and 2/25 an unclear thrombus age. 4/25 cases had additional fibrosclerotic occlusions extending to the central venous outflow. 3/25 cases were rated as early failure with occurrence of the lesions within 60 days of creation. One case failed due to sustained recoiling, even not responding to cutting balloons, and one case due to additional occlusion of the radial artery, which could not be crossed. Among the 36 successful interventions, 26/36 cases

had a thrombus age of less than one week, 4/36 a thrombus age of one week or older, and 6/36 an unclear thrombus age.

Logistic Regression Analysis

The predictability, which means to predict the outcome of the intervention under the influence of the abovementioned variables of the three groups of interest, was 73 % (177/241) for the total of $n = 241$ cases, 79 % (117/149) to achieve success during the intervention, and 65 % (60/92) for no success. In the logistic regression analysis, the variable high level of experience proved to be relevant with an odds ratio of 2.300, the lower bound of the 95 % confidence interval (CI) at 1.199 and the upper bound of the 95 % CI at 4.410 (Table 5). There were two variables among the four subgroups of lesion types that had a relevant impact on the success rate. The calculated odds ratio for the variable combination of stenosis and additional thrombotic occlusion was 3.189 with the lower bound of the 95 % CI at 1.495 and the upper bound of the 95 % CI at 6.802, while the odds ratio for the variable stenosis reached the highest level of 12.053 with the lower bound of the 95 % CI at 5.774 and the upper bound of the 95 % CI at 25.158 (Table 5).

Discussion

Patent vascular access is the basic prerequisite for adequate hemodialysis in patients with ESRD for sustaining quality of life and long-term survival [10]. As the anatomical locations for creating hemodialysis fistulas are limited, both the maintenance and the salvage of dysfunctional AV fistulas are key issues in the long-term care of ESRD patients. In the last two decades, there has been a gradual shift in the management of dysfunctional hemodialysis fistulas, with interventional radiology today playing the leading role in first-line treatment [7, 10 – 13]. Interventional revision of dysfunctional hemodialysis fistulas (Fig. 1) represents the least invasive procedure to re-establish sufficient blood flow, as compared to the alternative of surgical revision [7]. Numerous prospective and retrospective studies have demonstrated the value of an endovascular approach in salvaging hemodialysis fistulas with technical success rates of more than 90 % for dilation of stenoses [7, 10, 12 – 17] and of up to 90 % for declotting of thrombosed hemodialysis fistulas [7, 10, 18 – 25].

When reviewing the major guidelines for hemodialysis access, the EBPG and the KDOQI, we see a controversy that needs to be resolved. While it is stated in the EBPG that dysfunctional hemodialysis fistulas, without any further specification in terms of the lesion type, should be treated immediately [8], the KDOQI guidelines only specify that the thrombosed fistula should be treated urgently, and do not address optimal timing for other lesion types [6]. Furthermore, immediate revision of dysfunctional he-

modialysis fistulas would certainly be affected by an emergency setting, probably with a negative impact on the outcome. We designed our analysis to address this issue of the influence on the success rate when intervention is performed irrespective of the time of day, irrespective of the level of experience of the interventionalist available at that time, and irrespective of the specific lesion type.

For the group of interest "time of day", we found interventions being performed during routine working hours offer a significantly higher success rate than those during emergency working hours, with $p=0.017$. However, a closer look at the results of the logistic regression analysis did not prove that the time of day has a considerable impact on the success rate in our setting. This indicates that the relatively better results during routine working hours cannot easily be explained by better staffed teams in the angiographic theater during regular working hours versus only minimally staffed teams during emergency working hours. We consider the below mentioned factor "level of experience" to create this bias towards better results during routine working hours. For the group of interest "level of experience", there were significant differences in the success rates between a low and high level of experience, with $p=0.022$, which, of course, could have been expected. In the logistic regression analysis, a high level of experience was one of the three factors with relevant impact on the outcome of interventions in dysfunctional hemodialysis fistulas, with an odds ratio of 2.300. This underlines the importance of an experienced interventionalist treating complex lesions in dysfunctional hemodialysis fistulas in ESRD patients as presented in **Fig. 1**. It is obvious that the most experienced interventionalists would be available more often during routine working hours than during emergency working hours, thus explaining the different success rates with respect to the time of day. For the group of interest "lesion type", the success rates of the specific lesion types differed significantly, with $p<0.001$. With an overall success rate of 82%, the stenosis lesion type proved to have a high likelihood of being treated successfully. Our results indicate that if thrombotic events occur in addition to an underlying stenosis, the success rate decreases considerably down to a rate of 59% for the combination of stenosis and additional thrombotic occlusion.

Compared to data published in the literature with reported success rates of above 90% for stenosis treatment [7, 10, 12–17], the overall rate of 82% in our study remains somewhat lower, but the rate of 94% for stenoses treated during routine working hours by experienced interventionalists is equivalent to the literature. Our overall success rate of 59% for the treatment of stenosis and additional thrombosis, however, is considerably lower than the published results of up to 90% [7, 10, 19–21]. Again, the rate of 84% for lesions treated during routine working hours by experienced interventionalists corresponds to the literature. We see the abovementioned emergency setting as the major reason for our overall lower results, as the only acceptable success rate of 84% across all variables for this subgroup is found for interventions performed during routine working hours by experienced interventionalists. Additionally, only manual aspiration maneuvers were performed in clotted hemodialysis fistulas. Maybe, the use of mechanical thrombectomy devices could have offered better results, as reported in the literature [19–21]. The thrombus age had a considerable influence on the outcome of the intervention, as there was a high proportion of 40% (10/25) of the cases with older thrombus among the failed interventions, and a high proportion of 72% (26/36) of the cases with fresh thrombus among

the successful interventions. Nevertheless, the lesion type combination of stenosis and additional thrombosis with an odds ratio of 3.189 and the lesion type stenosis with the very high odds ratio of 12.053 had a relevant influence on the success in our analysis.

Fibrosclerotic occlusions, usually caused by repeated punctures [26] along the AV fistula for hemodialysis over a long period of time, showed a fairly low success rate of 39%. The majority of 55% (11/20) of the failed interventions were long lesions with extensive collaterals or extending to the central venous outflow, indicating chronically progressive disease. Recently, Chen et al. reported a similarly low success rate of 46% in their study population for reopening occluded fibrosclerotic lesions [27]. If interventional recanalization of these occluded fibrosclerotic segments of AV fistulas fails via both antegrade and retrograde approach, surgical revision should be sought early to avoid the formation of extensive collateralization. There were three mentionable cases each of failed interventions in hemodialysis fistulas having not matured in the subgroups, fibrosclerotic occlusion and combination of stenosis and additional thrombotic occlusion. Sheer thrombotic occlusions were very unlikely to be treated successfully with a total success rate of only 18%. The high proportion with 24 cases of early failure of hemodialysis fistulas among thrombotic occlusions may explain the discouraging success rate. The thrombus age also has to be considered as a relevant factor with the majority of cases with older thrombus among the failed interventions and with almost all successful interventions at fresh thrombus. Unfortunately, a sheer thrombotic occlusion may not be distinguished from the combination of stenosis and thrombotic occlusion as the thrombosis usually masks the underlying stenosis. Thus, it is not possible to state that sheer thrombosis should immediately be referred to surgical revision. In a recent study by Yurkovic et al., similarly low success rates of only up to 17% are reported for declotting hemodialysis grafts [18]. Mudunuri et al. found similarly poor primary and cumulative patency for thrombectomy of early graft failure, stating it may not be worthwhile [28]. However, they focused on early graft failure and investigated the outcomes of thrombectomy procedures, thus their results cannot easily be compared to ours. Additional investigations have to follow to understand the pathomechanism of thrombosis in hemodialysis fistulas, and more efficacious techniques have to be identified for interventional revision of that lesion type [18].

There are several limitations in this study that should be addressed. First, it was not planned and conducted as a prospective, randomized trial, but only as an observational study with consecutive patient enrollment. Second, we did not check for the patency rates of the treated hemodialysis fistulas, which, however, was not mandatory to target the study's objective. Third, it remains unclear whether the results for declotting sheer thrombosis could have been better, if other declotting equipment and thrombolytic agents would have been utilized rather than just performing manual aspiration maneuvers.

Our study offers results for interventions in acute dysfunctional hemodialysis fistulas in a real life setting. We do not recommend unrestricted implementation of the EBPG in terms of immediate interventional revision, as our results suggest the availability of an experienced interventionalist, which has recently been highlighted by the Qualification Guideline of the DRG and DeGIR [29] and is more likely during routine working hours. Furthermore, the decrease in the success rates from stenosis to stenosis with additional thrombosis emphasizes the need to avoid any thrombotic

event, since thrombosis may become impossible to resolve [11]. The success rates for fibrosclerotic and thrombotic occlusions remain unsatisfactory.

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Dedication

Herrn Prof. Heller zur Emeritierung gewidmet.