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► To cite this version:

Carole Philipponnet, Julien Aniort, Bruno Pereira, Kazra Azarnouch, Mohammed Hadj-Abdelkader, et al.. Systematic Review of Atrial Vascular Access for Dialysis Catheter. *Kidney International Reports*, 2020, 5, pp.1000 - 1006. 10.1016/j.ekir.2020.04.006 . hal-03491670

HAL Id: hal-03491670

<https://hal.science/hal-03491670>

Submitted on 15 Jul 2022

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Systematic Review of atrial vascular access for dialysis catheter

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Running title: Atrial vascular access for dialysis catheter: a salvage approach

ABSTRACT

Introduction :The last decade has seen a steady increase worldwide in the prevalence of end stage renal disease. Hemodialysis is the major modality of renal replacement therapy in 70 to 90% of patients, who require well-functioning vascular access for this procedure

The recommended access for hemodialysis is an arteriovenous fistula or a vascular graft. However, recourse to central venous catheters remains essential for patients whose chronic renal disease is diagnosed at the end stage or in whom an arteriovenous fistula cannot be created or maintained. Tunneled dialysis catheter (TDC) exposure can induce venous stenosis and occlusions and result in superior vena cava syndrome and/or vascular access loss. Exhaustion of conventional vascular accesses is one of the greatest challenges that nephrologists and patients have to face. Several unconventional salvage-therapy routes for TDC placement in patients with exhausted upper body venous access have been reported in the literature.

Methods :We report two new cases of intra atrial TDC placement for patients with exhausted vascular access and make a meta-analysis of cases from the literature.

Results :51 patients were included. The TDC was inserted by a cardiovascular surgeon in all cases. At the end of follow-up, 75% patients were alive. The median survival time was 25 months. Survival time of hemodialysis patients with intra atrial TDC was lower than that observed with conventional TDC.

Conclusion :This unconventional technique is safe and functional for hemodialysis patients with exhausted venous access. Atrial vascular access for TDC placement is salvage therapy and is therefore potentially lifesaving.

Key words:

Dialysis catheter; hemodialysis; intra-atrial catheter; exhausted vascular accesses.

Introduction

Over the past decade there has been a steady increase in the prevalence of end stage renal disease (ESRD) worldwide, with more than 2 million patients requiring renal replacement therapy (RRT). Hemodialysis is the major modality of RRT in 70 to 90% of patients, who need well-functioning vascular access for the procedure.

We report two hemodialysis patients with exhausted venous access who underwent atrial vascular access for tunneled dialysis catheter (TDC) placement to provide RRT, in one case for ESRD and for prolonged acute kidney injury (AKI) in the other. We combined these two patient reports with all previously published cases involving a similar intravascular device to carry out a systematic meta-analysis.

Methods

Study selection

The data of the two patients in our center with an intra-atrial hemodialysis catheter inserted between January 2010 and October 2019 were recorded. To identify relevant articles and abstracts of previously published cases of patients who had undergone the same procedure, a systematic literature search was performed using medical subject headings (MESH) in EMBASE, CENTRAL and MEDLINE (1980 to April 2019). The search was restricted to English language publications involving humans. The keywords used were ("renal dialysis"[MH] OR "hemodialysis"[TW] OR "kidney dialysis"[TW] OR "haemodialysis"[TW] OR "extracorporeal dialysis"[TW] OR "extracorporeal dialyses"[TW] OR "renal dialysis"[TW] OR "renal dialyses"[TW] OR "dialysis renal"[TW] OR "hemodialyses"[TW]) AND ("cardiac catheterization"[MH] OR "heart catheterization"[TW] OR "cardiac catheterization"[TW] OR "heart catheterizations"[TW] OR "catheterization cardiac"[TW] OR "cardiac catheterizations"[TW] OR "cardiac catheters"[MH] OR "cardiac catheter"[TW] OR "heart catheters"[TW] OR "intracardiac catheters"[TW] OR "intracardiac catheter"[TW] OR "heart

catheter"[TW] OR "cardiac catheters"[TW] OR intra-atrial catheter*[TW] OR (intra-atrial[TW] AND catheter*[TW])).We also hand-searched abstracts from international meetings.

Inclusion/exclusion criteria

The inclusion criteria for studies (including case reports) and patients were ESRD requiring hemodialysis and use of an intra-atrial hemodialysis catheter. The search process, eligibility assessment and data extraction were performed independently by two physicians (CP and BS). The study was performed in accordance with the PRISMA statement : Flow chart is in Figure 1; Prisma checklist in Supplementary file S1. Prospero register number : CRD42019115344.

Quality assessment

Quality assessment was made independently by three investigators (CP, BS and BP) using the framework developed by Murad et al. to evaluate the methodological quality of case reports/series (1). The level of evidence on this pyramid ranges from 0 to 10, with five items being measured and awarded 0, 1 or 2 points each. We assessed case and case series quality with a dedicated tool based on the criteria of Pierson, Bradford Hills and the Newcastle-Ottawa scale (1). Of the 8 items, 5 were analyzed in all the case and case series but the 4th, 5th and 6th items were considered as not relevant (applicable to cases of adverse drug events). The items were rated on a scale of 10 points: 0, not satisfactory; 1, partially satisfactory; and 2, satisfactory. The first item was considered satisfactory if the study described explicitly all the patients who had an IATDC over a certain period of time. The second item was considered satisfactory if exposure was adequately ascertained. The third was considered satisfactory if outcome was adequately ascertained with catheter patency and patient's outcome. The seventh item, which assesses whether follow-up was long enough for outcomes to occur, was considered satisfactory either when a competitive event occurred (kidney transplantation, switch from hemodialysis to peritoneal dialysis or hemodialysis weaning) or when follow-up duration was at least 25 months, which corresponds to the median survival time of our study population. The seventh item was

considered partially satisfactory when follow-up duration was between 7 and 24 months, with 7 months corresponding to the first interquartile of the median survival time of our study population. The last item was considered satisfactory if a surgeon could replicate the insertion procedure using the surgical description. Study quality is detailed in Supplementary File S2.

Data management and statistical analysis

Statistical analysis was performed with Stata software (version 13; StataCorp, College Station, TX, USA). For descriptive analyses, data were presented as individual data for case reports and as median [interquartile range] for case series. All analyses took into account between- and within-study variability. To address the non-independence of data due to clustering by study, random-effects models were preferred over the usual statistical tests. The percentage of alive patients was estimated with the random-effects model as described by Der Simonian and Laird (2). The statistical heterogeneity in results was assessed on confidence intervals and I^2 , which quantifies inconsistency across studies describing the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error. Values of I^2 range between 0 and 100% and are typically considered low at < 25%, moderate at 25–50%, and high at > 50%. Overall survival was then estimated, excluding study for which individual follow-up data were not available (10), by the Fine and Gray method (3), with censoring at the date of death and at the date of kidney transplantation, switch to peritoneal dialysis and renal recovery, defined as competing events. This analysis concerned 24/51 patients.

Results

Patients

The first patient was a 58-year-old man with mesangial IgA nephropathy requiring hemodialysis and placement of a left radiocephalic AVF. His medical history included ischemic cardiopathy and severe arteritis treated by aortobifemoral bypass. He underwent

unsuccessful kidney transplantation, which resulted in hyperimmunization. Peritoneal dialysis was ruled out because of anuria and poor compliance.

A tunneled dialysis catheter (TDC) was placed in the right internal jugular vein after AVF thrombosis had occurred. It was removed when a left humeral-cephalic AVF was functional. The AVF required multiple angioplasties for stenosis and was ultimately occluded by thrombosis. A second TDC was placed in the left internal jugular vein. The clinical course was complicated by five TDC-related septic shocks which required admission to the intensive care unit, systemic antibiotics and a TDC replacement in the interventional radiology department after venous dilatation. All CT-scan and angiographies carried out to assess the vascular network showed extensive thrombosis of the brachiocephalic vein confluence and the proximal portion of the superior vena cava. The patient underwent aortic valve replacement for severe aortic stenosis and coronary artery bypass graft. During the cardiac surgery the TDC was ablated and replaced by a new TDC directly inserted into the superior vena cava. Because of malfunction, the TDC was exchanged over a guidewire by the interventional radiologist. A new TDC-related septic shock occurred, the TDC was removed in the operating room, and systemic antibiotics were introduced for long-term treatment. A temporary hemodialysis catheter was placed at the right femoral site for 15 days, and replaced by a TDC inserted directly into the right atrium by the cardiac surgeon as salvage therapy (Figure 2). Trans lumbar, trans hepatic or trans renal TDC are also salvaging approach for the vascular access. In our center, we had no experience on these techniques and a multidisciplinary meeting retained the indication of an IATDC.

The surgical procedure was as follows. Approach by right anterior thoracotomy at the 3rd intercostal space; partial adhesiolysis to free up the right lateral pericardium surface; opening of this segment of the pericardium and placement of two cuffs up against the Teflon tips on the right atrium, ready to hold the hemodialysis catheters in place; placement of Surgicel® fibrillar™ hemostat in the lumens to facilitate remote hemostasis if catheter ablation is needed; catheter tunneling via the intercostal space, just below the thoracotomy space; second tunneling path toward the lateral face of the right pectoralis major and catheter

exchange over guidewire; layer-by-layer closure of the various incisions; end-of-procedure transesophageal echocardiogram to check the position of the two catheter tips. Any adverse events associated with intra atrial TDC catheter placement such as arrhythmia, troponin elevation, myocardial dysfunction were noted. Nineteen months later, the patient died of metastatic bronchoalveolar carcinoma with a functional IATDC.

The second patient was a 30-year-old man with no past medical history admitted to the intensive care unit after a car accident that had caused multiple bone fractures, dissection of the left renal artery, and ischemic necrosis of the colon requiring multiple orthopedic surgeries and colectomy with ileostomy. Surgical and radiological attempts to restore left kidney perfusion failed. During his ICU stay the patient developed multiple episodes of septic shock that required courses of antibiotics including nephrotoxic antibiotics. He received several injections of iodinated contrast agents for diagnostic imaging and interventional radiology treatments.

RRT for AKI was initiated using a left internal jugular temporary hemodialysis catheter subsequently changed at the right and left femoral sites. All the catheters were complicated by septic thrombophlebitis and finally removed. A CT-scan was performed to identify an insertion site appropriate for venous access. It showed multiple thrombosis of the left internal jugular extended to the left innominate venous trunk, at the superior vena cava, the right brachiocephalic artery and at the initial segment of the right internal jugular vein, and of the right and left iliac veins. Peritoneal dialysis was ruled out because of prior abdominal surgery. Thus, the cardiovascular surgeon placed a new TDC directly into the right atrium to allow RRT using the surgical procedure described above. Four months later the patient recovered kidney function, and the IATDC was removed at bedside without additional precautions compared to the removal of tunneled catheters. On the other hand, systematic monitoring was carried after removal by ultrasound to ensure the absence of pericardial effusion. No TDC complication occurred with this last TDC. Two years later, the patient was still alive and free from dialysis.

Literature review

The above procedure of intra-atrial hemodialysis catheter insertion has been described in four case reports (4-7) and four small case series (8-11). The quality assessment of the studies is given in Supplemental file S2. With the addition of our 2 patients, a total of 51 patients were included in the meta-analysis. Their characteristics and outcomes are shown in Table 1. All the patients had exhausted conventional vascular accesses: they were not suitable for peritoneal dialysis or emergency kidney transplantation. All the IATDCs were inserted by a cardiovascular surgeon using the same procedure as that described in our first case report. Six patients developed IATDC-related sepsis one of whom died as a result. At the end of follow-up 38/51 patients were still alive (Figure 2). Seven patients died within 15 days following IATDC insertion: three catheter-related deaths and four unrelated catheter deaths (myocardial infarction N=2, sepsis N=1, metabolic N=1). Six additional patients died later than 15 days after IATDC insertion, from non-catheter-related sepsis (N=2), cerebrovascular events (N=2), neoplasia (N=1), and unknown causes (N=1). The 24/51 patients for whom individual follow-up data were available had a median survival time of 25 [7-not applicable] months (Figure 3) whereas the median survival described in Oguz et al., study with no individual follow-up data available, was 27.5 ± 14 .

Discussion

Therapy for end stage renal disease (ESRD) requires kidney transplant or RRT including peritoneal dialysis and hemodialysis. Hemodialysis is sometimes the only technique that can be performed in patients with both contra-indication to kidney transplant (e.g. patients with active tumor growth or very severe polyvascular disease) and peritoneal dialysis (e.g. patients with prior abdominal surgeries). In these patients, the lack of vascular access results in fatal outcome. The recommended access for hemodialysis in ESRD patients is an arteriovenous fistula (AVF) or a vascular graft. However, recourse to central venous catheters remains essential for patients whose chronic renal disease is diagnosed only at the end stage or in whom an arteriovenous fistula cannot be created or maintained. When it is necessary to use permanent dialysis catheters it is recommended to use tunnelled dialysis catheters (TDC) inserted in the internal jugular vein.

Exhaustion of conventional vascular accesses is one of the greatest challenges that nephrologist and patients have to face. TDC exposure can result in venous stenosis and occlusions and superior vena cava syndrome and/or vascular access loss (12). Most recent works on innovations in chronic hemodialysis catheters have focused on new materials (such as carbothane and polyurethane) and new designs to prevent catheter-associated complications (13).

Several unconventional salvage-therapy routes for TDC placement have been used in patients with no upper body venous access (14) including: (i) needle recanalization (through a thrombosed vessel or by creating a new tract to the central vasculature through a small venous collateral or through the subcutaneous tissues (15,16)), (ii) a translumbar approach (direct percutaneous puncture in the infrarenal inferior vena cava) (17,18), (iii) a transhepatic approach (direct percutaneous puncture in the inferior vena cava via the right or middle hepatic vein) (19,20), and (iv) a transrenal approach (direct percutaneous puncture in the inferior vena cava via the renal vein) (21,22). Intra-atrial placement is an alternative strategy. To the best of our knowledge, the present study collates all published cases of patients with an IATDC. As shown, IATDC exchange or removal for dysfunction, thrombosis or infection was scarce suggesting that IATDC patency was good, achieved adequate blood flow rates, and that IATDC placement was associated with prolonged survival.

In the US Renal Data System, 510 000 ESRD patients initiated hemodialysis between 2006 and 2010. Of the 82,5% patients receiving dialysis with a TDC, 78% had 1-year survival and 45% 5 year-survival with a median survival time of 3 years (23). In our meta-analysis, median survival time in patients with an IATDC was 25 [7-NA] months (Figure 3). These findings suggest that the survival time observed in patients with an IATDC is lower than in patients with conventional TDC. However, the population with an IATDC formed a subgroup of patients with highly severe comorbid conditions.

Our study has several strengths. First, we performed a quality assessment of cases and case series with a validated tool (1). Second, we identified for the first time all patients with

an IATDC and describe the successful use of an unrecognized technique as salvage therapy.

Our study has also several major limitations. First, the patients were retrospectively identified in our center and in documented reports and hence we cannot rule out the possibility that some with IATDC were not included. However, a randomized controlled trial would have been impossible because there was no other alternative therapy. Second, only 51 patients were included in the analysis. At the same time, however, IATDC is a very rare procedure. Third, individual data from one case series were not available and hence these patients could not be included in the Kaplan Meier analysis (10).

In conclusion, IATDC is an unconventional but safe procedure for adequate vascular access in hemodialysis patients with exhausted venous access. The technique requires a collaborative multidisciplinary approach involving radiologist, cardiac surgeon and nephrologist.

Atrial vascular access for TDC placement can potentially be lifesaving.

Disclosures:

-Author financial disclosures :none

- Funding statement:

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors”.

- Competing Interests Statement:

This research has any competing interests

Supplementary material :

S1 : Prisma checklist

S2 : Quality assessment of the studies

Supplementary information is available at KI Report's website.

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Acknowledgements

We thank Jeffrey Watts for his help with traduction.

FIGURES LEGENDS:

Figure 1: Prima Flow Diagram

Figure 2: Intra-atrial tunneled dialysis catheter in patient n°1

Figure 3: Survival time with intra-atrial tunneled dialysis catheter (in 24 patients)

Table 1: Characteristics of patients and outcomes in the different studies on IATDC

	Number of patients	Sex	Age (years) ^a	Dialysis time (month) ^b	Follow up (months)	IATDC infection/dysfunction	Outcome
Chavanon 1999 (1)	1	M	43	36	4	1/1	Transplantation
Santos Araujo 2006 (2)	1	F	33	156	36	0/0	Pursuit hemodialysis
Wales 2008 (3)	1	M	46	120	3	0/0	Pursuit hemodialysis
Agrawal 2009 (6)	3	F	65	84	7	1/0	Death
Agrawal 2009 (6)		M	41	372	25	1/1	Death
Agrawal 2009 (6)		F	42	120	15	0/1	Transplantation
Villagran 2011 (4)	1	F	55	60	10	0/0	Pursuit hemodialysis
Pereira 2017 (8)	7	F	76	28	0,1	1/0	Death
Pereira 2017 (8)		M	54	17	1,2	1/1	Death
Pereira 2017 (8)		F	65	149	3,3	0/1	Death
Pereira 2017 (8)		M	74	111	23,9	0/0	Peritoneal dialysis
Pereira 2017 (8)		F	69	50	0,36	0/0	Death
Pereira 2017 (8)		F	81	96	50	0/1	Pursuit hemodialysis
Pereira 2017 (8)		F	44	80	11,7	1/1	Pursuit hemodialysis
Yasa 2007 (5)	8	NA	54 (38-66) ^c	NA	10,2 (3-15) ^c	NA	1 death / 7 Pursuit hemodialysis
Oguz 2012 (7)	27	10 M / 17 F	59 (47-71) ^c	78,9 (33-130) ^c	NA	0/3	5 deaths / 22 Pursuit hemodialysis
Philipponnet 2020	2	M	30	1	4	0/0	Hemodialysis weaning
Philipponnet 2020		M	58	196	19	0/0	Death

F, female ; IATDC, intra-atrial tunneled dialysis catheter ; M, male ; NA, not available

a, Age at the time of IATDC placement ; b, Time between end-stage renal disease and IATDC placement; c, mean and standard deviation



PRISMA Flow Diagram

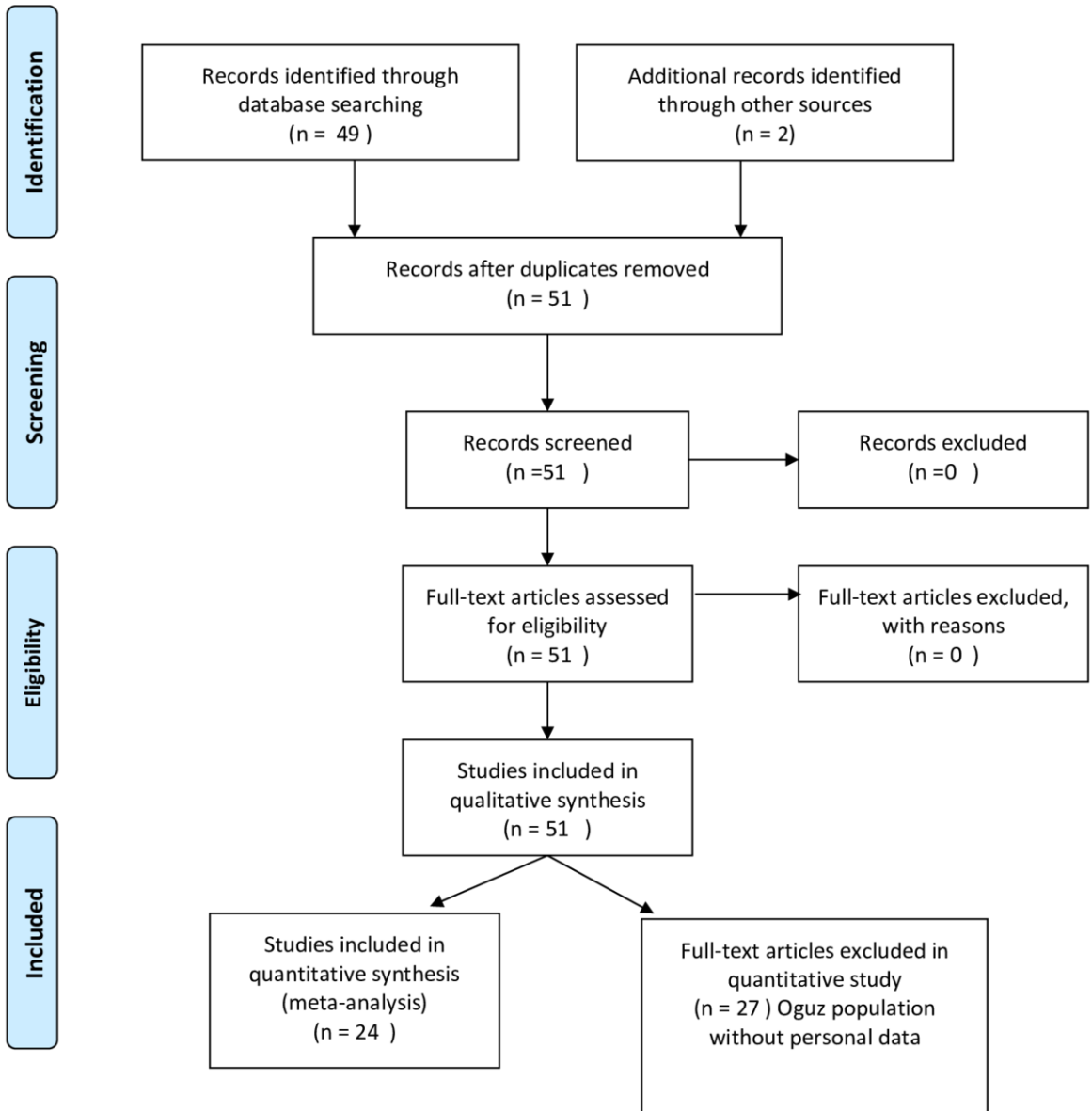


Figure 1 : Prisma Flow Diagram

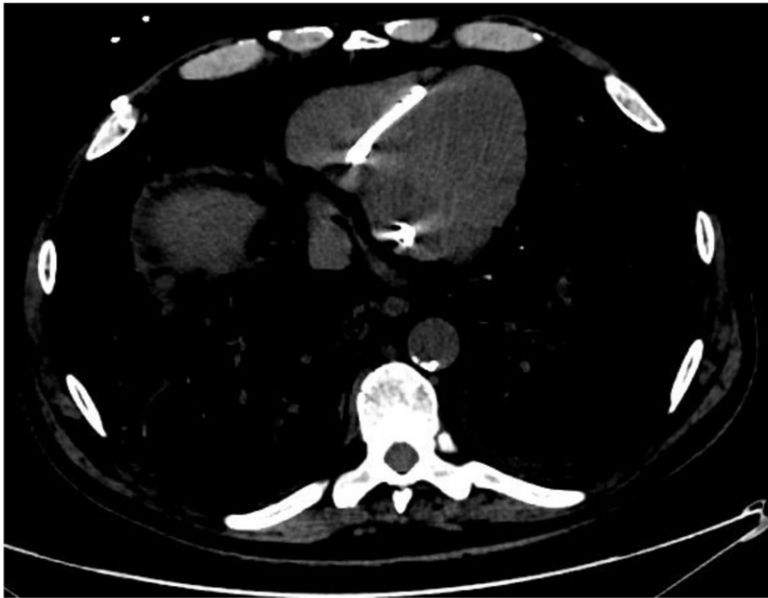


Figure 2: Intra-atrial tunneled dialysis catheter in patient n°1 (computed tomography scan).

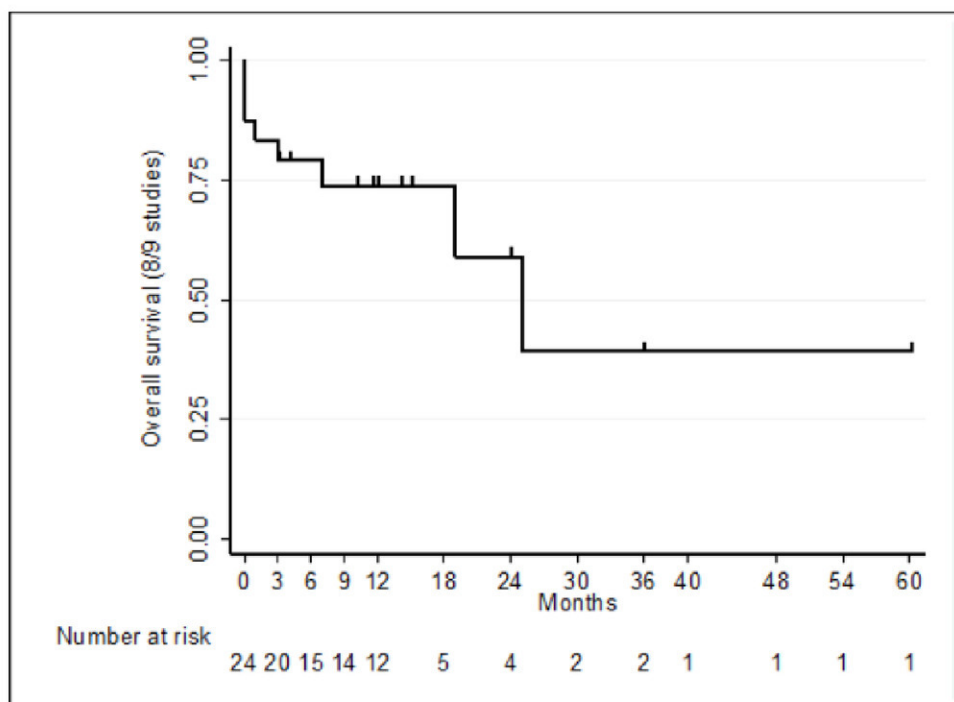


Figure 3: Survival time with intra-atrial tunneled dialysis catheter (in 24 patients)