Introduction: The last decade has seen a steady increase worldwide in the prevalence of end-stage renal disease (ESRD). Hemodialysis is the major modality of renal replacement therapy (RRT) 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 can result in superior vena cava syndrome and/or vascular access loss. Exhaustion of conventional vascular accesses is 1 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 2 new cases of intra-atrial TDC placement for patients with exhausted vascular access and perform a meta-analysis of cases from the literature.

Results: A total of 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.

Conclusions: 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.

Methods: We report 2 new cases of intra-atrial TDC placement for patients with exhausted vascular access and perform a meta-analysis of cases from the literature.

Results: A total of 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.

Conclusions: 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.

Kidney Int Rep (2020) 5, 1000–1006; https://doi.org/10.1016/j.ekir.2020.04.006

KEYWORDS: dialysis catheter; exhausted vascular accesses; hemodialysis; intra-atrial catheter

© 2020 International Society of Nephrology. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
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). For descriptive analyses, data were presented as individual data for case reports and as median and interquartile range for case series. All analyses took into account between-study 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 DerSimonian and Laird. The statistical heterogeneity in results was assessed on confidence intervals and I², 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 I² range between 0% and 100% and are typically considered low at <25%, moderate at 25% to 50%, and high at >50%. Overall survival was then estimated, excluding study for which individual follow-up data were not available, by the Fine and Gray method, 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 of 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 arteriovenous fistula (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 5 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 computed tomography scans 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 approaches for vascular access. In our center, we had no experience with these techniques, and a multidisciplinary meeting retained the indication of an IATDC.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.1

Figure 2. Intra-atrial tunneled dialysis catheter in patient 1.
The surgical procedure was as follows: approach by right anterior thoracotomy at the third intercostal space; partial adhesiolysis to free up the right lateral pericardial surface; opening of this segment of the pericardium, and placement of 2 cuffs up against the Teflon tips on the right atrium, ready to hold the hemodialysis catheters in place; placement of Surgicel fibrillar hemostat (Johnson & Johnson Medical N.V., Diegem, Belgium) 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 2 catheter tips. Any adverse events associated with IATDC catheter placement such as arrhythmia, troponin elevation, or 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 who was 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 intensive care unit 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.

Renal replacement therapy for acute kidney injury was initiated using a left internal jugular temporary hemodialysis catheter that was subsequently changed at the right and left femoral sites. All the catheters were complicated by septic thrombophlebitis and finally removed. A computed tomography 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 renal RRT using the surgical procedure described above. Four months later, the patient recovered kidney function, and the IATDC was removed at the bedside without additional precautions compared to the removal of tunneled catheters. 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 of dialysis.

**Literature Review**

The above procedure of intra-atrial hemodialysis catheter insertion has been described in 4 case reports and 4 small case series. The quality assessment of the studies is given in Supplementary 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, 1 of whom died as a result. At the end of follow-up, 38 of 51 patients were still alive (Figure 2). Seven patients died within 15 days following IATDC insertion: 3 catheter-related deaths and 4 non–catheter-related 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 of 51 patients for whom individual follow-up data were available had a median survival time of 25 (7-not determined) months (Figure 3), whereas the median survival described in the Oguz et al. study, with no individual follow-up data available, was 27.5 ± 14.

**DISCUSSION**

Therapy for ESRD requires kidney transplantation or RRT, including peritoneal dialysis and hemodialysis. Hemodialysis is sometimes the only technique that can be performed in patients with contraindications to both kidney transplantation (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 outcomes. The recommended access for hemodialysis in ESRD patients is an 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 TDCs inserted in the internal jugular vein.

Exhaustion of conventional vascular accesses is 1 of the greatest challenges that nephrologist and patients
have to face. Exposure of TDCs can result in venous stenosis and occlusions and superior vena cava syndrome and/or vascular access loss. 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.

Several unconventional salvage-therapy routes for TDC placement have been used in patients with no upper body venous access, 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), (ii) a translumbar approach (direct percutaneous puncture in the infrarenal inferior vena cava), (iii) a transhepatic approach (direct percutaneous puncture in the inferior vena cava via the right or middle hepatic vein), and (iv) a transrenal approach (direct percutaneous puncture in the inferior vena cava via the renal vein). Intratra-atrial placement is an alternative strategy.

To the best of our knowledge, the present study collates all published cases of patients with an IATDC.

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

| First author, year | No. of patients | Sex | Age (yr)
|--------------------|----------------|-----|--------|
| Chavanon et al., 1999 | 1 | M | 43 |
| Santos-Araujo et al., 2006 | 1 | F | 33 |
| Wales et al., 2008 | 1 | M | 46 |
| Agrawal et al., 2009 | 3 | F | 65 |
| Agrawal et al., 2009 | M | 41 |
| Agrawal et al., 2009 | F | 42 |
| Villagran et al., 2011 | 1 | F | 55 |
| Pereira et al., 2017 | 7 | F | 76 |
| Pereira et al., 2017 | M | 54 |
| Pereira et al., 2017 | F | 65 |
| Pereira et al., 2017 | M | 74 |
| Pereira et al., 2017 | F | 69 |
| Pereira et al., 2017 | F | 81 |
| Yosa et al., 2007 | 8 | N/A |
| Oguz et al., 2012 | 27 | M/17 F |
| Phillipponnet et al., 2020 (current study) | 2 | M | 30 |
| Phillipponnet et al., 2020 (current study) | M | 58 |

| Dialysis time (mo)
|------------------|
| 36 |
| 156 |
| 120 |
| 84 |
| 372 |
| 120 |
| 60 |
| 28 |
| 17 |
| 149 |
| 111 |
| 50 |
| 96 |
| 80 |
| 54 (38–66) |
| 59 (47–71) |
| 78.9 (33–130) |
| 1 |
| 30 |
| 196 |

| Follow-up (mo)
|------------------|
| 4 |
| 36 |
| 7 |
| 25 |
| 15 |
| 10 |
| 0.1 |
| 28 |
| 1.2 |
| 3.3 |
| 23.9 |
| 0.36 |
| 50 |
| 11.7 |
| N/A |
| N/A |
| 10.2 (3–15) |
| N/A |
| 1 |
| 3 |
| 4 |
| 19 |

| IATDC infection/dysfunction
|-----------------------------|
| 1/1 |
| 0/0 |
| 1/0 |
| 1/1 |
| 1/0 |
| 0/0 |
| 0/1 |
| 1/1 |
| 0/1 |
| 0/0 |
| 0/1 |
| 1/1 |
| 0/1 |
| N/A |
| N/A |
| 0/3 |
| 0/0 |
| 5 Deaths/22 pursued hemodialysis |
| 1 Death/7 pursued hemodialysis |
| Hemodialysis weaning |

Outcome

| Transplantation |
| Pursued hemodialysis |
| Death |
| Pursued hemodialysis |
| Transplantation |
| Death |
| Pursued hemodialysis |
| Death |
| Peritoneal dialysis |
| Death |
| Pursued hemodialysis |
| Pursued hemodialysis |
| Death |
| Pursued hemodialysis |
| Hemodialysis weaning |
| Death |

IATDC, intra-atrial tunneled dialysis catheter; N/A, not available.

| aAge at the time of IATDC placement.
| bTime between end-stage renal disease and IATDC placement.
| cMean and SD.

Figure 3. Survival time with intra-atrial tunneled dialysis catheter in 24 patients.
As shown, IATDC exchange or removal for dysfunction, thrombosis, or infection was scarce, suggesting that IATDC patency was good, that it achieved adequate blood flow rates, and that IATDC placement was associated with prolonged survival.

In the US Renal Data System, approximately 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.2 Second, we identified for the first time all patients with an IATDC and described the successful use of an unrecognized technique as salvage therapy.

Our study also has 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 1 case series were not available, and hence these patients could not be included in the Kaplan–Meier analysis.1

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 a radiologist, cardiac surgeon, and nephrologist. Atrial vascular access for TDC placement can potentially be lifesaving.

DISCLOSURE

All the authors declared no competing interests.

ACKNOWLEDGMENTS

We thank Jeffrey Watts for his help with translation. This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

REFERENCES

1. Oguz E, Ozturk P, Erkul S, Calkavur T. Right intra-atrial catheter placement for hemodialysis in patients with multiple venous failure. Hemodial Int. 2012;16:306–309.
2. Murad MH, Sultan S, Haffar S, Bazerbachi F. Methodological quality and synthesis of case series and case reports. BMJ Evid Based Med. 2018;23:60–63.
3. Der Simonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials. 1986;7:177–188.
4. Fine JP, Gray RJ. A proportional hazards model for the subdistribution of a competing risk. J Am Stat Assoc. 1999;94:96–1009.
5. Chavanon O, Maurizi-Balzan J, Chavanis N, et al. Successful prolonged use of an intracardiac catheter for dialysis. Nephrol Dial Transplant. 1999;14:2015–2016.
6. Santos-Araújo C, Casanova J, Carvalho B, Pestana M. Prolonged use of an intracardiac catheter for dialysis in a patient with multiple venous access failure. Nephrol Dial Transplant. 2006;21:2670–2671.
7. Wales L, Anderson JR, Power A, et al. End-stage vascular access: direct intra-atrial insertion of a dialysis catheter. Exp Clin Transplant. 2008;6:169–170.
8. Villagrán Medinilla E, Carnero M, Silva JA, Rodríguez JE. Right intra-atrial catheter insertion at the end stage of peripheral vascular access for dialysis. Interact Cardiovasc Thorac Surg. 2011;12:648–649.
9. Yaşa H, Lafci B, İlhan G, et al. Placing of permanent catheter through right anterior mini thoracotomy in patients with chronic renal failure. EJVES Extra. 2007;13:90–91.
10. Agrawal S, Alaly JR, Misra M. Intracardiac access for hemodialysis: a case series. Hemodial Int. 2009;13(suppl 1). S18–23.
11. Pereira M, Lopez N, Godinho I, et al. Life-saving vascular access in vascular capital exhaustion: single center experience in intra-atrial catheters for hemodialysis. J Bras Nefrol. 2017;39:36–41.
12. Agarwal AK, Khabiri H, Haddad NJ. Complications of vascular access: superior vena cava syndrome. Am J Kidney Dis. 2017;69:309–313.
13. Agarwal AK, Haddad NJ, Vachharajani TJ, Asif A. Innovations in vascular access for hemodialysis. Kidney Int. 2019;95:1053–1063.
14. Rahman S, Kuban JD. Dialysis catheter placement in patients with exhausted access. Tech Vasc Interv Radiol. 2017;20:65–74.
15. Athreya S, Scott P, Annamalai G, et al. Sharp recanalization of central venous occlusions: a useful technique for hemodialysis line insertion. Br J Radiol. 2009;82:105–108.
16. Funaki B, Zaleski GX, Leef JA, et al. Radiologic placement of tunneled hemodialysis catheters in occluded neck, chest, or small thyrocervical collateral veins in central venous occlusion. Radiology. 2001;218:471–476.
17. Rajan DK, Croteau DL, Sturza SG, et al. Translumbar placement of inferior vena caval catheters: a solution for challenging hemodialysis access. Radiographics. 1998;18:1155–1167; discussion 1167–1170.
18. Power A, Singh S, Ashby D, et al. Translumbar central venous catheters for long-term haemodialysis. *Nephrol Dial Transplant*. 2010;25:1588–1595.

19. Po CL, Koolpe HA, Allen S, et al. Transhepatic Perm-Cath for hemodialysis. *Am J Kidney Dis*. 1994;24:590–591.

20. Stavropoulos SW, Pan JJ, Clark TW, et al. Percutaneous transhepatic venous access for hemodialysis. *J Vasc Interv Radiol*. 2003;14:1187–1190.

21. Dewan PA, Penington EC, Henning P, Juriedini KF. Venous access via the renal vein: a technical innovation. *Pediatr Surg Int*. 1998;13:457–459.

22. Law WP, Cheung CY, Chan HW, et al. Hemodialysis catheter insertion using transrenal approach. *Hemodial Int*. 2015;19:E14–E16.

23. Malas MB, Canner JK, Hicks CW, et al. Trends in incident hemodialysis access and mortality. *JAMA Surg*. 2015;150:441–448.