# Correlation between the position of double

*by* Christian Dananto

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REVIEW

# Correlation between the position of double-lumen catheter tip with the incidence of recirculation among patients who undergo hemodialysis: a literature review

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ABSTRACT

INTRODUCTION: Hemodialysis is a medical procedure to artificially replace the functions of kidney, particularly of its role to filter and excrete various substances such as electrolytes, salts, metabolic breakdowns, inactive or active drugs, and toxins. The quality of hemodialysis can be objectively measured using the recirculation rate (R%) calculation. Recirculation describes a condition when the dialyzed blood reenter the systemic circulation without a full equilibration. Recirculation could be caused by several factors, such as inadequate flow within the vessel lumen and other catheter – related defects. This review aimed to analyze the outcome of hemodialysis (as showed by recirculation rate) with the catheter tip placement.

EVIDENCE ACQUISITION: Literatures reviewed in our study were gathered from PubMed and Google Scholar. We also reviewed the articles cited within the literatures to broaden the search results.

EVIDENCE SYNTHESIS: Out of thirteen articles gathered, nearly all of them showed satisfying results among catheters with the tip located either at superior vena cava or cavoaortic junction or right atrium, if compared by the inferior vena cava or iliac veins. These indicate that higher and stable laminar flow are required for the dialysis to be effective. The results also correspond with the previous recommendation stated by KDOQI. Recirculation rate was measured using salin dilution/ultrasound dilution/low flow method.

CONCLUSIONS: Tip placement at upper area (right atrium, superior vena cava or cavoatrial junction) offer better outcome as reflected by the R% compared by the lower area (inferior vena cava or external iliac vein).

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KEY WORDS: Catheters; Renal dialysis; Review.

## Introduction

Hemodialysis is a life-saving procedure to artificially replace the functions of kidney, either temporarily or permanently. Its crucial functions including excretion and secretion of various substances such as electrolytes, salts, hormones, metabolic breakdowns, drugs, and toxins as well. Kidney also plays important role in neuroendocrine system, particularly of the already well – known renin angiotensin aldosterone system (RAAS).[1, 2] It is indicated when the kidney loses its function, proved by the fall of the glomerular filtration rate below 15 mL/min/1.73 mm[2].[3] Both temporary and permanent hemodialysis are done through a machine called dialyzer, a filtering media constructed by a semipermeable membrane and a fluid – filled space (dialysate) and will be connected to the patient's circulation via a tube – like tool called catheter. Dialysis catheter varies from the aspect of shapes, sizes, and lengths, by which the most commonly used is the double lumen catheter that allows two contradictive flow of the blood within the same tube; with the arterial access/route that passes the blood from patient's circulation towards the dialyzer and venous access/route which brings back the blood towards the circulation.[3, 4] Double lumen catheter (DLC) offers several advantages: minimize invasiveness of the procedure and hence, reduces the risk of infection and systemic complication, it also promotes less vascular injury and better healing process if compared by the single lumen.[5, 6] However, due to the design of the entry and exit port at the tip of this catheter, the effectivity highly depends on the tip positioning, location, flow speed, and any other conditions since recirculation could occurs.[7] Catheter recirculation describes a condition when the dialyzed blood returns to the patient's circulation without full equilibration. There are various insertion sites along with their distal tip locations; internal jugular vein (mainly the right side), subclavian vein, and femoral vein. DCL tip that is inserted at these sites should be resided within the superior vena cava, *cavoatrial junction*, or right atrium. Superior vena cava is divided into 2 (two) indistinct areas based on the position of carina (the start point of trachea bifurcation), termed as upper and lower SVC zones.[7, 8] Tip positioning in regard to the catheter recirculation has been a matter of debate, KDOQI in 2019 renewed the recommendation that the tip of DLC should be located at the mid-right atrium, since this position is believed to be the safest area. This study reviewed several literatures to identify and analyze the correlation between recirculation rate and the DLC tip positions.

## Evidence acquisition

This study reviewed the literatures gathered from two major databases, PubMed and Google Scholar. Advanced search was conducted on PubMed with the keywords used were ("double lumen" OR "dual lumen") AND ("catheter" AND "recirculation" AND "hemodialysis," "catheter tip position" AND "recirculation" AND "hemodialysis") OR ("recirculation" AND "tip" AND ("superior vena cava" OR "inferior vena cava" OR "right atrium"). Advanced search was also conducted on Google Scholar with all of the words "catheter tip position and recirculation rate recirculation;" exact phrase: "hemodialysis;" with at least one word "recirculation." The showed literatures were further selected based on the publication year, by which we set a 30-year study, starting from 1992 until 2022. This attempt resulted in 61 and 418 literatures gathered from PubMed and Google Scholar, respectively. We also reviewed the articles cited on the references within the article to broaden the search results.

## Evidence synthesis

The information reviewed from the articles consisted of: author (with study location and publication year); study design; population age (in years, with the format as mean±SD or median (IQR), except stated otherwise within the table); insertion site(s); duration of catheterization (in days, same format as population age, except stated otherwise); evaluation/measurement of catheter tip recirculation; location of the tip; and brief discussion regarding the results. The results are showed as in Table I.[9-25]

Seventeen articles were finally reviewed after selected based on the relevancy, animal – model or in-vitro studies were excluded and were not reviewed; out of 17 articles, 8 articles (47%) were observationals,[10-13, 16, 19-21] 8 randomized clinical trials (47%),[9, 14, 15, 18, 22-25] and a laboratory investigation paper (6%).[17] The population of this study were middle aged and older. All of the studies also used the internal jugular vein as the insertion site, followed and some of them used subclavian vein and femoral vein. Catheter insertion and tip locations were confirmed by using ultrasound guidance or fluoroscopic guidance by radiologists and chest radiographs (correspond to the recommendation by KDOQI 2019), Hwang *et al.* used angiography to confirm the catheter tip final location.[25] The exact regions of superior vena cava (either upper SVC/ 3 cm from the carina or lower SVC/3 cm below the carina as described earlier) were not specifically mentioned by the authors. Catheter tips that were inserted from femoral vein resided in inferior vena cava; Carson *et al.*[18] however resided the tip of femoral catheter at the iliac veins.

Recirculation rate (R%) was measured using saline dilution method, ultrasound — dilution method, or low/slow — flow method. Small number of articles collected from the past 30 years showed that comprehensive studies regarding the correlation between DLC tip position and the recirculation rate were still limited; probably because most clinicians refer or "stick" to the recommendations stated by KDOQI.[26, 27]

### General aspects of hemodialysis

*Principle and indications*

Hemodialysis is one form of renal replacement therapy (RRT) by which a machine called dialyzer filters and removes excess substances contained within the patient's blood such as electrolytes, salts, and other waste products. Diffusion is the main principle of how hemodialysis works (Figure 1); the solutes from area with high concentration will move down the gradient towards the area with less concentration. In this case, the solutes from the circulation (blood) move down towards the dialysate (consists of sodium chloride (NaCl) and bicarbonate ($NaHCO_3$), deionized water, and acidic concentrates.[3, 28] Besides concentration gradient, the permeability of one membrane also significantly affects the rate of diffusion process.

KDOQI 2015 Updates stated that hemodialysis must be initiated if the measured glomerular filtration rate falls below the level of 30 mL/min/1.73 $m^2$; however, *Persatuan Nefrologi Indonesia* (PERNEFRI) 2003 version postulated different cut-off for the HD initiation, with the established criteria as follow: 1) ideally all patients with measured

TABLE I.—*Characteristics of the literatures reviewed.*

| Author | Study design | Age (year) | Insertion site(s) | Catheter/tip design | Tip location |
|---|---|---|---|---|---|
| Parienti *et al.*[9] (France, 2010) | RCT | 64.9±14.8 | Femoral vein (50.2%) and internal jugular vein (49.8%) | NA | Femoral: IVC, IJV: SVC |
| Little *et al.*[10] (Ireland, 2000) | Observational (Prospective) | Mean (range): 60.8 (23.0- 87.9) | Femoral vein (66.7%) and internal jugular vein (33.3%) | Vascath (Bard) | Femoral: IVC, IJV: SVC |
| Tan *et al.*[11] (USA, 2012) | Observational (prospective) | 53.0±15.5 | Internal jugular vein (73%); femoral vein (23.8%); subclavian vein (3%) | Temporary catheter = Mahukar catheter; Tunneled/cuffed catheter: AngioFlow | Femoral: IVC, IJV: SVC |
| Leblanc *et al.*[12] (France, 1998) | Observational (retrospective) | NA | Internal jugular vein (right side 100%) | Twincath | SVC – Atrial junction and Right atrium |
| Senecal *et al.*[13] (Canada, 2004) | Observational (prospective) | NA | Right internal jugular vein (59.5%); left internal jugular vein (18.9%); right subclavian vein (18.9%); left subclavian vein (2.7%) | NA | SVC and SVC-atrial junction |
| Kelber *et al.*[14] (USA, 1993) | RCT | 56±7 | Subclavian vein (23.5%); internal jugular vein (23.5%); femoral vein (53%) | NA | Subclavian and IJV: within 1 to 2 cm of the junction between SVC and RA; femoral: IVC |
| Sombolos *et al.*[15] (Greece, 1996) | RCT | 55.6±18.4 | Internal jugular vein (88.2%); subclavian vein (11.8%) | Flexxicon Vascath | Superior vena cava |
| Atapour *et al.*[16] (Iran, 2008) | Observational (prospective) | 52.0±15.7 | Right internal jugular vein | HemoCath | Beginning at the right atrium |
| Clark *et al.*[17] (USA, 2014) | Laboratory investigation | NA | Right internal jugular vein | Palindrome (symmetrical tip) | Superior vena cava |
| Carson *et al.*[18] (Canada, 2005) | RCT | Functional group: 68.2±9.7; Dysfunctional group: 68.7±15.72 | Right IJV: 84.2%; Left IJV: 5.3%; Right FV: 10.5% | PermCath | IJV (right/left): SVC and SVC-RA junction; Femoral: External iliac vein and confluence of iliac veins |
| Moossavi *et al.*[19] (USA, 2008) | Observational (retrospective) | Mean (range): 64 (23-90) | R. Internal jugular vein (50%), Femoral vein (7%), subclavian (9.8%), R. Translumbar (2.8%) | Step-tip; Split-tip; Symmetrical tip | Subclavian and IJV: SVC and RA; Femoral: up to IVC (not specifically mentioned) |
| Pannu *et al.*[20] (Canada, 2006) | Observational (prospective) | 66.7±14.5 | R. Internal jugular vein (85.3%); LIJV (13.7%); femoral vein (1%) | CardioMed Catheter | IJV (both R + L): SVC/RA junction (confirmed by radiograph); femoral: IVC |
| Moist *et al.*[21] (2006) | Observational (prospective) | 66.0±15.2 | Internal jugular vein (100%) | PermCath | SVC and/or Right Atrium (not specifically mentioned) |
| Mankus *et al.*[22] (USA, 1998) | RCT | NA | Internal jugular vein (100%) | Ash Split Cath; Mahurkar Catheter | Superior vena cava |
| Trerotola *et al.*[23] (USA, 1999) | RCT | Ash Split: 52, Bard Tip: 58 | Right internal jugular vein (100%) | Ash Split Cath and OptiFlow/Bard (step-tip) | Superior vena cava |
| Trerotola *et al.*[24] (USA, 2002) | RCT | Ash split: 53.3±14.3, Bard (Opti-Flow): 56.2±12.9 | Right internal jugular vein (100%) | Ash Split Cath and OptiFlow/Bard (step-tip) | Superior vena cava |
| Hwang *et al.*[25] (South Korea, 2012) | RCT | Palindrome (53±15); Step-tip (57±18) | Right internal jugular vein (100%) | Palindrome catheter (symmetrical) and step-tip catheter | Right mid-atrium (confirmed by angiography) |

GFR<15 mL/min; 2) creatinine clearance test /GFR<10 mL/min with the signs and symptoms of uremia and/or malnutrition; 3) creatinine clearance test /GFR<5 L/min, either symptomatic or not.[29, 30]

*Types of hemodialysis*

Hemodialysis can be temporary or permanent/chronic. Temporary dialysis commonly prescribed for patients who currently waiting for arteriovenous fistula maturation, waiting for the availability of renal transplant, inaccessible or defect at the regular vascular access (AV injury), and any other conditions.[31, 32] Acute or urgent dialysis is indicated in various emergency setting, where immediate 'blood cleansing' is required, as seen in acidosis, electrolyte imbalance (particularly hyperkalemia), drug or substance intoxication, fluid overload (proved by the presence

| Evaluation technique | Outcome |
|---|---|
| Saline dilution technique | Recirculation rate was significantly higher among femoral group if compared by the (internal) jugular group; insertion of dual lumen catheter (DLC) at the right jugular vein was strongly associated with lower catheter dysfunction compared by the left side. |
| Saline dilution technique; HD01 Transonic machine (Transonic Systems, Ithaca, NY) | Statistical analysis showed recirculation incidence among femoral catheter was significantly higher than internal jugular catheterization. |
| Saline dilution technique; Transonic HD-02 system | Recirculation cases was twice higher among femoral group than the jugular group (P<0.05); moreover, recirculation rate was significantly higher among patients receiving temporary (Mahukar) catheter compared by the cuffed (AngioFlow) |
| Saline dilution technique | Recirculation rate (R%) of catheter with the distal tip resided within the SVC-atrial and/or right atrial junction was ranged from 5% until 10% and similar with the other studies conducted; this indicating the low number of recirculation among jugular catheterizations. |
| Ultrasound-dilution method (Transonic Systems Inc., Ithaca, NY) | The recirculation rate (R%) was less than 15% if the DCL was inserted from the IJV (with the tip located at SVC and/or atrial junction), suggesting that SVC region was an optimal site for temporary catheter installation. |
| Two-needle method at blood flow rates of 2S0, 300, 3S0, and 400 mL/min | The efficiency based on recirculation rate (R%) was significantly better on subclavian and IJV group compared by the femoral group. This correspond with several studies that stated higher R% if the tip location was lower than RA. |
| Urea recirculation measurement | Recirculation rate (R%) as reflected by urea concentration was lower at this site. |
| Low flow method | The patients were divided into two groups – those who received regular (non-reversed) catheter and reversed catheter. Overall R% among regular catheters was low - 6.6±7.1%, but reverse catheter R% was significantly higher, with the overall R% of 22.0±21.6%. This indicated that despite of the catheter tip location, the catheter design also influence the R% during dialysis using DLC. |
| Computationally labeling the blood in the venous lumen | Statistical test showed that catheter tip placement at SVC was associated with low incidence of R%, also nearly all catheters have R% close to zero. |
| Ultrasound – dilution technique (HDO2 Flow Meter; Transonic Inc, Ithaca, NY) | For the maximum Qb (blood pump speed), recirculation rate among all catheters were 0. Dysfunctioned catheters showed signficiantly higher R%. Femoral R% (64% and 78%) were higher than IJV group (21±7.8%). Several factors could influence the quality of hemodialysis, such as catheter tip positiong (related to the blood flow), insertion sites, and functionality of one catheter. Femoral (IVC / lower) position along with decrease in functionality further aggravate the R% incidence. |
| Ultrasound dilution technique | In this study, the highest catheter recirculation (CR) was seen in femoral group (38 to 50%), followed by the left jugular (33%), these results were nearly twice higher as the right IJV (18%). Statistical test showed there was correlation between CR and catheter type and tip site placement; with split tip has the lowest CR count. |
| Qb (maximum blood pump speed) measurement, tapering of the speed until the indicator reahed 100 mL/min. | This study stated that significant/high rate of recirculation (R% > 10%) was infrequent in the use of SV-RA junction (along with the tunnelization of the catheter). |
| Ultrasound guidance:Transonic HDO1 monitor (Transonic Systems Inc., Ithaca, NY) | Overall blood flow speed was 352.1±48.8 mL/min, major/significant recirculation (R% >10%) ranged from 7.6-27.3%. The results showed that catheterization at IJV was a right choice and not associated with dialysis inadequacy. |
| Ultrasound velocity dilution technology | No significant recirculation rate (R) difference between Ash Split (split-tips), Tesio Twin (paired single-lumen catheter), and Mahurkar catheter (step-tip). The results indicating that catheter insertion through the internal jugular vein was favorable and brought promising results |
| Ultrasonic dilution technique (Transonic HDO1; Transonic Systems, Ithaca, NY | All catheters were having low recirculation rate (< 6%, on all flow rates); however, recirculation rate was significantly higher on Bart (step-tip) group if compared by the As split (split-tip) group (P<0.05). This result may suggest that split-tip catheter was more recommended to be used over the step-tip type. |
| Ultrasonic dilution technique (Transonic HDO1; Transonic Systems, Ithaca, NY | The two types of catheters could deliver adequate blood flow rates; however, Opti-Flow (step-tip) catheter was significantly correlated with higher recirculation rate if compared by the Ash split (split-tip) catheter. |
| Saline dilutin technique | In both catheters, the recirculation rate was low and not significantly different. Reversing the arterial and venous line resulted in significantly higher R% on step-tip if compared by the palindrome (symmetrical catheter). Midatrium, hence, is considered as the ideal site to optimize the catheter function, despite of the tip type/design |

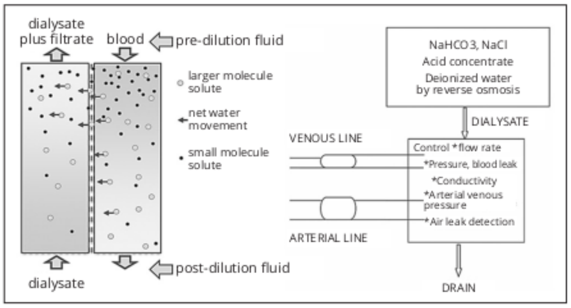


Figure 1.—Principle of how hemodialysis works.

of pulmonary edema), and uremia (potentially cause encephalitis and pericarditis).[33]

## Catheter in hemodialysis

### *Choosing the catheters*

The flow of the catheter must be kept at the level of >300 mL/min, this protocol is aimed to prevent the incidence of catheter-related mechanical dysfunctions such as thrombosis and kinking. Linear flow accompanied by the appropriate tip design also reduce the risk of recirculation at the tip of the catheter. Several attempts are made to optimize the performance of dialysis catheter, one of them is to modify and develop different catheter shapes and lengths. KDIGO Update 2012 recommend to use the non-tunneled, dual-lumen catheter for temporary/short-term/acute setting, such as dialysis in emergent acute kidney injury.[34, 35]

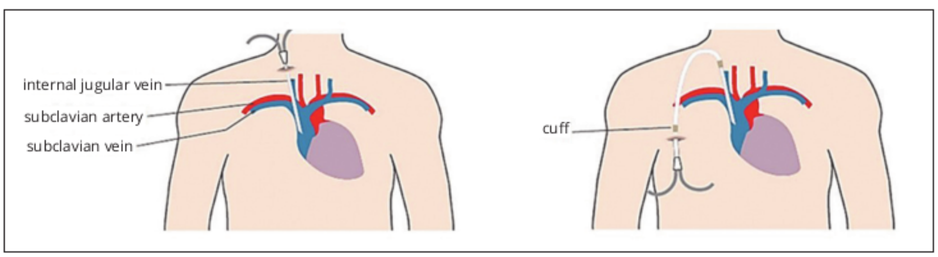
Referring to the Law of Poiseuille regarding the fluid dynamics, blood flow within the catheter is proportional with the lumen diameter and inversely correlated with its length.[36]

### *Types of hemodialysis catheter*

Catheters used for hemodialysis can be tunneled (planned for long-term or prolonged period) or non-tunneled (shorter period than the tunneled) (Figure 2). Non tunneled catheters are also available in straight or curved. The curved type is the most preferred form of NTC since it is more comfortable and tend to more stable (less kinking episodes) than the straight NTCs. Several trials also proved that lower cases of bacteremia and central venous catheters (CVC) removals are seen among patients receiving precurved NTCs.[37, 38] Kidney Disease Outcomes Quality Initiative guidelines (KDOQI) in 2006 recommend to not use non-tunneled catheter for more than a week for femoral vein and up to 21 days for internal jugular vein and subclavian vein.[39-41]

In double lumen catheters (DLC), there are two pressures that work along the tube, namely inflow pressure (negative pressure) and outflow pressure (positive pressure). These contraflow system accompanied by the tip design are crucial factors in the recirculation phenomenon; hence, different shapes of catheter lumen are currently developing and have been studied for the past decades (Figure 3).[42] First

Figure 2.—Non-tunneled and tunneled catheter.



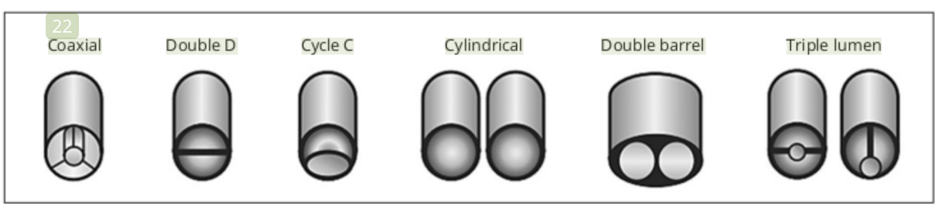




Figure 3.—Different lumen designs of hemodialysis catheters.

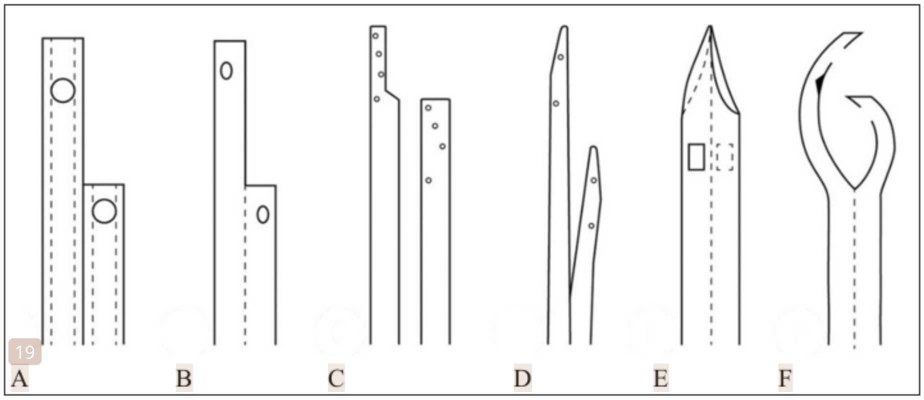



Figure 4.—Different types of catheter tip.

variant is the coaxial tip design; it is characterized by the presence of acute angles and large blood contact surface with the inner catheter surface, as these factors will cause ineffective blood flow and turbulence, coaxial catheter is no longer recommended. Double 'O' catheter consists of two cylindrical lumens and arranged side by side, making this catheter slightly like an ellipse; the large diameter is the main disadvantage of this catheter. Most widely used catheter type is the double 'D', resembles a letter 'D' that is mirrored toward the catheter septum; this catheter has acute angles and could disrupt the blood flow during dialysis process. Last catheter type, as well that is considered as the best catheter is cycle-C catheter, which combines that shape of a cylindrical/circular lumen along with the kidney-shaped lumen, this configuration offers optimal mechanical support for the blood flow.[42-44]

Tip of the catheter is one factor that plays an important role in the pathological process of recirculation. Its arrangement determines the direction of blood flow, either to the inside or outside of a catheter. In general, the tip of dual lumen catheter can be divided into step-tip (shotgun) or split-tip (Figure 4), another design is symmetrical or palindrome, by which multiple holes or obliterations are made to ease the flow of the blood. Several studies revealed that these three catheter (tip) types are correlated with the lower incidence of recirculation and increased dialysis quality; however, comparative studies between these catheters are still limited, although some literatures claimed that step-tip has higher recirculation rate compared to the other tip designs.[4, 19, 22-25, 45]

Step-tip catheter is showed in Figure 4 (A: PermCath and B: Mahukar; C describes the Tesio (Twin) catheter; D showed the Ash Split catheter (split-tip); E, F are the Tal Palindrome (symmetrical tip due to the arrangement of holes that are sideways) and CentrosFlo, respectively.[45] The flow in each type of catheter is also influenced by the tip and hole design, as shown in Figure 5, namely (from A to C) Shaldon, Uldall, and Mahurkar catheter. Shaldon is a twin (single lumen) catheter, its insertion and implantation can be either staggered or placed separately, one in the artery and one in the venous vessel. Uldall catheter has concentric morphology by which the artery blood flows at outer lumen. Blood flow in the venous and arterial lumen is separated by a septum with the distal lumen (of arterial line) is obstructed by a solid matter.[22, 45]

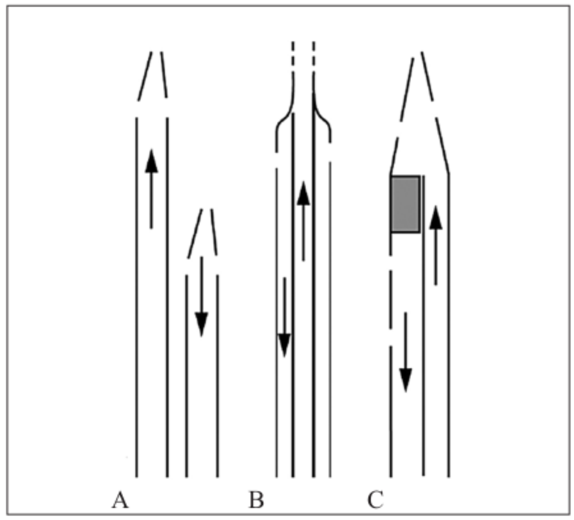



Figure 5.—Flow direction between different catheter tip designs.

## Tip location

### *Catheter insertion sites*

There are several anatomical sites that can be used to insert dialysis catheter, these sites are all venous in origin, such as internal jugular vein, subclavian vein, and (common) femoral vein.[26, 27] Internal vein is a bilateral venous structure that extends from the posterior cranial fossa towards the jugular foramen inferiorlaterally. Blood that comes from the upper region (brain, skull, facial structures and compartments, and also the neck area drains to IJV. Internal jugular vein is the most commonly used (as well the most preferred, mainly the right side) because of the straighter and wider structure if compared by the left IJV; this straight direction allows an effective, laminar (non-turbulent) blood flow.[46]

Subclavian vein is located nearby the internal jugular vein and classified as the deep vein, rather superficial. Anatomically this bilateral structure extends below the pectoralis major muscle and has the direct extension towards the axillary vein; also, the course between the right and left subclavian vein are not symmetrical. Left subclavian vein receives both hematological contents and lymphatic drainages, chiefly from the thoracic duct, meanwhile the right subclavian ven receives lymphatic drainage from the right lymphatic duct.[47, 48] The last (as well least preferred) site for catheterization is the femoral vein. This large vein receives blood drainage from the popliteal vein and later will continue superiorly as external iliac vein that eventually joins with the internal iliac vein to become common iliac vein. This vein is arranged together with the femoral artery and nerve (neurovascular bundle); several anatomical studies describe this arrangement as 'NAVEL' that consists of nerve, artery, vein, empty space, and lymphatics. Femoral vein is the least preferred site due to the numerous reports of catheter dysfunction (high recirculation rate along other mechanical anomalies) and prominent infectious complication. This occurs due to the low flow, turbulence, and anatomical site that tend to be not hygienic.[40, 49]

### *Tip location*

DLC tip positioning is divided into three zones: upper superior vena cava (SVC), lower SVC, and right atrium (RA). Upper zone of SVC is defined as the area 3 cm above the carina (the bifurcation of trachea), meanwhile the lower SVC is 3 cm below. Right atrium, specifically the middle part (commonle described as the mid-atrium) is the recommended location by KDOQI in 2019 Updates. These marks for the tip localization usually confirmed through radioimaging interventions such as chest radiographs (X-ray) or angiography (Figure 6). Carina is located approximately 3 tu 4 cm higher than the cavoatrial junction in adults.[7, 25]

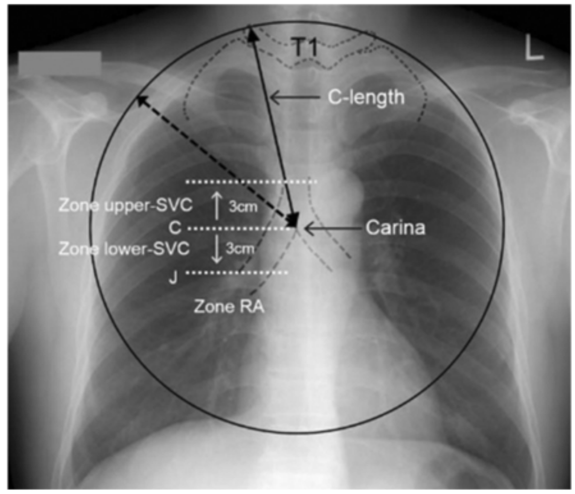



Figure 6.—Radiographical hallmark of tip positioning.

Determining the optimal position for DLC tip is a complex approach and is still debated for the objective effectivity (and safety). A literature review showed several different opinions and experiences regarding the outcome of dialysis based on the tip position; however, several studies have proved that if central venous catheter tip is located within the vascular (SVC) compartment, vascular injury and perforation tends to be higher and is associated with unsafe protocol.[7, 8, 26]

Putting the tip at the atrium also emerges some considerations, particularly of the lethal effect from the perforating cardiac muscles that could lead to cardiac tamponade and other tissue injury such as pneumothorax or hematothorax.[7, 26, 37, 50, 51]

Another recommendations beside KDOQI come from Infusion Nursing Society (INS) and European Society of Parenteral and Enteral Nutrition (ESPEN) that recommended lower third of superior vena cava or the cavoatrial junction; Association of Anesthetist of Great Britain and Ireland (AAGBI) recommended lower SVC or upper RA as the tip location.[52]

## Recirculation

### *Pathological mechanism*

According to KDOQI 2019 Updates, recirculation describes the phenomenon when the dialyzed blood returns to the

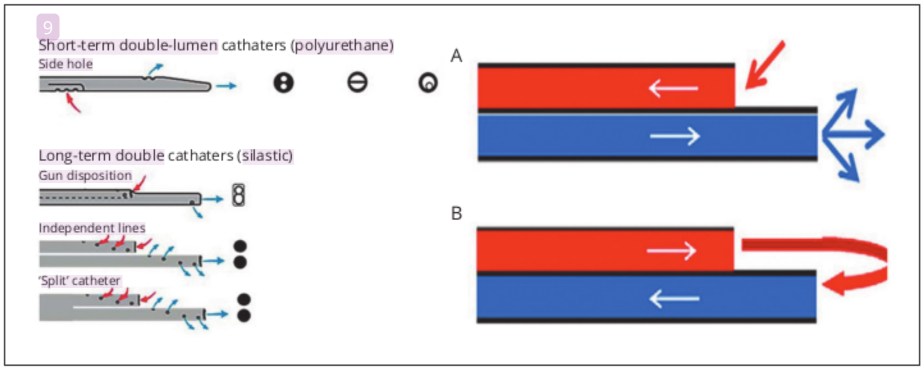



Figure 7.—Normal flow and recirculation in dual lumen catheter; step-tip.

systemic circulation without full equilibration. This occurs when the blood that already exit the venous outline of catheter reenter the arterial line. The normal flow of a dual lumen catheter with step-stip is shown as in Figure 7 (left side of the image), when the flow is reversed (Figure 7B) the received (dialyzed) blood recirculates to the arterial line.[53, 54]

Several factors that significantly influence the degree and risk of recirculation including blood flow speed (determined by either the catheter itself, the vessel, or both), duration of catheterization and dialysis process, catheter tip type, tip location, and patient's antropometry.[7, 26]

## Findings from previous studies

### *Recirculation by tip location*

#### Superior vena cava, cavoatrial junction, and right atrium

All of the articles included the internal jugular vein as insertion site, with the tips were located either at superior vena cava, cavoatrial junction, or right atrium. Some studies also inserted the dialysis catheter through the subclavian vein[11, 13-15, 19] with the same tip location.

Recirculation rate (R%) was significantly low if the catheter was inserted through internal jugular vein or subclavian vein and the tip was located at the superior vena cava or right atrium (P<0.05), several nonanalytic studies also revealed low/acceptable rate of recirculation at this site. These satisfying results correspond with the previous guidelines available.[7, 13-19, 26, 52]

#### Inferior vena cava

Inversely with the upper region, lower placement of the tip significantly correlated with the higher recirculation rate, catheter dysfunctions, and catheter removal.[9-11, 14, 19] This also correspond with the previous statements that femoral vein was associated with higher recirculation rate and any other comorbidities; hence, this site should not be considered as the first site to insert catheter (even the length >25 cm), as stated by KDOQI regarding femoral DLC.[14, 19, 26, 52]

### *Measurement of recirculation*

Recirculation rate can be calibrated either using saline dilution method, ultrasound dilutin method or by urea recirculation rate measurement. Saline/ultrasound dilution method is done by injecting a small amount of saline bolus through the venous chamber and then measuring the amount of saline solution at the arterial chamber.[9-12, 25] The amount of saline is then quantitatively measured/detected by using ultrasound probe, as well to determine the blood flow (Qb) of related catheter.[12, 13, 18, 19]

## Conclusions

Recirculation rate is influenced by several conditions, one of them is the position of catheter tip. Although the exact, optimal position have not been determined and still a matter of debate, several evidences from clinical trials and prospective studies have proven that tip installation at superior vena cava and/or mid-atrium favors lower recirculation rate, if compared by the femoral vein. However, despite of the advantages offered, some potentially life-threatening complications must be taken into account before doing this procedure, such as cardiac tamponade, vascular or cardiac perforation, and pneumothorax.

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