Diagn Interv Radiol 2021; 27: 644–648

INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Lateral tilt during IVC filter placement does not predict the need for advanced filter retrieval techniques

Peter White
Younes Jahangiri
Khashayar Farsad
John Kaufman
Ramsey Al-Hakim

PURPOSE
We aimed to determine if lateral inferior vena cava (IVC) filter tilt at placement predicts the need for subsequent advanced retrieval techniques.

METHODS
A retrospective chart review was performed of all Gunther Tulip IVC filter placements with subsequent retrievals between February 2015 and October 2017. Chart and imaging review was performed for patient, filter placement, and filter retrieval demographics/characteristics. Degree of agreement between two measurement sets was evaluated with the intraclass correlation (ICC) analysis. Categorical variables were compared with chi-square or Fisher exact test, as appropriate. Kendall rank correlation was used to measure correlation between categorical variables.

RESULTS
There was poor agreement between filter tilt angle at the time of placement and retrieval (ICC coefficient, 0.54). Mean difference ± standard deviation between tilt angle at the time of placement and retrieval was 4.6°±4.3° ($p = 0.35$). Among patient- or procedure-related factors, a common femoral vein access on placement (regression coefficient, -2.90; $p = 0.039$) was associated with a lower difference between placement and retrieval filter tilt angles compared to internal jugular vein access. Higher filter tilt angle measured at the time of retrieval (OR: 1.19, $p = 0.025$), hook embedment (OR: 77.3, $p < 0.001$), and a longer dwell time (OR: 1.25, $p = 0.002$) were associated with the need for advanced retrieval techniques. However, in univariate and multivariate analysis filter tilt angle at the time of placement was not associated with the subsequent need for advanced retrieval technique ($p = 0.16$).

CONCLUSION
Lateral tilt at the time of placement is poorly associated with lateral tilt at the time of retrieval and does not correlate with the need for advanced retrieval technique.

Multiple factors have been shown to increase the likelihood of failed inferior vena cava (IVC) filter retrieval or need for advanced IVC filter retrieval technique including longer dwell time and imaging presence of embedded filter hook, IVC penetration, and/or filter tilt on computed tomography (CT) or fluoroscopy (1–6). This is clinically relevant as the need for advanced retrieval techniques has been shown to increase retrieval associated complications (3). However, these prior studies have focused on lateral filter tilt at the time of retrieval or on pre-retrieval CT. The significance of lateral tilt at time of placement is not as well studied. One prior study has examined the clinical significance of design modifications of IVC filters with the intent of self-centering, and demonstrated no identifiable clinical benefit (7). Another recent study also investigated IVC filter positional parameters, and demonstrated that net filter tilt (defined as the difference in angulation from placement to retrieval) is associated with filter retrieval outcome (8). In addition, studies have examined the hemodynamic effects of lateral tilt, effect of tilt on filtration, and deployment techniques to minimize tilt during filter placement (9–11). However, the direct association of outcomes and placement lateral tilt have not been previously well studied. The purpose of our study is to retrospectively examine the relationship of placement and retrieval lateral tilt, and evaluate if the degree of filter tilt at placement predicts the need for subsequent advanced retrieval techniques.

From the Dotter Department of Interventional Radiology (P.W. ✉ *whitpe@ohsu.edu),* Oregon Health and Science University, Portland, Oregon, USA.

Received 19 November 2019; revision requested 13 January 2020; last revision received 25 July 2020; accepted 3 September 2020.

Published online 20 August 2021.

DOI 10.5152/dir.2021.19411

You may cite this article as: White P, Jahangiri Y, Farsad K, Kaufman JA, Al-Hakim RA. Lateral tilt during IVC filter placement does not predict the need for advanced filter retrieval techniques. Diagn Interv Radiol 2021; 27: 644–648

Methods

This retrospective study was approved by an institutional review board (IRB) (IRB project #18163) and the protocol was compliant with the Health Insurance Portability and Accountability Act. A retrospective chart review was performed of all Gunther Tulip IVC filter placements with subsequent retrievals performed at our institution between February 2015 and October 2017. Individual informed consent was not required. All IVC filter placements were performed under fluoroscopic guidance. Chart review was performed for patient, filter placement, and filter retrieval demographics (Table 1). Advanced retrieval was defined as any technique other than conventional loop snare technique, which is routinely used after an initial failed attempt using a traditional loop snare technique. Filter dwell time was defined as the time from filter placement to filter retrieval.

Imaging review

Imaging review was performed by a single PGY-4 Diagnostic Radiology resident. IVC diameter was measured on pre-placement venograms at the location of subsequent IVC filter deployment. At our institution, an IVC venogram is routinely performed prior to IVC deployment, but not routinely performed after deployment of the IVC filter. All operators do obtain a post-deployment intraprocedural radiograph immediately after deployment of the IVC filter. To measure lateral tilt at the time of IVC filter placement without a post-deployment venogram, a technique was developed using the lumbar vertebral spinous process as an internal reference. A line was drawn connecting the spinous processes of the two lumbar vertebrae adjacent to the IVC filter, termed the "spine reference line." A line was then drawn through the center of the IVC by connecting the midpoint of the IVC at the level of the filter apex to the midpoint of the IVC at the level of the filter base, termed the "IVC reference line." The angle between the IVC filter longitudinal axis on post-deployment intra-procedural radiograph relative to the spine reference line was measured. The angle between the IVC reference line relative to the spine reference line was then measured. A signing convention of positive for counterclockwise and negative for clockwise relative to the spinous reference line was used. The "calculated IVC filter tilt" was then obtained by subtracting the two measured angles and taking the absolute value (Fig. 1).

Main points

- Lateral tilt at the time of IVC filter placement is poorly associated with lateral tilt at the time of retrieval.
- Lateral tilt at the time of placement does not correlate with the need for subsequent advanced retrieval techniques.
- Lateral tilt at the time of retrieval and dwell time are both independent predictors of the need for advanced retrieval techniques.

Table 1. Summary of the baseline and follow-up characteristics of the study population (n=71)

	Mean±SD or n (%)	Min–max
Patient-related		
Age (years)	57.9±16.3	22–92
Sex		
Male	48 (67.6)	
Female	23 (32.4)	
IVC diameter (mm)	24.2±4.7	15.4–35.3
Placement-related		
Access side		
Right	65 (91.6)	
Left	6 (8.4)	
Access vein		
Common femoral vein	59 (83.1)	
Internal jugular vein	12 (16.9)	
Baseline filter tilt angle (°)	5.8±4.0	0.1–17.6
Retrieval-related		
Filter hook embedment	10 (14.1)	
Filter tilt angle at retrieval (degree)	5.3±4.0	0.5–18.7
Filter strut penetration (mm)	8.8±4.8	0–24.7
Filter dwell time (months)	4.2±4.2	0.1–19.2
Advanced retrieval	11 (15.5)	

SD, standard deviation; IVC, inferior vena cava.

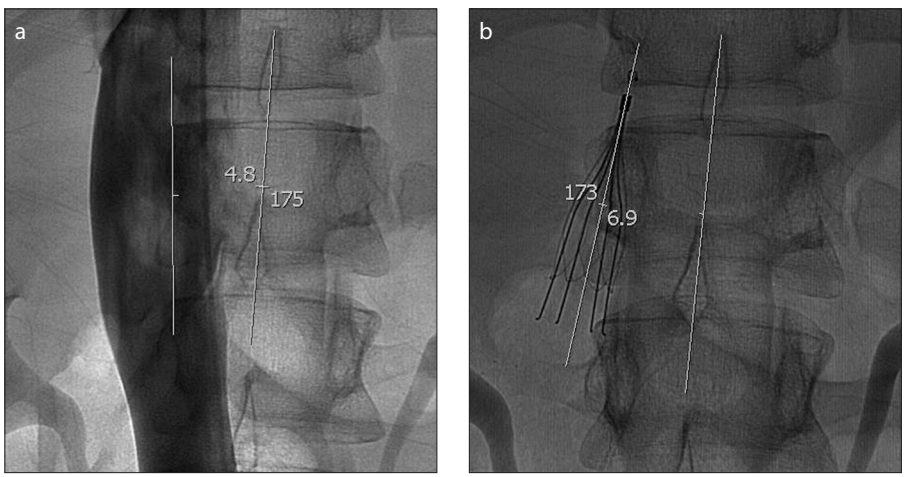

Figure 1. a, b. Panel **(a)** shows the angle between the spinous reference line and IVC measured as +4.8°, and panel **(b)** shows the angle between the spinous reference line and IVC filter longitudinal axis measured as -6.9°. A signing convention of positive for counterclockwise and negative for clockwise relative to the spinous reference line was used. The "calculated IVC filter tilt" was then obtained by subtracting the two measured angles and taking the absolute value (11.7° in this example).

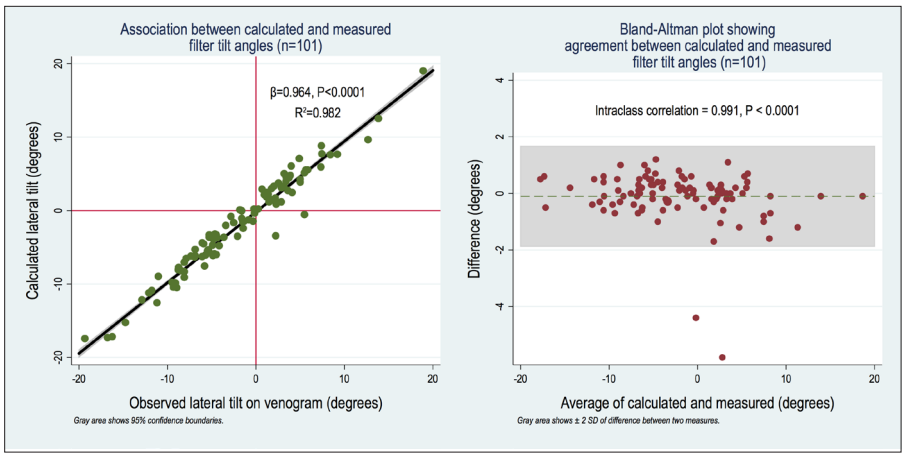

Figure 2. a, b. Two-way mixed effects analysis of variance (ANOVA) model between calculated and observed IVC filter lateral tilt demonstrates excellent agreement (absolute ICC, 0.991; $p < 0.001$).

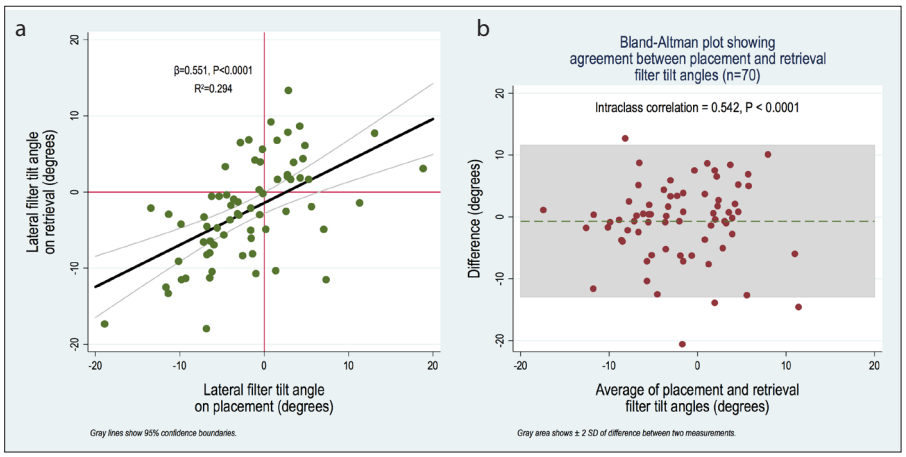

Figure 3. a, b. Linear regression modeling **(a)** shows a poor fitting ($R^2 = 0.294$) of the IVC filter tilt angles on placement and retrieval, and Bland-Altman plot **(b)** shows fair agreement between two measurements with up to 20° difference between filter tilting on retrieval and placement.

For validation of this technique, the calculated IVC filter tilt was measured using the post-retrieval venograms and pre-retrieval venograms that also had a post-placement venogram. In these same cases, the IVC filter lateral tilt was also directly measured on the procedural venogram ("observed IVC filter tilt"). Evaluation of association between two different sets of angle measurements was done using a univariate linear regression model with residuals (R^2) calculation. Degree of agreement between two measurement sets was evaluated with the intraclass correlation (ICC) analysis (12), and visualized using the Bland-Altman plot (13). For the purpose of ICC analysis, a two-way mixed effects analysis of variance (ANOVA) model was applied and the absolute agreement between two measurements was calculated (14). Venograms were available for calculated and observed IVC filter tilt measurement in 32 filter placements and 69 filter retrievals. Filter placement and retrieval data were pooled in order to assess agreement between calculated and observed filter tilt angles (n=101). Agreement between two sets of numerical measurements were classified based on their ICC coefficient as poor (<0.4), fair (0.4–0.59), good (0.6–0.74) and excellent (0.75–1.0) (14). There was excellent agreement between calculated and observed IVC filter tilt angles (absolute ICC: 0.991, $p < 0.001$) (Fig. 2). Because of this strong correlation, observed filter tilt angles with missing values were replaced with the calculated values for the purpose of comparison between placement and retrieval filter tilt angles.

Statistical analysis

Numerical values were reported as mean ± standard deviation and compared between two groups using the Mann-Whitney U test. Categorical variables were summarized as frequency (%) and compared with the chi-square or Fisher exact test, as appropriate. Kendall rank correlation (Kendall's tau-b) was used to measure correlation between categorical variables. Comparison of baseline and retrieval filter tilt angles was done using the paired t test.

Univariate linear regression analysis was applied to evaluate whether any of the patient- or procedure-related factors are associated with absolute value of the change in the filter tilt angles between placement and retrieval. The associations of assessed factors with occurrence of advanced filter retrieval were evaluated using the uni- and multivariate logistic regression models. Factors with significant association in the univariate analysis were selected for the multivariate model. Interaction between factors was checked using the Pearson or Kendall rank correlation, as appropriate.

All analyses were done using Stata for Macintosh version 14.2 (StataCorp LP). *p* values less than 0.05 were considered as statistically significant.

Results

The patients' mean age was 57.9±16.3 years and 67.6% of them were male. A total of 71 Gunther Tulip IVC filters were included in this study. Mean IVC diameter at filter placement was 24.2±4.7 mm. A common femoral and internal jugular vein access was used to deploy the filters in 83.1% and 16.9% of cases, respectively. Mean absolute filter tilt angles at baseline and retrieval were 5.8°±4.0° (range, 0.1°–17.6°) and 5.3°±4.0° (0.5°–18.7°), respectively. Mean filter dwell time was 4.2 months (range, 0.1–19.2 months). A fair agreement between filter tilt angle at the time of placement and retrieval was detected with ICC analysis (ICC = 0.54; 95% CI: 0.35–0.69). Mean difference ± standard deviation between tilt angle at the time of placement and retrieval was 4.6°±4.3° ($p = 0.35$) (Fig. 3). Eleven cases (15.5%) required advanced filter retrieval. Advanced techniques included forceps (n=2), wire loop and snare (n=6), and laser sheath (n=3). Only one case underwent correction of tilt during the placement procedure after initial filter deployment, and the final lateral tilt angle after adjustment was used in this case. No significant interaction was found between factors included in the multivariate model.

Among patient- or procedure-related factors, a common femoral vein compared

Table 2. Association between patient-related and procedure-related factors with change in filter tilt (°) between placement and retrieval time (n=71)

Factor	Regression coefficient ± SE	*p*
Patient-related		
Age (years)	-0.01±0.03	0.76
Sex (male vs. female)	0.03±1.11	0.97
IVC diameter (mm)	0.02±0.12	0.87
Placement-related		
Access side (right vs. left)	-0.68±1.85	0.71
Access vein (CFV vs. IJ)	-2.90±1.38	0.039
Baseline filter tilt angle (°)	0.19±0.13	0.13
Retrieval-related		
Filter hook embedment	0.99±1.54	0.52
Filter strut penetration (mm)	-0.05±0.11	0.63
Filter dwell time (months)	0.05±0.13	0.70
Advanced retrieval	1.54±1.47	0.30

SE, standard error; IVC, inferior vena cava; CFV, common femoral vein; IJ, internal jugular vein.

Table 3. Factors associated with advanced filter retrieval (n=71)

	Univariate model		Multivariate model	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Patient-related				
Age (years)	0.97 (0.93–1.00)	0.082		
Sex (male vs. female)	0.81 (0.21–3.11)	0.76		
IVC diameter (mm)	1.02 (0.89–1.16)	0.82		
Placement-related				
Access vein (CFV vs. IJ)	0.27 (0.06–1.13)	0.073		
Placement filter tilt angle (°)	1.11 (0.96–1.30)	0.16		
Retrieval-related				
Retrieval filter tilt angle (°)	1.19 (1.02–1.38)	0.025	1.21 (1.02–1.43)	0.029
Filter hook embedment*	77.3 (11.2–535.9)	<0.001	Excluded	
Filter leg penetration into the IVC wall (mm)	1.00 (0.87–1.15)	0.98		
Filter dwell time (months)	1.25 (1.09–1.44)	0.002	1.25 (1.07–1.46)	0.006

OR, odds ratio; 95% CI, 95% confidence interval; IVC, inferior vena cava; CFV, common femoral vein; IJ, internal jugular vein.
*Excluded from the multivariate model because filter hook embedment is one of the criteria for advanced filter retrieval: 8/11 advanced retrieval vs. 2/60 simple retrieval cases presented with hook embedment ($p < 0.001$).

to internal jugular vein access on placement was associated with a lower difference (regression coefficient: -2.90, $p = 0.039$) between placement (common femoral 5.8°±3.9° vs. internal jugular 5.8°±4.9°) and retrieval (common femoral 4.9°±3.4° vs. internal jugular 7.2°±6.3°) filter tilt angles (absolute filter tilt angle change: 4.1°±0.5° vs. 7.0°±1.3° in common femoral and internal jugular vein access, respectively; $p = 0.039$). There was no association between difference in lateral tilt angles and filter dwell time ($p = 0.70$) (Table 2).

Placement filter tilt angle was not associated with the subsequent need for advanced retrieval technique (routine 5.5°±3.9° vs. advanced 7.4°±4.5°, $p = 0.16$) (Table 3). Furthermore, there was a poor correlation between severe filter tilt (≥10° absolute filter tilt) on placement and retrieval (Kendall's tau-b: 0.26, $p = 0.052$; Fisher exact test). Severe filter tilt (≥10° absolute filter tilt) compared to <10° absolute filter tilt at the time of placement was associated with the need for subsequent advanced retrieval on univariate analysis. However, in multivariate model including severe filter tilt angle and filter dwell time, only longer filter dwell time was associated with advanced filter retrieval technique (OR: 1.21, $p = 0.018$).

In univariate analysis, a higher filter tilt angle measured at the time of retrieval (routine 4.8°±3.6° vs. advanced 8.2°±5.2°, OR: 1.19, $p = 0.025$), and a longer dwell time (OR: 1.25, $p = 0.002$) were associated with advanced retrieval. Also, hook embedment on retrieval was strongly associated with advanced retrieval (8/11 advanced retrieval vs. 2/60 simple retrieval; OR: 77.3, $p < 0.001$). In a multivariate model including absolute retrieval filter tilt angle and dwell time, both of the factors maintained their significant association (OR: 1.21, $p = 0.029$ and OR: 1.25, $p = 0.006$, respectively).

Discussion

Our results demonstrate that lateral tilt at the time of filter placement is poorly associated with lateral tilt at the time of filter retrieval. While our study confirms findings of prior studies that lateral tilt at the time of filter retrieval is associated with the need for advanced filter retrieval techniques, our results did not show a significant correlation between lateral tilt at the time of placement and the need for advanced filter retrieval techniques. Hence, lateral tilt at the time of filter placement is currently not directly linked to outcomes during retrieval. This finding is important given prior studies demonstrating an increased risk of filter retrieval associated complications with advanced retrieval techniques compared to routine technique (3). Furthermore, the lack of correlation with placement lateral tilt and outcomes during retrieval suggests that filters placed with lateral tilt do not require "repositioning", which has implications on daily practice.

Our results also demonstrate that filter placement from a common femoral vein approach is associated with less filter tilt change over time compared to the internal jugular vein approach. The etiology of this finding is unclear. We hypothesize that this is likely related to the difference in technique in placement between the two access sites. When placed from a common femoral vein approach, the filter legs are

released all at once without control from the operator. Comparatively, when the filter is released from an internal jugular approach the operator can exert uneven force distribution on the legs. This difference in applied force on the legs during an internal jugular vein approach compared to the even release of the legs during a common femoral vein approach may explain the difference in change of lateral tilt as the filter "relaxes" over time.

It is worth noting the lack of associated factors with change in lateral tilt over time. In addition to a poor association of filter placement and retrieval angle, there was no association between change in lateral filter tilt and dwell time ($p = 0.70$). While lateral tilt at the time of retrieval and dwell time independently predict the need for advanced retrieval techniques, the two do not appear to be correlated. Furthermore, there were no patient- or filter-related factors in our study that predicted the change in lateral filter tilt over time other than access site. Specifically, filter strut penetration did not correlate with the change in lateral filter tilt over time. A recent study has also shown a lack of clinical significance in the placement of the filter hook relative to the renal veins (15). Based on our results, it seems that the IVC may be more dynamic than originally considered (including hydration status and respiratory variation), which could explain the unpredictable change in IVC filter lateral tilt between placement and retrieval. Overall, our understanding of factors impacting change in lateral tilt after filter placement is poor and requires further study given the clear clinical impact of filter tilt at the time of retrieval.

This study has multiple limitations. First, this study only assessed the lateral tilt of the IVC filter and not the anteroposterior tilt. A prospective study using orthogonal or cross-sectional imaging would likely provide even more clinically relevant information and it is our hope that our study will help direct future research looking at this important topic. Furthermore, this study includes only Gunther Tulip filters and extrapolation to other conical and non-conical IVC filters is not clear. Finally, the clinical implications of the lack of association between filter placement and retrieval tilt are not clear, and direct clinical studies are necessary.

In conclusion, lateral tilt at the time of placement is poorly associated with lateral tilt at the time of retrieval and does not correlate with the need for advanced retrieval technique. Further studies are necessary to understand what patient and/or filter factors affect the change in lateral tilt between placement and retrieval.

Conflict of interest disclosure

PW, YJ, and RA declare that they have no conflict of interests. KF reports personal fees from Cook Medical, personal fees from Neuwave Medical, personal fees from Bayer, grants from Terumo, and grants from Guerbet, outside the submitted work. JK reports medical advisory board member for Argon Medical and personal fees from Cook Medical, outside the submitted work.

References

1. Dinglasan LA, Oh JC, Schmitt JE, Trerotola SO, Shlansky-Goldberg RD, Stavropoulos SW. Complicated inferior vena cava filter retrievals: associated factors identified at preretrieval CT. Radiology 2013; 266:347–354. [Crossref]
2. Avgerinos ED, Bath J, Stevens J, et al. Technical and patient-related characteristics associated with challenging retrieval of inferior vena cava filters. Eur J Vasc Endovasc Surg 2013; 46:353–359. [Crossref]
3. Al-Hakim R, Kee ST, Olinger K, Lee EW, Moriarty JM, McWilliams JP. Inferior vena cava filter retrieval: effectiveness and complications of routine and advanced techniques. J Vasc Interv Radiol 2014; 25:933–940. [Crossref]
4. Lee SY, Lee J. Is external compression on the IVC a risk factor for IVC filter abutment? A single center experience of 141 infrarenal celect filter insertions. Eur J Radiol Open 2018; 5:73–78. [Crossref]
5. Dowell JD, Wagner D, Elliott E, Yildiz VO, Pan X. Factors associated with advanced inferior vena cava filter removals: A single-center retrospective study of 203 patients over 7 years. Cardiovasc Intervent Radiol 2016; 39:218–226. [Crossref]
6. Marquess JS, Burke CT, Beecham AH, et al. Factors associated with failed retrieval of the Gunther Tulip inferior vena cava filter. J Vasc Interv Radiol 2008; 19:1321–1327. [Crossref]
7. Shelgikar C, Mohebali J, Sarfati MR, Mueller MT, Kinikini DV, Kraiss LW. A design modification to minimize tilting of an inferior vena cava filter does not deliver a clinical benefit. J Vasc Surg 2010; 52:920–924. [Crossref]
8. Gotra A, Doucet C, Delli Fraine P, et al. Predicting inferior vena cava (IVC) filter retrievability using positional parameters: A comparative study of various filter types. Diagn Interv Imaging 2018; 99:615–624. [Crossref]
9. Knott EM, Beacham B, Fry WR. New technique to prevent tilt during inferior vena cava filter placement. J Vasc Surg 2012; 55:869–871. [Crossref]
10. Matsui Y, Horikawa M, Ohta K, Jahangiri Noudeh Y, Kaufman JA, Farsad K. Mechanisms of Gunther Tulip filter tilting during transfemoral placement. Diagn Interv Imaging 2017; 98:543–549. [Crossref]
11. Singer MA, Wang SL. Modeling blood flow in a tilted inferior vena cava filter: Does tilt adversely affect hemodynamics? J Vasc Interv Radiol 2011; 22:229–235. [Crossref]
12. Bartko JJ. Measurement and reliability: statistical thinking considerations. Schizophr Bull 1991; 17:483–489. [Crossref]
13. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; 1:307–310. [Crossref]
14. Hallgren KA. Computing inter-rater reliability for observational data: an overview and tutorial. Tutor Quant Methods Psychol 2012; 8:23–34. [Crossref]
15. Tullius TG, Jr., Bos AS, Patel MV, Funaki B, Van Ha TG. Complications and retrieval data of vena cava filters based on specific infrarenal location. Cardiovasc Intervent Radiol 2018; 41:239–244. [Crossref]