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INTERVENTIONAL

An analysis of factors associated with increased fluoroscopy time or the need for complex techniques at IVC filter retrieval

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Abstract

Objectives To evaluate factors associated with increased fluoroscopy time or the need for complex techniques at IVC filter retrieval.

Methods This is a single-institution retrospective cohort study of 187 consecutive patients who underwent IVC filter retrieval. An analysis was performed on associations of patient factors with increased fluoroscopy time and/or the need for complex retrieval techniques. A complex retrieval was defined as one requiring more than standard sheath and snare technique.

Results Access vein during filter placement was not associated with filter tilt at placement or removal ($p = 0.61$ and 0.48). Neither the direction of the hook nor its relationship to the tilt was associated with the need for complex retrieval or increased retrieval fluoroscopy time ($p = 0.25$, 0.23, $p = 0.18$, 0.23). Tilt angle at placement correlated with hook apposition at time of removal ($p = 0.01$). Hook apposition was associated with complex retrieval and increased fluoroscopy time ($p < 0.01$). Larger tilt angle at placement was not associated with complex retrieval ($p = 0.22$), but a larger angle at removal was ($p < 0.01$). Longer dwell time correlated with the need for complex retrieval ($p = 0.02$). Filter type, sex, and age were not associated with complex retrievals ($p = 0.58$, $p = 0.90$, $p = 0.99$).

Conclusion Contrary to previous hypotheses and studies, access vein for filter placement did not affect filter tilting, and direction of filter hook–tilt relationship did not affect retrieval fluoroscopy time or the need for complex retrieval techniques. Increased filter placement angle was associated with a larger angle at removal and hook–wall apposition, both of which were associated with complex retrievals.

Key Points

- *Filter hook orientation did not correlate with retrieval complexity.*
- *Filter insertion vein did not correlate with filter tilt.*
- *Filter tilt and hook apposition to the caval wall at the time of retrieval correlated with retrieval procedure complexity.*

Keywords Vena cava filters · Fluoroscopy · Radiology, interventional

Abbreviations

CPT	Current procedural terminology
DVT	Deep venous thrombosis
FDA	US Food and Drug Administration
IVC	Inferior vena cava
PA	Posteroanterior
PE	Pulmonary embolism

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Introduction

Pulmonary embolism is estimated to cause 200,000 deaths annually in the USA [1]. Inferior vena cava (IVC) filters are indicated in patients with venous thromboembolism in the setting of ineffective anticoagulation or a contraindication to anticoagulation. Prophylactic filter placement in patients undergoing operations deemed high risk for pulmonary embolism is controversial and represents a small percentage of overall filter use [2]. There is increasing awareness of complications associated with implanted filters, particularly with long dwell times. These complications include caval thrombosis/occlusion and filter penetration, migration, fracture, and embolization [3]. Accordingly, the FDA recommends removal of IVC filters as soon as protection from

pulmonary embolism is no longer needed and that the risk/benefit profile for filter removal in all patients be considered [4]. Removal of retrievable filters is technically successful in 84–100% of cases [3, 5, 6]. Standard filter retrieval consists of using a snare to engage the filter hook and removing the filter through a sheath. Complex filter retrieval techniques have been described, including stiff-wire displacement, dual access, balloon displacement, sling, hangman, sandwich, rigid forceps dissection, and excimer laser sheath extraction [5, 7, 8].

Stiff-wire displacement involves advancing a stiff wire between the filter apex and the caval wall with the goal of displacing the apex away from the caval wall before advancing either a retrieval cone or a coaxial snare over the wire to engage the apex [7]. Dual access also employs placing a wire between the filter apex and the caval wall, but a through-and-through "flossing" technique where jugular and femoral access is employed in order to maximize traction on the wire [7]. Balloon displacement employs inflating a balloon between the embedded filter and the caval wall in order to displace the filter away from the wall [7]. The sling technique involves using a reverse curve catheter to direct a guidewire through the legs of the filter in a U-turn, such that the wire can be snared in a para-axial fashion, thus creating a sling below the apex of the filter. A sheath can then be advanced over the filter apex held by the sling [7]. The hangman technique is a modified loop snare technique where the loop goes between the filter hook and the caval wall, but not through the filter struts [8]. The sandwich technique involves advancing femoral and jugular sheaths over a through-and-through "flossing" wire passed between the filter and the caval wall and "rocking" the filter free [7]. Rigid forceps can be used to "micro-dissect" the tissue surrounding the filter tip and grasp and remove it [7]. Excimer laser sheaths can be used to remove embedded filters without aggressive force by using photothermal ablation to treat the tissue adherent to the filter [9].

Severe filter tilting and the need for complex retrieval techniques have previously been associated with prolonged retrieval fluoroscopy times [5, 6]. Data on the association between other filter factors and retrieval fluoroscopy time remains relatively sparse. Factors such as long dwell time, filter tilting, hook embedment, advanced patient age, filter insertion access vein, and tine perforation have been previously shown to be associated with failed or complex retrievals [5, 6, 10–15]. However, the results of these studies and the association of the above factors with failed or complex retrievals have been inconsistent (Table 1). The heterogeneity in results may be due to the variety of filter types studied and the different analytical techniques (e.g., treating variables as continuous vs. categorical data). For example, Zhou et al studied Celect filters (Cook) and did not find filter retrieval angle to be associated with retrieval success using groups of < 10° and > 10° ($p = 0.22$) [16]. Meanwhile, Dowell et al studied five filter brands and found filter retrieval angle to be associated with advanced retrieval, mean 5.7° vs. 11.9° ($p < 0.01$) [10].

Table 1 Results from prior studies evaluating associations between patient and filter factors and complex or failed IVC filter retrievals

Article	Not significant	Significant
Gender		
Dowell et al. [5]		$p = 0.03$
Dinglasan et al. [12]	$p = 0.32$	
Marquess et al. [15]	$p = 0.81$	
Age		
Marquess et al. [15]		$p = 0.01$
Dowel et al. [5]	$p = 0.56$	
Avgerinos et al. [10]	$p = 0.15$	
Dinglasan et al. [12]	$p = 0.12$	
Dwell time		
Avgerinos et al. [10]		$p < 0.01$
Marquess et al. [15]		$p < 0.01$
Lee et al. [18]		$p < 0.01$
Geisbusch et al.[19]		$p < 0.01$
Diglasan et al. [12]		$p < 0.05$
Gotra et al. [21]		$p = 0.01$
Zhu et al. [6]	$p = 0.4$	
Dowell et al. [5]	$p = 0.92$	
Tsui et al. [20]	$p = 0.94$	
Zhou et al. [16]	$p = 0.88$	
Indication		
Avgerinos et al. [10]		$p = 0.02$
Marquess et al. [15]	$p > 0.05$	
Hook apposition		
Avgerinos et al. [10]		$p < 0.01$
Dinglasan et al. [12]		$p < 0.01$
Placement angle		
Dowell et al. [5]	$p = 0.31$	
Retrieval angle		
Dowell et al. [5]		$p < 0.01$
Avgerinos et al. [10]		$p < 0.01$
Dinglasan et al. [12]		$p < 0.01$
Gotra et al.[21]		$p = 0.04$
Marquess et al. [15]	$p = 0.36$	
Zhou et al. [16]	$p = 0.22$	
Brand		
Bos et al. [22]		$p = 0.04$
Gotra et al.. [21]	$p = 0.06$	
Dowel et al. [5]	$p = 0.73$	

It has been hypothesized that a filter's tilt–hook relationship is associated with complex retrieval, but to our knowledge this has not been formally analyzed [10]. The purpose of this study was to test this hypothesis. In addition, given the

inconsistent findings in the existing literature, we sought to evaluate other previously studied patient and filter characteristics with regard to increased filter retrieval fluoroscopy time and the need for complex filter retrieval techniques.

Materials and methods

Study design

This study was approved by the institutional review board at our institution and was HIPAA compliant. The requirement for informed consent was waived. This is a single-institution retrospective cohort study of 187 consecutive patients who underwent IVC filter retrieval from 2006 through 2016. There were 96 females and 91 males (median age, 57; range 18–88). All filter retrievals were performed in the interventional radiology section at a large tertiary care center by one of 13 operators with 1 to 32 years of experience. The cases were identified through QSight, an inventory log based on CPT code. Filter retrieval was classified as complex when there was a technical failure to remove the filter or more than standard sheath and snare retrieval techniques were required.

Data collection

Images from IVC filter placement and retrieval and medical records were reviewed. Two radiology residents and an interventional radiology fellow under the supervision of the principal investigator performed data collection. Data that was collected included filter placement and removal dates, gender, age at removal, procedure room time, fluoroscopy time, hook direction, insertion access vein, tilt direction and angle at time of insertion and removal, hook apposition, filter brand, indication for filter placement, and whether complex retrieval techniques were required. Filter tilt angle was measured as the greatest angle between the vertical axis of the filter compared to the long axis of the cava on any projection, most commonly a PA view (Fig. 1). Filter tilt was considered right, left, or straight based on where the apex was directed on PA view. The hook direction was classified as right, left, or en face based on where the hook was open towards on the PA projection. Hook–tilt classifications included the open hook "towards" and "away" from the apex tilt direction, "other" when the hook orientation was en face in the PA orientation regardless of the filter tilt, and "straight" when the filter was not tilted. The hook was considered apposed to the wall when on retrieval cavogram there was no contrast interposed between the hook and the wall.

In four patients, the insertion access vein could not be ascertained because the procedure was performed at an outside institution, and in 23 patients the tilt angle at insertion was not known because a post-placement cavogram was not performed. In two patients, the tilt direction at time of removal was not known because a pre-retrieval cavogram was not performed. Filter type was unknown in 10 patients who had their filters placed outside hospitals. One patient had a CRUX filter retrieved, precluding measurement of tilt angle (Volcano Corporation). A limited analysis was performed when data was missing.

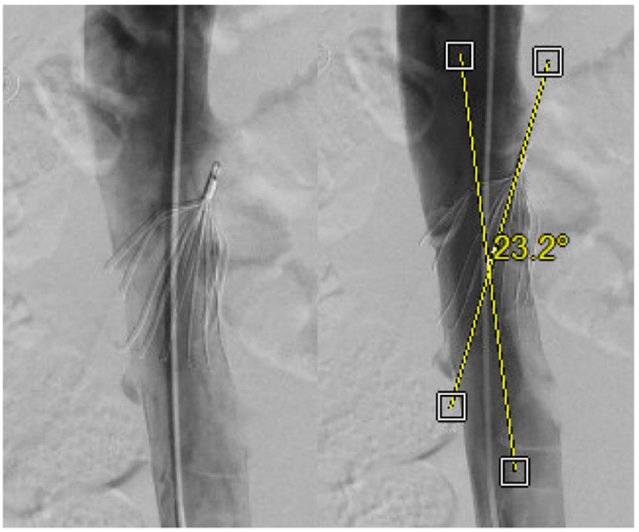

Fig. 1 Filter tilt angle was measured as the greatest angle between the vertical axis of the filter compared to the long axis of the cava on any projection, most commonly a PA view. This filter hook is apposed to the left caval wall

Statistical analysis

The association of factors with complex filter retrieval was analyzed using Fisher's exact test and Wilcoxon rank sum tests for categorical and continuous variables, respectively. A univariate logistic regression analysis of factors associated with complex retrieval was done, including Wald chi-square test p values. Based on these results, a multivariate logistic regression model was built. We were limited to two factors in our multivariate model due to the overall small number of complex retrieval events. The association of categorical factors with fluoroscopy time (in minutes) and angle of filter was analyzed using Wilcoxon rank sum tests and Kruskal-Wallis tests. The correlation between continuous variables was analyzed using Spearman's rank correlation coefficient. A univariate linear regression analysis of factors associated with log-transformed fluoroscopy time was done, including Wald chi-square test p values. Statistical tests were two-sided and 5% was set as the level of significance. All statistical analysis was done in R 3.4.2 (software info) including the "aod," "chron," and "mada" packages.

Results

One hundred eighty-one of the 187 patients underwent a technically successful retrieval (96.7%). Five of the failures were early in the study period and did not have any complex retrieval techniques attempted. The other failure consisted of an embedded hook with failure of loop snare, recovery cone (Bard Peripheral Vascular), hangman, rigid forceps, and bidirectional techniques. Fourteen complex retrievals were performed. Ten complex retrievals consisted of either the hangman or sling techniques. Two complex retrievals were with rigid forceps. One complex retrieval consisted of stiff-wire displacement. One retrieval was considered complex as time was spent unsuccessfully trying to retrieve a broken tine that was determined to be endothelialized.

Patient factors

Gender was not associated with a complex retrieval or increased fluoroscopy time ($p = 0.99$ (Table 2) and $p = 0.20$). Patient age at filter retrieval was not associated with a complex retrieval ($p = 0.78$) or increased fluoroscopy time ($\rho = 0.02$, 95% CI -0.13, 0.16). Indication for filter placement was contraindication to anticoagulation in 108 patients, prophylaxis in 56 patients, submassive or massive pulmonary embolus in 9 patients, high DVT or PE clot burden in 6 patients, failure of anticoagulation in 3 patients, IVC clot in 2 patients, thromboembolism with hypercoagulable state in 2 patients, and thrombolysis in 1 patient. There was a trend towards complex retrieval in the failure of anticoagulation group but this failed to reach statistical significance ($p = 0.08$). Univariate regression

Table 2 Association of patient and technical factors with complex IVC filter retrievals

Factor	Routine ($n = 167$)	Complex ($n = 20$)	Significance
Sex	Males 11% complex vs. females 10% complex		$p = 0.99$
Age	57 (18–88)	60 (20–78)	$p = 0.78$
Dwell Time (Days)	61 (3–1485)	194 (14–743)	$p < 0.01$*
Indication			$p = 0.08$
Contraindication	97 (90%)	11 (10%)	
Prophylactic	51 (91%)	5 (9%)	
Anticoagulant failure	1 (33%)	2 (67%)	
Other	18 (90%)	2 (10%)	
Hook direction			$p = 0.23$
Right	50 (86%)	8 (14%)	
Left	51 (86%)	8 (14%)	
En face	66 (94%)	4 (6%)	
Hook–tilt relationship			$p = 0.22$
Towards	3 (38%)	5 (62%)	
Away	0 (0%)	4 (100%)	
Straight	0 (0%)	1 (100%)	
Other	2 (40%)	3 (60%)	
Hook apposition			$p < 0.01$*
No	161 (96%)	7 (4%)	
Yes	5 (28%)	13 (72%)	
Placement angle	4° (0–19°)	5° (0–21°)	$p = 0.39$
Retrieval angle	4° (0–24°)	10° (0–30°)	$p < 0.01$*
Brand			$p = 0.58$
Cook Gunther Tulip	64 (91%)	6 (9%)	
Bard Eclipse	45 (90%)	5 (10%)	
Bard Denali	43 (88%)	6 (12%)	
Bard G2 Express	3 (100%)	0 (0%)	
Bard Meridian	1 (50%)	1 (50%)	
ALN Optional	1 (100%)	0 (0%)	
Volcano Crux	1 (100%)	0 (0%)	
Gunther Tulip Vena Cava MReye Filter	1 (100%)	0 (0%)	

*Denotes statistically significant findings. Medians and ranges are presented for continuous variables

analysis also showed that gender, age, and filter indication were not associated with complex retrieval or increased fluoroscopy time (Tables 3 and 4).

Technical factors

Filter tilt angle at placement correlated with hook apposition to the caval wall at time of removal (medians: not apposed 4° vs. apposed 7.5°, $p = 0.01$). Hook apposition was associated with complex retrieval and increased fluoroscopy time (both $p < 0.01$). Larger tilt angle at placement was not associated with complex retrieval ($p = 0.39$) or increased fluoroscopy time ($\rho = -0.01$, 95% CI -0.17, 0.14). A larger angle at filter removal was associated with complex retrieval ($p < 0.01$) but not increased fluoroscopy time ($\rho = 0.15$, 95% CI < 0.01, 0.29). There was a moderate correlation between the angle of filter at placement and removal ($\rho = 0.56$, 95% CI 0.44–0.66). Longer filter dwell time correlated with the need for complex retrieval ($p < 0.01$) but not increased fluoroscopy time ($\rho = 0.07$, 99% CI -0.08, 0.21). Univariate logistic regression analysis supported that hook apposition to the caval wall at the time of removal (OR 59.80, 95% CI 16.64–214.91, $p < 0.01$), filter removal angle (OR 1.13, 95% CI 1.05–1.22, $p < 0.01$), and dwell time (OR 1.01, 95% CI 1.00–1.00, $p = 0.02$) were associated with complex retrieval whereas filter placement angle was not (Table 3). Days in place (OR 1.00, 95% CI 1.00–1.01, $p = 0.01$) and hook apposition (OR 88.35, 95% CI 20.56–379.68, $p < 0.01$) remained associated with complex retrieval in a multivariate model. Univariate regression analysis also supported that hook apposition to the caval wall was the only variable associated with increased retrieval fluoroscopy time ($p < 0.01$, Table 4). The median retrieval fluoroscopy time for hook apposition was 17 min compared to 5 min without hook apposition ($p < 0.01$).

Access vein during filter placement was not associated with the filter tilt angle at placement or removal ($p = 0.61$, 0.48). Neither the direction of the filter hook (right, left, en face) nor its relationship to the filter tilt was associated with the need for complex retrieval or increased retrieval fluoroscopy time ($p = 0.23$, 0.47, $p = 0.22$, 0.56). Filter type was not associated with complex retrieval or increased fluoroscopy time ($p = 0.58$ and 0.76). These findings were supported by univariate regression analysis (Tables 3 and 4).

Discussion

The results of this study indicate that hook–wall apposition at the time of filter retrieval is associated with increased retrieval fluoroscopy time while gender, filter indication, hook direction, hook–tilt relationship, angle at placement, angle at removal, age, dwell time, and filter brand are not. This study indicates that prolonged filter dwell time, hook apposition to the caval wall at the time of retrieval, and a larger filter retrieval angle are associated with the need for complex retrieval techniques while gender, age, indication, hook direction, hook–tilt relationship, placement angle, and brand are not.

Table 3 Univariate logistic regression analysis of factors associated with complex retrieval

Factor	Odds ratio	95% CI	*p* value
Sex (M vs. F)	1.06	(0.42–2.68)	0.90
Age at removal (continuous)	1.00	(0.97–1.03)	0.99
Days in place (continuous)	1.00	(1.00–1.00)	0.02*
Indication			0.14
Prophylactic vs. contraindication	0.86	(0.28–2.62)	
Anticoagulant failure vs. contraindication	17.64	(1.48–210.63)	
Other vs. contraindication	0.98	(0.20–4.80)	
Hook direction			0.25
Left vs. right	0.98	(0.34–2.81)	
En face vs. right	0.38	(0.11–1.33)	
Hook–tilt relationship			0.23
Straight vs. away	0.48	(0.09–2.57)	
Towards vs. away	1.41	(0.44–4.44)	
Other vs. away	0.42	(0.11–1.58)	
Hook apposed to wall (yes vs. no)	59.80	(16.64–214.91)	< 0.01*
Insertion angle (continuous)	1.06	(0.96–1.18)	0.22
Removal angle (continuous)	1.13	(1.05–1.22)	< 0.01*

*Denotes significant findings

Table 4 Univariate linear regression analysis of factors associated with fluoroscopy time

Factor	Estimate	Standard error	*p* value
Sex (M vs. F)	-0.12	0.11	0.26
Age at removal (continuous)	0.00	0.00	0.72
Log (days in place) (continuous)	0.06	0.04	0.18
Indication			0.11
Prophylactic vs. contraindication	0.03	0.12	
Anticoagulant failure vs. contraindication	0.80	0.42	
Other vs. contraindication	0.29	0.17	
Hook direction			0.18
Left vs. right	-0.20	0.13	
En face vs. right	-0.22	0.13	
Hook–tilt relationship			0.23
Straight vs. away	0.10	0.17	
Towards vs. away	0.28	0.15	
Other vs. away	0.04	0.14	
Hook apposed to wall (yes vs. no)	0.88	0.17	< 0.01*
Insertion angle (continuous)	0.01	0.01	0.55
Removal angle (continuous)	0.02	0.01	0.06

*Denotes significant findings

Neither the orientation of the filter hook (left, right, en face) nor the orientation of the hook with respect to the angle of filter tilt was associated with increased fluoroscopy time or complex retrieval, as previously hypothesized. Placing the filter with the hook oriented towards the center of the IVC is not supported by this study, but nonetheless remains a logical practice [10].

Our study failed to demonstrate an association between insertion access vein and tilt at either insertion or removal (Table 5). This is supported by a recent study by Avgerinos that did not find a difference between complex retrievals based on right internal jugular vs. bilateral femoral vein filter placement ($p = 0.75$) [10]. However, a separate study looking at 159 filters found filter tilt angles to be higher in the femoral insertion group than in the jugular insertion group (6.6° vs. 4.3°, $p = 0.02$) and another study found a difference in filter retrieval failure rates based on right internal jugular vs. bilateral femoral vein insertion access (9% (14/156) vs. 24% (8/33), $p = 0.03$) [15, 17]. The heterogeneity in these study results may be in part explained by the subgroup analysis performed by Cohen et al that showed this finding was dependent on filter brand without significance in the Denali group, which constituted 26% of filters in our study [17].

Table 5 Insertion vein–tilt angle results

Insertion vein	*n*	Factor	*p* value
		Placement filter angle	0.61
Right internal jugular	75	4 (0–21)	
Left internal jugular	2	10 (4–16)	
Right common femoral	69	4 (0–16)	
Left common femoral	17	2 (0–10)	
		Removal filter angle	0.48
Right internal jugular	83	5 (0–30)	
Left internal jugular	3	4 (0–16)	
Right common femoral	75	4 (0–20)	
Left common femoral	20	2.5 (0–17)	

Medians and ranges are presented

Filter tilt at placement was not associated with the need for complex retrieval. However, a larger angle at the time of filter placement did moderately correlate with a larger angle at removal and hook–wall apposition, both of which were associated with increased retrieval fluoroscopy time and retrieval complexity. Our statistical analyses support these seemingly contradictory statements, and we postulate that with larger study numbers we would find an association between filter tilt at placement and complex retrieval. Other recent studies strongly support the association between filter tilting and complex or failed retrievals (Table 1). Based on our study, it is not possible to ascertain a maximum tilt angle at placement beyond which consideration should be given to immediately removing the filter and replacing it, but this is a potential topic of further study.

Contrary to previous studies, we did not find female gender to be associated with complex or failed retrievals. Similarly, this study did not confirm advanced age as

being associated with complex retrieval techniques. We did not find an association between filter brand and the need for complex retrievals or prolonged fluoroscopy retrieval times. This study confirmed filter tilting, long dwell time, and hook embedment are associated with the need for complex retrieval techniques. The heterogeneity of findings on these variables in other studies is displayed in Table 1. Again, the difference in findings may be due to the different brands of filters studied and the different measurement methods employed.

Our study is limited in being a single-center retrospective study at a large tertiary care center. We cannot rely heavily on the odds ratio estimates for hook apposition due to our relatively small sample sizes resulting in large estimates and confidence intervals. We were also limited in the number of factors we could include in our multivariate statistical analysis due to our small number of events. However, the number of operators, their wide range of experience, and use of multiple different filter types improve the robustness of our analyses. Our 2-D classification system of hook orientation (right, left, en face) is overly simplistic given the 3-D nature of the filter and cava, but this also reflects information available in clinical practice and broadens the applicability of our findings.

Conclusion

Contrary to previous hypotheses and studies, access vein for filter placement did not affect filter tilting and direction of filter hook–tilt relationship did not affect retrieval fluoroscopy time or complexity. Confirming previous hypotheses, a larger angle at the time of filter placement was associated with a larger angle at time of removal and hook–wall apposition, both of which were associated with increased retrieval fluoroscopy time and complexity. While it continues to be good practice to minimize the tilt angle at the time of IVC filter placement, current evidence does not definitively favor one access vein over another.

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Compliance with ethical standards

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Informed consent Written informed consent was waived by the Institutional Review Board.

Ethical approval Institutional Review Board approval was obtained.

Study subjects or cohorts overlap Some study subjects or cohorts have been previously reported in abstract form in JVIR.

Methodology
- Retrospective
- Observational
- Performed at one institution

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