Usefulness of a Computerized Reminder System to Improve Inferior Vena Cava Filter Retrieval and Complications

Bassem Mikhael, MD, MBA[a,*], Mazen Albaghdadi, MD[b], Farhad Abtahian, MD, PhD[c], Cheryl MacKay, MS[e], Eric Secemsky, MD[b], Michael R. Jaff, DO[d], and Ido Weinberg, MD[e]

Inferior vena cava filters (IVCF) are associated with complications which may be due to delayed retrieval. Initiation of an automated reminder system may improve retrieval rates and reduce complications. A computerized reminder system, which provides interactive email reminders after implantation while collecting IVCF use data, was implemented. IVCF retrieval was compared before ("reminder not provided" group) and after ("reminder provided" group) implementation. Data regarding implantation, retrieval, and complications were collected. The primary efficacy outcome was retrieval rate, and the primary safety outcome was indwelling complication rate. Secondary outcomes were time to retrieval and a composite adverse outcome defined as IVCF thrombosis, deep venous thrombosis (DVT), pulmonary embolism, and death. A total of 1,070 IVCF insertions were included, 715 in the "reminder not provided" group and 355 in the "reminder provided" group. Patient age (61 vs 64 years, p = 0.95) and gender (42% vs 40% female, p = 0.55) were similar in the "reminder not provided" and "reminder provided" groups, respectively. In the "reminder provided" group, the retrieval rate was higher (148/297 [49.8%] vs 223/715 [31.2%], p = 0.0001), the indwelling complication rate was lower (30/319 [9.4%] vs 115/715 [16.1%], p = 0.005), and the time to retrieval was shorter (112 days vs 146 days, p = 0.02). The composite adverse outcome occurred less frequently in the "reminder provided" group: (85/355 [23.9%] vs 297/715 [41.5%], p = 0.0001). The system was associated with increased odds of IVCF retrieval (odds ratio 2.56; 95% confidence interval: 1.82 to 3.59; p < 0.0001) and reduced odds of the composite adverse outcome (odds ratio 0.72; 95% confidence interval: 0.60 to 0.80; p < 0.0001). In conclusion, implementing a computerized email reminder system was associated with higher IVCF retrieval rates, fewer indwelling complications, and shorter dwell times. **(Am J Cardiol 2019;123:348−353)**

Inferior vena cava filters (IVCF) are designed to prevent recurrent pulmonary embolism (PE) and venous thromboembolism (VTE)-related mortality. Multiple studies have not shown mortality benefit with these devices.[1−3] The clinical benefit of IVCF may be limited by procedural and device-related complications, which may in part be due to delayed device retrieval.[4−7] In light of the risks of delayed IVCF retrieval, the Food and Drug Administration (FDA) issued a safety communication in 2014 strongly recommending that filters be retrieved as soon as mechanical protection from PE is no longer needed.[8] Unfortunately, appropriate IVCF retrieval rates remain low in contemporary practice.[7,9] Quality improvement initiatives to improve surveillance and retrieval rates have been successfully implemented and have primarily consisted of telephone and/or email follow-up by dedicated staff.[10−13] However, the optimal method of system-wide mechanisms for promoting IVCF retrieval remains unclear, especially where multiple physicians from multiple disciplines insert IVCF. We therefore implemented an automated, computerized system in our hospital that provides reminders to retrieve IVCF while also collecting data about appropriate postinsertion device management. In this study, we examine IVCF retrieval practice patterns and complications before and after implementation of this system.

Methods

We compared IVCF retrieval before and after implementation of an automated computer reminder system. All IVCF implantations at our institution from January 1, 2009 to December 31, 2011 that occurred before implementation of the automated computer reminder system (the "reminder not provided" group) were analyzed retrospectively; data were collected retrospectively by detailed chart review performed and quality checked by 2 physicians (FA and IW). Following implementation of the system, all IVCF implants were tracked in a prospective registry from June 1, 2013 to June 1, 2015 (the "reminder provided" group). Further

[a]Department of Medicine, Massachusetts General Hospital, Boston, Massachusetts; [b]Division of Cardiology, Massachusetts General Hospital, Boston, Massachusetts; [c]Division of Cardiology, Rochester General Hospital, Rochester, New York; [d]Department of Medicine, Newton-Wellesley Hospital, Newton, Massachusetts; and [e]Vascular Medicine, Division of Cardiology, Massachusetts General Hospital, Boston, Massachusetts. Manuscript received July 12, 2018; revised manuscript received and accepted September 21, 2018.

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*Corresponding author: Tel: 617-724-9557; fax: 888-971-2248.
E-mail address: bmikhael@partners.org (B. Mikhael).

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prospective data collection was not feasible due to resource limitations. The time gap between the "reminder not provided" and the "reminder provided" groups reflects the time to develop and implement the new system. Analysis was then performed comparing the "reminder not provided" group and the "reminder provided" group, as detailed below. Institutional review board approval was obtained for all retrospective and prospective data analyses and collection.

The IVCF retrieval computerized reminder system was developed at a large academic medical center within a multispecialty Vascular Center (The Paul and Phyllis Fireman Vascular Center). The computerized reminder system operates according to a standardized algorithm, summarized in Figure 1. Once an IVCF is placed, it is identified by a billing code triggered by the implanting physician, and is automatically added to the system's internal database. After 30 days, the attending physician who implanted the IVCF receives an interactive automated email to their academic address inquiring as to whether the IVCF has been retrieved. If the physician indicates that the IVCF has been retrieved, there are no further emails, and the retrieval date are automatically logged in the database. If the physician indicates that the IVCF has not been retrieved, the physician indicates whether an unsuccessful attempt occurred (and provides the attempt date), or a statement that the IVCF will not be retrieved and provides the clinical reason. Reasons include persistent contraindication to anticoagulation, high risk for VTE, patient or primary care physician refusal, patient loss to follow-up, or patient death. Lack of response to the email triggers repeat emails at 1-week intervals until a response is achieved.

Baseline demographic information was collected for each patient, including gender, age, presence of known malignancy, indication for IVCF placement (including active bleeding and VTE, documented failure of anticoagulation, prophylaxis for trauma or bleeding, prophylaxis for poor lung reserve, surgery and acute thrombosis, and VTE with contraindication to anticoagulation), and anticoagulation status, whereas the filter was indwelling (none, prophylaxis only, or therapeutic). The performing service (vascular medicine/cardiology, interventional radiology, or vascular surgery) as well as filter brand used was also documented for each patient. Data regarding the performing service are reported in a blinded fashion ("Service 1, 2, 3") to encourage participation in this publication. Complication data were divided into 3 phases of IVCF use: insertion complications (occurring at the time of insertion), indwelling complications (occurring after insertion but before retrieval, if retrieval occurred), and retrieval complications (occurring at the time of retrieval). Minor complications were defined as those that required little or no therapy, and major complications were those that required in-hospital therapy or resulted in permanent sequelae or death.[14] Of these, a subset was defined as significant complications: embolization, thrombus, infection, perforation, migration, DVT/PE, or tilt. Insertion complications were defined as deployment failure, filter tilt ($>15^{\circ}$),

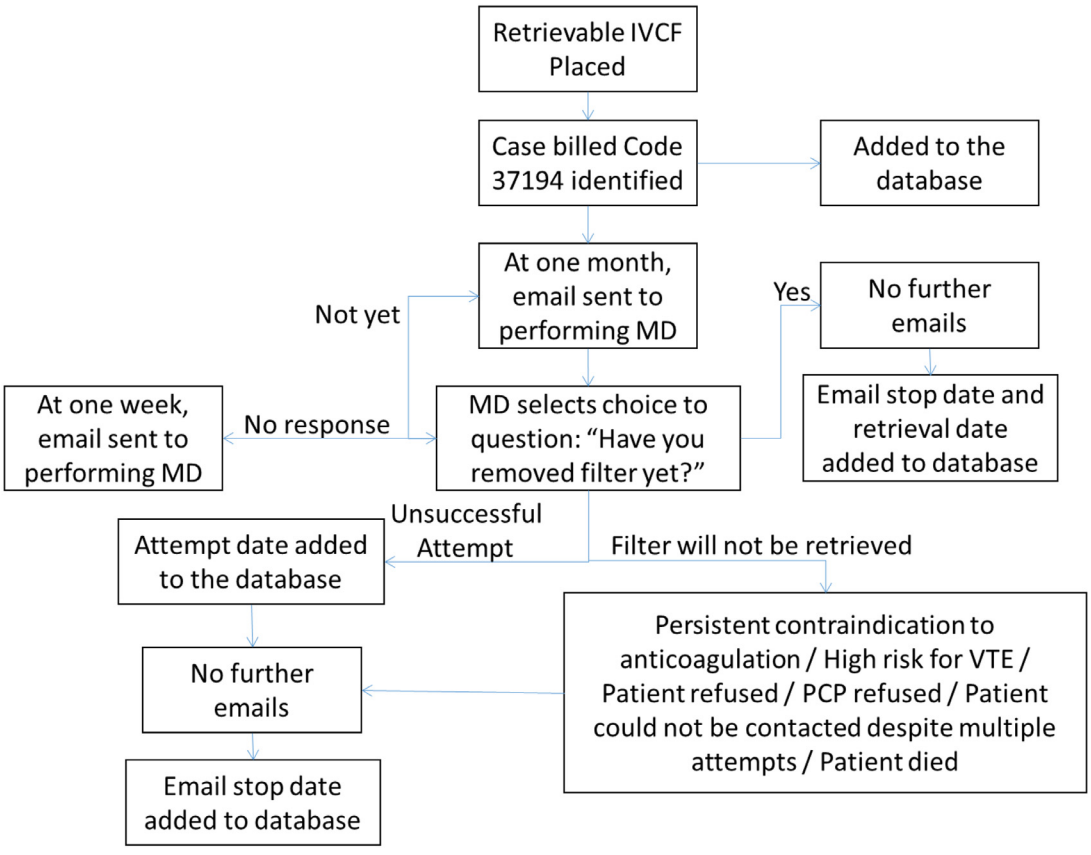

Figure 1. IVCF computer reminder system operational algorithm.

Table 1
Patient demographics, IVCF placement indication, and anticoagulation status

	No reminder (n = 715)		Reminder (n = 355)		p Value
Total					
Female	300	*(42.0%)*	142	*(40.0%)*	
Male	415	*(58.0%)*	213	*(60.0%)*	0.55
Age (median, years)	61.0		64.0		
1st quartile-3rd quartile	49.1-73.6		55.0-73.0		0.95
Malignancy	276	*(38.6%)*	173	*(48.7%)*	
Female	135	*(18.9%)*	80	*(22.5%)*	0.02
Male	141	*(19.7%)*	93	*(26.2%)*	
Service*					
Service 1	306	*(42.8%)*	175	*(49.3%)*	0.05
Service 2	153	*(21.4%)*	111	*(31.3%)*	0.0005
Service 3	256	*(35.8%)*	69	*(19.4%)*	0.0001
Indication					
Active bleeding and VTE	188	*(26.3%)*	121	*(34.1%)*	0.01
Documented failure of anticoagulation	18	*(2.5%)*	8	*(2.3%)*	1
Other	24	*(3.4%)*	23	*(6.5%)*	0.03
Prophylaxis (trauma, bleeding)	203	*(28.4%)*	102	*(28.7%)*	1
Prophylaxis for poor lung reserve	44	*(6.2%)*	25	*(7.0%)*	0.43
Surgery and acute thrombosis	110	*(15.4%)*	39	*(11.0%)*	0.06
VTE and contraindications to AC	128	*(17.9%)*	37	*(10.4%)*	0.001
Anticoagulation					
None	212	*29.7%*	161	*45.4%*	0.001
Prophylaxis	217	*30.3%*	69	*19.4%*	0.0001
Therapeutic	286	*40.0%*	125	*35.2%*	0.42

* Services are vascular medicine, vascular interventional radiology, and vascular surgery.

hematoma, and filter malposition. Indwelling complications were defined as filter-retained thrombus, embolization, infection, IVC perforation (>3 mm outside the IVC wall), IVC thrombosis, IVCF migration, PE, recurrent DVT, tilt (>15°), and hook embedded into vessel wall. Retrieval complications were defined as IVC tear, hematoma, and pneumothorax. With regards to retrieval, data were collected on the time to retrieval, success of retrieval, and if unsuccessful, the reason for failure (defined as adherence to vessel wall, failure to engage the IVCF hook, severe tilt, and filter thrombosis). The primary efficacy outcome was retrieval rate, and the primary safety outcome was indwelling complication rate. Secondary outcomes were time to retrieval as well as a composite adverse outcome, defined as IVCF thrombosis, DVT, PE, and death.

Baseline characteristics were compared using the Fisher's exact test and Mann-Whitney U test for categorical and continuous data, respectively; the data were non-normal by the Shapiro-Wilk test and so nonparametric tests were used. Differences in complication rates were compared with the Fisher's exact test. Multivariable logistic regression analysis was performed to evaluate the effect of the automated system on retrieval rates and a composite adverse outcome. Based on review of the literature and clinical experience, the following variables were chosen for adjustment: age, active malignancy, medical service implanting the IVCF, indication for IVCF implantation, and anticoagulation regimen (none, prophylactic, or therapeutic). These variables have previously been demonstrated to be associated with retrieval and clinical outcomes following IVCF implantation.[14] All analyses were performed using SPSS software (IBM Corporation, Version 25, Armonk, NY).

Results

A total of 1,070 IVCF insertions were included in the analysis, 715 in the "reminder not provided" group and 355 in the "reminder provided" group. Patient age (61 vs 64 years, p = 0.95) and gender (42% vs 40% female, p = 0.55) were similar in the "reminder not provided" and "reminder provided" groups, respectively; other baseline demographic information is summarized in Table 1.

The indwelling complication data are reported in Table 2. There were fewer indwelling complications in the "reminder provided" group compared with the "reminder not provided" group, (30/319 [9.4%] vs 115/715 [16.1%], p = 0.005). There were 20 complications which were not identically defined in both groups; to allow for direct comparison, the analysis was repeated with these 20 complications excluded. Still, there were fewer indwelling complications in the "reminder provided" group (29/319 [9.1%] vs 96/715 [13.4%], p = 0.05).

The retrieval attempt and complication data are reported in Table 3. The retrieval rate was higher in the "reminder provided" group compared with the "reminder not provided" group: (148/297 [49.8%] vs 223/715 [31.2%], p = 0.0001). This effect persisted after excluding patients who died within 90 days or developed a permanent indication for IVCF: (149/225 [66.2%] vs 222/492 [45.1%], p = 0.0001) in the "reminder provided" and "reminder not provided" groups, respectively. The median time to retrieval was shorter in the "reminder provided" group: (112 days vs 146 days, p = 0.02). In patients who had an IVCF for a prophylactic indication, numerically fewer complications were observed in the

Table 2
Indwelling IVCF-related complications

	No reminder (n = 715)		Reminder (n = 319)		p Value
None	600	*(83.9%)*	289	*(90.6%)*	
Non-significant complication	8	*(1.1%)*	N/A		
Filter-retained thrombus	8				
Significant complication	107	*(15.0%)*	30	*(9.4%)*	0.005
Embolization	1	*(0.1%)*			
Filter-retained thrombus	5	*(0.7%)*			
Infection	1	*(0.1%)*			
IVC perforation	3	*(0.4%)*			
IVC thrombus	15	*(2.1%)*	3	*(0.9%)*	
Migration	1	*(0.1%)*			
Pulmonary embolism	16	*(2.2%)*	4	*(1.3%)*	
Recurrent DVT	63	*(8.8%)*	12	*(3.8%)*	
Severe Tilt	2	*(0.3%)*	10	*(3.1%)*	
Hook embedded into wall			1	*(0.3%)*	

"reminder provided" group: (9/102 [8.8%] vs 31/203 [15.3%]) and median time to retrieval was shorter: (129 days vs 154 days, p = 0.58).

The composite adverse outcome (Table 4) of IVCF thrombosis, DVT, PE, and death occurred less frequently in the "reminder provided" group: (85/355 [23.9%] vs 297/715 [41.5%], p = 0.0001). In an analysis excluding patients who died in fewer than 90 days, this effect persisted: (44/317 [13.9%] vs 195/614 [31.8%], p = 0.0001).

After controlling for age, active malignancy, medical service implanting the IVCF (vascular surgery, vascular medicine, or interventional radiology), indication for IVCF implantation, and anticoagulation regimen (none, prophylactic, or therapeutic), the automated email reminder system was associated with increased odds of IVCF retrieval (odds ratio 2.56; 95% confidence interval: 1.82 to 3.59) and reduced odds of the composite adverse outcome (odds ratio 0.72; 95% confidence interval: 0.60 to 0.80) after controlling for the same variables.

Discussion

In this analysis of a modern cohort of patients receiving IVCF for a variety of indications, implementation of a novel, computerized email reminder system was associated with higher IVCF retrieval rates, shorter retrieval times, fewer indwelling filter complications, and a reduction in a composite adverse outcome. The patients selected were a

Table 3
IVCF retrieval attempts and retrieval complications

	No reminder (n = 715)			Reminder (n = 297)			p Value
Retrieval attempt							0.0001
Yes	223	*(31.2%)*		148	*(49.8%)*		
No	492	*(68.8%)*		149	*(50.2%)*		
Retrieval successful							0.09
Yes	203	*(91.0%)*		142	*(95.9%)*		
No	20	*(9.0%)*		6	*(4.1%)*		
Adherence to wall		9	*(4.0%)*		3	*(2.0%)*	
Failure to engage		1	*(0.4%)*				
Severe tilting		1	*(0.4%)*				
Thrombus in filter		4	*(1.8%)*		2	*(1.4%)*	
No reason listed		5	*(2.2%)*		1	*(0.7%)*	
Retrieval complication							0.33
Yes	8	*(3.6%)*		2	*(1.4%)*		
No	215	*(96.4%)*		146	*(98.6%)*		
Minor	2	*(0.9%)*					
IVC tear dye extravasation		1	*(0.4%)*				
Hematoma		1	*(0.4%)*				
Other					2	*(1.4%)*	
Major	6	*(2.7%)*					
IVC tear		3	*(1.3%)*				
Hematoma		1	*(0.4%)*				
Pneumothorax		1	*(0.4%)*				
IVC dissection		1	*(0.4%)*				
Time to retrieval	146			112			0.02
Interquartile range	80-210			52-204			

Table 4
IVCF association with composite clinical outcome

	No reminder (n = 715)		Reminder (n = 355)		p Value
Composite outcome					0.0001
Yes	297	*(41.5%)*	85	*(23.9%)*	
No	418	*(58.5%)*	270	*(76.1%)*	
Composite outcome Excluding death < 90 days					0.0001
Yes	195	*(31.8%)*	44	*(13.9%)*	
No	419	*(68.2%)*	273	*(86.1%)*	

cohort of patients treated at a quaternary academic medical center, across the 3 major specialties of physicians who implant IVC filters.

Because of the well-documented association of IVCF and complications, the FDA issued a safety communication recommending that physicians remove IVCF as soon as protection is no longer needed.[8] The low IVCF retrieval rates seen in past studies,[15–18] as well as in the "reminder not provided" group included in our cohort, are a testament to the need for quality improvement initiates and measures to improve IVCF retrieval rates. The variety of measures which have been previously attempted have primarily relied on dedicated follow-up, and while showing some success,[13] such initiatives included an institutional protocol for dedicated follow-up,[19] dedicated nurse practitioner and patient follow-up,[13] patient letter mailing and automated clinic visit scheduling,[20] reporting to physicians,[21] physician assistant mediated follow-up and reminders,[22] and patient correspondence in conjunction with hematology consultation.[23] Common to these approaches is that they are labor intensive and reliant on particular dedicated staff members. In an increasingly cost-constricted healthcare environment, the long-term sustainability of such resource intensive initiatives is unclear. To our knowledge, our study of a computerized email-only reminder system is unique in demonstrating an association with higher rates of filter retrieval and lower complications, in a minimally resource intensive and automated fashion.

Furthermore, because not designed specifically to answer this question, we would hypothesize that the most likely mechanism for the association with reduction in indwelling complications seen in our study is the reduction in dwell times as a result of earlier retrieval. Other studies have also found that complications occur more frequently as dwell time increases.[24]

An additional potential benefit of the automated system is providing insight into physician decision-making regarding IVCF retrieval. For example, a distinction can be made between 2 patients who have IVCF that are not retrieved; one due to lack of follow-up, and the other due to an active physician decision to leave the IVCF in place for a clear clinical reason. Of course, in patients in whom IVCF are not retrieved, these data are limited by the accuracy of information provided by the reporting physician. However, such data offer the potential to provide an additional tool for quality improvement and monitoring and eliminate the need for manual chart review.

Strengths of the present study include the use of multidisciplinary patient-level data across multiple indications and an interventional design comparing "reminder not provided" and "reminder provided" groups. The multidisciplinary nature of our data supports a utility for our system in other healthcare environments, although this needs to be proven.

There are several limitations to the study. First, trial design was retrospective. Patients were not randomized to receive the intervention (i.e., the reminder system) or not. This may have introduced bias, for instance, due to unequal prevalence of imaging studies. Similarly, we may have had unmeasured confounders, such as variance in use of novel oral anticoagulant therapy or variance in the utilization rate of IVCF. However, most observed complications in both groups manifested clinically. Also, comparisons for many baseline characteristics either did not reveal differences or were controlled for by our analysis.

In conclusion, implementation of an email reminder system for IVCF implantation was associated with higher IVCF retrieval rates, fewer indwelling complications, shorter dwell times, and a reduction in a composite adverse outcome. Unlike many other initiatives designed to improve IVCF retrieval patterns, a computerized system is far less labor and cost intensive and is not dependent on particular interested personnel. Centers offering IVCF implantation should consider implementation of similar systems to strive for optimal post-IVCF insertion management.

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