Impact of an Integrated Electronic Health Record Protocol on Inferior Vena Cava Filter Retrieval Attempt Rates: An Observational Cohort Study

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ABSTRACT

Introduction: To improve inferior vena cava (IVC) filter retrieval rates, an electronic health record prompt for scheduling retrieval before patient discharge was implemented.

Methods: This retrospective comparative cohort study was conducted in a single Midwestern tertiary care medical center. Adult patients with IVC filters placed for a medical (Medical subgroup) or trauma (Trauma subgroup) indication before and after protocol implementation and who had follow-up documented in the electronic health record were included. IVC filter retrieval attempt rates both overall and by indication for placement before and after protocol implementation were compared.

Results: Three hundred eighty-five patients met eligibility criteria: 223 before implementation (Before group) and 162 after implementation (After group). The attempted retrieval rate for the After group was 11.4% higher than the Before group ($P = .012$). Attempted retrieval rates in the Medical Before and After subgroups were 56.2% and 76.0%, respectively ($P = .001$). The Trauma subgroups' rates were similar to each other ($P = .594$). Time to retrieval attempt was significantly shorter in the Medical After subgroup than in the Medical Before subgroup ($P = .018$) but similar in the Trauma subgroups.

Conclusions: Attempted retrieval rates were significantly higher in the After group and Medical After subgroup. Trauma subgroup rates were similar, likely because a previous intervention to increase retrieval in trauma patients was in place during the pre-implementation period of our study. Findings suggest that using an automated electronic health record-based prompt to facilitate IVC filter retrieval scheduling could greatly improve retrieval rates and patient safety.

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INTRODUCTION

Venous thromboembolism, which includes deep venous thrombosis and pulmonary embolism, affects as many as 900 000 individuals each year in the United States.[1] Inferior vena cava (IVC) filters are designed to be temporarily placed as a prophylactic option for patients at high risk for potentially fatal pulmonary embolism. The most widely recognized indication for IVC filter placement is venous thromboembolism when anticoagulation is contraindicated. Other indications include recurrent venous thromboembolism despite adequate anticoagulation, as well as high-risk trauma and certain surgeries and malignancies.[2]

Complications from IVC filter placement are relatively minor and include venous injury or perforation, misplacement of the filter, and insertional site deep venous thrombosis.[3] However, the long-term complications of retained IVC filters—including IVC thrombosis, IVC filter migration, IVC perforation, filter fracture, embolization, and tilting—are being recognized increasingly as major health concerns.[4] These concerns prompted the US Food and Drug Administration (FDA) to release a safety communication in 2010 and an update in 2014 regarding the concerns over long-term retention of IVC filters and recommended removal as soon as a filter is no longer clinically indicated.[5,6]

Approximately 65 000 IVC filters are placed in the United States annually.[7] Unfortunately, this rate of filter placement generally has not been accompanied by a comparable retrieval rate. Reported rates of IVC filter retrieval vary widely. One study conducted in Florida found that only 6.6% of 131 791 filters were

retrieved successfully.[8] Another study evaluating all IVC filters entered in the National Vascular Quality Initiative Registry from January 2012 to August 2018 showed a 34.5% retrieval rate.[9]

Practice patterns for IVC filter retrieval planning vary by institution. In the current study, the Interventional Radiology (IR) Department performed all IVC filter placement and retrieval procedures. The IR Department documents all IVC filter placements (medical and trauma patients) in a database that is reviewed quarterly to identify patients who need filter retrieval. In January 2005, a structured, protocol-driven retrieval process was implemented by the trauma service with the aim of increasing IVC filter retrieval rates. This protocol provided the trauma service with an independent database to track and plan retrieval before discharge, affording them an additional layer of filter tracking. A 2019 study found that this 2-layer retrieval tracking process resulted in more than 2 times the rate of removal of filters placed for trauma indications than of those placed for medical indications.[10]

To improve retrieval rates system-wide, on January 13, 2016, the IR Department implemented an appointment reminder retrieval strategy that focused on using the electronic health record (EHR) for IVC filter retrieval planning before patient discharge. When an order for IVC filter placement is made in the EHR, the EHR automatically populates a message to the IR scheduling team. This message prompts the scheduler to triage the patient for follow-up with the assistance of a physician assistant or nurse practitioner. Thus, when patients with IVC filter placements are discharged, they already have an appointment for filter retrieval. The IVC filter database continues to be reviewed approximately every quarter to update clinical events for patients with prolonged clinical course or retained filter.

The purpose of this study was to evaluate the efficacy of this integrated EHR retrieval protocol by comparing rates of attempted IVC filter retrieval before and after implementation of this protocol.

METHODS

Following study approval and waiver of informed consent by the Gundersen Clinic LTD, Human Subjects Committee/Institutional Review Board, the EHRs of all patients with a IVC filter placed in a 5-year period before (January 13, 2011- January 2, 2016: the Before group) and after (January 3, 2016- December 31, 2020: the After group) implementation of the retrieval protocol were reviewed retrospectively. The groups were further subdivided by indication for filter placement (Medical Before/After and Trauma Before/After). Eligible patients were 18 years or older at the time of filter placement and had documented follow-up in the EHR. Patients with no EHR data after their filter placement were deemed lost to follow-up and excluded from the analysis, as were those who died within 30 days of filter placement.

During the 10-year study period, 405 IVC filters were placed. Twenty patients were lost to follow-up, leaving 385 for final analysis. Patient demographic and clinical characteristics are provided in Table 1, and sociodemographic data are provided in Table 2. Of the filter placements reviewed, 223 and 162 were reviewed before and after implementation of the EHR retrieval protocol, respectively. Of the filter placements before protocol implementation, 137 were in the Medical subgroup and 86 were in the Trauma subgroup. Of those placed after protocol implementation, 104 and 58 were in the Medical and Trauma subgroups, respectively (Figure 1). Data for predetermined variables, including patient characteristics (age, sex, body mass index, smoking history, comorbid medical conditions) and dates of filter placement and retrieval attempts were abstracted from the study patients' EHRs.

Because the purpose of the intervention was to ensure that patients were scheduled for retrieval, the rates of attempted IVC filter retrieval were defined as the percentage of retrievable IVC filters in which retrieval was attempted—whether successfully or unsuccessfully—during the study period within each group. Time to retrieval was defined as the number of days between filter

Table 1. Medical and Trauma Subgroup Demographic and Clinical Characteristics Before and After EHR Retrieval Protocol Implementation

	Before		After	
Characteristic	**Medical n = 137**	**Trauma n = 86**	**Medical n = 104**	**Trauma n = 58**
Sex, n (%)				
Male	73 (53.3)	60 (69.8)	63 (60.6)	43 (74.1)
Female	64 (46.7)	26 (30.2)	41 (39.4)	15 (25.9)
Mean age by sex, years ± SD				
Men	64.9 ± 13.3	42.3 ± 17.5	62.9 ± 12.6	50.4 ± 18.8
Female	62.1 ± 17.3	52.9 ± 20.5	66.1 ± 13.9	48.2 ± 13.0
Body mass index, kg/m^2, n (%)				
< 30	62 (45.3)	57 (66.3)	39 (37.5)	37 (63.8)
≥ 30 to < 35	26 (19.0)	14 (16.3)	26 (25.0)	12 (20.7)
≥ 35 to < 40	25 (18.2)	7 (8.1)	19 (18.3)	6 (10.3)
≥ 40 to < 50	13 (9.5)	6 (7.0)	16 (15.4)	3 (5.2)
≥ 50	9 (6.6)	0 (0)	4 (3.8)	0 (0)
Unknown	2 (1.5)	2 (2.3)	0 (0)	0 (0)
Smoking status, n (%)				
Current	15 (10.9)	19 (22.1)	9 (8.7)	17 (29.3)
Former	61 (44.5)	23 (26.7)	35 (33.7)	14 (24.1)
Never	58 (42.3)	38 (44.2)	60 (57.7)	23 (39.7)
Never assessed	3 (2.2)	6 (7.0)	0 (0)	4 (6.9)
Comorbidities, n (%)				
Congestive heart failure	13 (9.5)	0 (0)	12 (11.5)	3 (5.2)
Nephrotic syndrome	1 (0.7)	0 (0)	0 (0)	0 (0)
Hypertension	68 (49.6)	13 (15.1)	63 (60.6)	19 (32.8)
Diabetes	20 (14.6)	5 (5.8)	16 (15.4)	7 (12.1)
History of stroke	13 (9.5)	29 (33.7)	19 (18.3)	40 (69.0)
History of MI	9 (6.6)	0 (0)	7 (6.7)	1 (1.7)
Coronary artery disease	18 (13.1)	1 (1.2)	10 (9.6)	4 (6.9)
Chronic lung disease	14 (10.2)	3 (3.5)	10 (9.6)	1 (1.7)

Abbreviations: EHR, electronic health record; MI, myocardial infarction.

Data are presented as number of patients (%) unless otherwise noted.

Percentages may not total 100 due to rounding.

Table 2. Sociodemographic Data for Patients Who Received IVC Filters Before (N = 223) and After (N = 162) EHR Retrieval Protocol

Characteristic	Before n (%)	After n (%)
Race		
Other	10 (4.5)	3 (1.9)
White	213 (95.5)	159 (98.1)
Ethnicity		
Hispanic	2 (0.9)	3 (1.9)
Non-Hispanic/Non-Latino	221 (99.1)	158 (97.5)
Refused	0 (0)	1 (0.6)
Insurance type		
Commercial/private	81 (36.3)	48 (29.6)
Medicaid	29 (13.0)	26 (16.0)
Medicare	71 (31.8)	80 (49.4)
Other	10 (4.5)	5 (3.1)
Self-pay	8 (3.6)	3 (1.9)
Unknown	24 (10.8)	0 (0)
Rural/urban		
Rural	70 (31.4)	55 (34.0)
Rural advantaged	43 (19.3)	25 (15.4)
Rural underserved	24 (10.8)	20 (12.3)
Urban	15 (6.7)	19 (11.7)
Urban advantaged	55 (24.7)	38 (23.5)
Urban underserved	0 (0)	1 (0.6)
Unknown	16 (7.2)	4 (2.5)

Abbreviations: IVC, inferior vena cava; EHR, electronic health record.
Percentages may not total 100 due to rounding.

implantation and retrieval attempt. Time to IVC filter retrieval attempt was further analyzed by time categories (0-119 days, 120-364 days, and 365+ days) to help account for significant outliers that would affect data interpretation (ie, individuals who retained filters for many years). The rates of attempted IVC filter retrieval and time to attempted IVC filter retrieval were determined before and after protocol implementation.

Categorical variables were compared using the χ^2 or Fisher exact tests. Continuous variables were evaluated with Wilcoxon rank sum tests. All statistical analyses were performed in SAS version 9.4 (SAS Institute Inc) with a significance level of .05.

RESULTS

Overall, 98 filters (25.4%) were placed for absolute indications, 100 filters (26.0%) for relative indications, and 185 filters (48.1%) for prophylactic indications. Two filters (0.5%) were placed for indications outside the Society of Interventional Radiology's guideline.[11] The most common indications for IVC filter placement in the Medical Before subgroup were pulmonary embolism with large clot burden (n = 31, 22.6%), bleeding complications on anticoagulation (n = 29, 21.2%), and surgery with thrombophilia history (n=28, 20.4%). After intervention, the most common indications were bleeding complications on anticoagulation (n = 27, 26.0%), pulmonary embolism with large clot burden (n = 22, 21.2%), and presence of deep vein thrombosis (n = 17, 16.3%).

Figure 1. Patient Selection Flow Chart

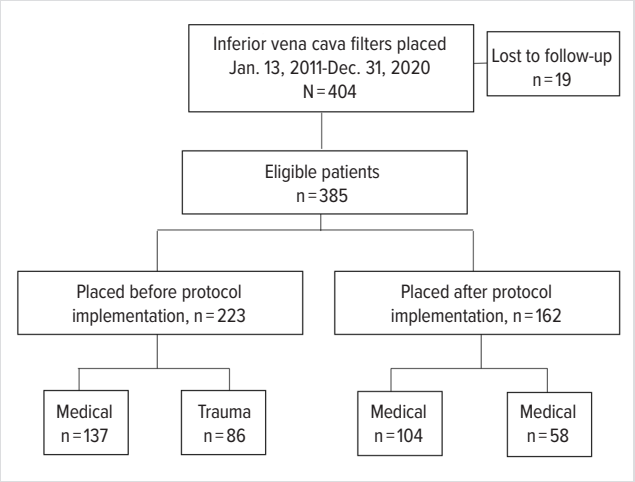
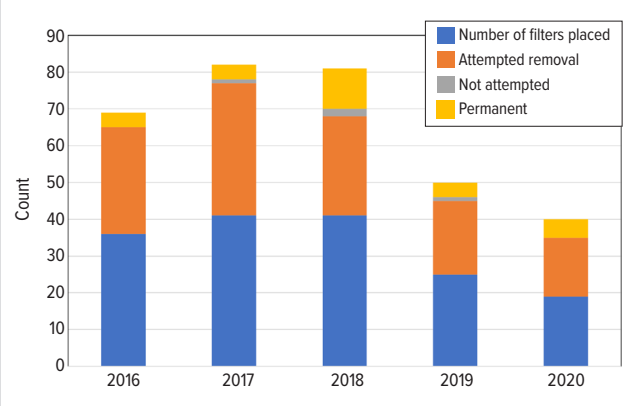


Figure 2. Inferior Vena Cava Filter Placement and Disposition Over Time



Collectively, IVC filter retrievals were attempted 11.4% more in the After group than in the Before group (131/162, 80.9% and 155/223, 69.5%, respectively, $P = .012$). The attempted retrieval rate in the Medical After subgroup increased by 19.8% versus the Medical Before subgroup (79/104, 76.0% and 77/137, 56.2%, respectively; $P = .001$). Of the 137 filters placed in the Medical Before subgroup, 49 were deemed permanent and 11 patients either did not keep their appointments or no appointment was made. Of 104 filters placed in the Medical After group, 22 were deemed permanent, and 3 scheduled retrieval appointments were not kept, for reasons inconsistently documented in the EHR. No significant difference in IVC filter attempted retrieval rates before and after intervention was found in the Trauma subgroup (78/86, 90.7% and 51/58, 87.9%, respectively; $P = .594$). The number and disposition of IVC filters placed over time are illustrated in Figure 2.

Although ensuring and improving the timeliness of retrieval attempts was the primary outcome, the rate of successfully removed IVC filters after protocol implementation was also of

interest. Successful IVC filter removal rates were similar in the Trauma Before and After subgroups (74/86, 86.0% and 50/58, 86.2%, respectively; $P = .945$), but in the Medical Before and After subgroups, the rate of successful retrieval improved significantly (70/137, 51.1% and 78/104, 75.0%, respectively; $P = .0002$).

In the Trauma Before and After subgroups, mean times to first IVC filter retrieval attempt were similar ($P = .795$). In the Medical After subgroup, mean time to first retrieval attempt was lower, but not significantly so ($P = .054$). However, when analyzing by time intervals (0-119, 120-364, and 365+ days) to account for outliers, time to retrieval attempt decreased significantly in the Medical After subgroup ($P = .018$) but not in the Trauma After subgroup ($P = .70$) (Table 3).

Table 3. Number and Percentage of Attempted IVCF Retrievals Before and After EHR Retrieval Protocol Categorized by Time and Indication

	Medical			Trauma		
Time Range	**Before**	**After**	***P***	**Before**	**After**	***P***
0–119 days	49 (63.64%)	66 (83.54)		56 (71.79)	37 (72.55)	
120–364 days	18 (23.38%)	9 (11.39)	.018	18 (23.08)	13 (25.49)	.70
365+ days	10 (12.99%)	4 (5.06)		4 (5.13)	1 (1.96)	

Abbreviations: IVCF, inferior vena cava filter; EHR, electronic health records.
Data are presented as number of attempted retrievals (%).
Percentages may not total 100 due to rounding.

DISCUSSION

Use of an integrated EHR retrieval protocol significantly increased attempted IVC filter retrieval rates overall (11.4%) and in the Medical After subgroup (20.7%). It also decreased time to filter retrieval attempt in the Medical After subgroup when accounting for outliers with analysis by time intervals. Successful filter retrieval also increased in the Medical After subgroup. Attempted retrieval rates and time to filter retrieval attempts were similar before and after intervention in the Trauma subgroup, likely due to a 2-layer tracking system that was already in place for trauma patients prior to implementation of the EHR retrieval protocol. The 2-layer tracking system used by the Trauma Before subgroup functions similarly to the EHR retrieval protocol in that it facilitates IVC filter retrieval planning and tracking prior to discharge.

Various institutions have implemented filter retrieval registries or databases to track IVC filter placement and plan for filter removal when clinically indicated. Sheehan et al conducted a study evaluating the efficacy of maintaining a prospective IVC filter registry within their institution from 2011 to 2020 and found that doing so resulted in retrieval rates of 92.5% overall for those eligible for filter removal.[12] The Cardiovascular and Interventional Radiology Society of Europe (CIRSE) and the British Society of Interventional Radiology (BSIR) have shown increased filter retrieval rates when online registries are maintained, with retrieval rates of up to 92% for some institutions.[13,14] Other studies also have demonstrated that preemptive scheduling of IV filter removal during the preoperative consent process for filter placement results in increased retrieval rates.[15] Ongoing efforts to leverage EHRs should be pursued, considering their potential to increase IVC filter retrieval rates and to reduce time to filter retrieval.

Similar efforts have been made to utilize the capabilities of the EHR to improve patient outcomes in other clinical contexts. A study by Banerjee et al demonstrated that an embedded EHR-based protocol into hospital admission and discharge was associated with a significant increase in nicotine replacement therapy prescriptions and improvement in quit rates.[16] Additionally, a recent study in *JAMA Surgery* demonstrated how the use of an embedded EHR-based intervention can significantly reduce the rate of low-value axillary surgery in older women with early-stage, node-negative, hormone receptor-positive breast cancer.[17] Considering the EHR's potential to increase IVC filter retrieval rates and improve other patient outcomes, efforts to leverage its power should be ongoing.

Given the retrospective nature of this study, a limitation is the vulnerability of the data source and confounding variables. Accuracy of the data collected relied upon quality of documentation in the EHR, which is subject to omissions, misclassification, and misreporting. Intent of filter permanence, patient preference for filter retrieval, reasons for failed attempts at filter retrieval, or other relevant data points were not readily available by EHR review. Changing practice patterns for IVC filter use over the study period also may have affected the rate of IVC filter placement and retrieval.

CONCLUSIONS

Study findings demonstrate that implementation of an integrated EHR prompt at the time of IVC filter placement to plan retrieval prior to discharge significantly increased rates of attempted filter retrieval, as well as reduced time to retrieval attempt in patients whose filters were placed for medical indications. A systematic, multidisciplinary approach to IVC filter use has the potential to significantly improve long-term patient safety, shorten duration of filter placement, and increase filter retrieval rates. To date, there are few reports of institutions leveraging EHRs for purposes of improving IVC filter retrieval rates. Therefore, future efforts should focus on using the EHR in a systematic way to assist in scheduling IVC filter retrieval.

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