Optional Inferior Vena Cava Filter Retrieval with Retained Thrombus: An in Vitro Model

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PURPOSE: Retrieval of an optional inferior vena cava (IVC) filter with retained thrombus may result in pulmonary emboli if the trapped thrombus is not removed along with the filter. An in vitro model was developed to determine the fate of trapped thrombus during filter removal.

MATERIALS AND METHODS: An in vitro IVC flow model was created with 25-mm inner diameter tubing and a 50% glycerol/water solution. Three different optional filters—Recovery (Bard, Tempe, AZ), Günther-Tulip (Cook Inc., Bloomington IN), and OptEase (Cordis Endovascular/Johnson & Johnson, Warren, NJ)—were evaluated in the study. A known mass of mature thrombus (porcine, aged 1 wk) was trapped within the optional filters. The filters were then retrieved according to the manufacturers' protocol, and the mass of thrombus recovered with the filter was determined. For each filter, five iterations were performed with initial thrombus sizes less than 1 g (group A) and an additional five iterations with initial thrombus sizes greater than 1 g (group B).

RESULTS: Thrombi from group A were statistically significantly smaller than those from group B ($P < .0001$). Retrieval of the Recovery filter resulted in an average of 25% (range, 0%–53%) and 4% (range, 0%–7%) of the clot being removed in group A and group B, respectively. Retrieval of the Günther-Tulip filter resulted in an average of 22% (group A) and 13% (group B) of the clot being removed. Retrieval of the OptEase filter resulted in an average of 43% (group A) and 0% (group B) of the clot being removed.

CONCLUSIONS: In our in vitro model, we have established that the mass of thrombus retrieved with optional filters is only a fraction of the initial clot burden. Because of the risk of pulmonary emboli, care should be taken when IVC filters with large amounts of trapped thrombus are removed from patients.

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Abbreviations: ID = internal diameter, IVC = inferior vena cava

THE efficacy of inferior vena cava (IVC) filters in preventing pulmonary emboli in an appropriate patient population is well established, and the evidence of prophylactic applications is growing (1–5). The number of retrievable or optional IVC filters placed during recent years has increased significantly (6–10). The Recovery filter (Bard, Tempe, AZ), the Günther-Tulip filter (Cook, Bloomington, IN), and the OptEase filter (Cordis Endovascular/Johnson & Johnson, Warren, NJ) are three optional IVC filters that have recently been introduced into the United States market. These optional filters may be placed as permanent devices but also provide the clinical opportunity of removal once the risk for pulmonary embolism or contraindication to anticoagulation has been eliminated (6,9,11,12). Removal of the optional filters is presumed to reduce the risk of long-term complications of IVC filtration (13–16). Once the decision to retrieve an IVC filter has been made, the interventionalist generally proceeds with a cavogram to evaluate for retained thrombus. If no retained thrombus is present, attempts are made to remove the filter. If thrombus is present within the retrievable filter, the clinical scenario changes and a decision must be made. The options include (*a*) leaving the filter in place as a permanent device with continued risk of long-term complications of IVC filtration, (*b*) retrieving the filter later with or without continued anticoagulation, (*c*) removing or lysing the retained thrombus before filter removal, or (*d*) simply removing the filter despite the retained thrombus (17–19). Currently, there is little evidence-based medicine to establish optimal patient care in this scenario.

Review of the manufacturers' rec-

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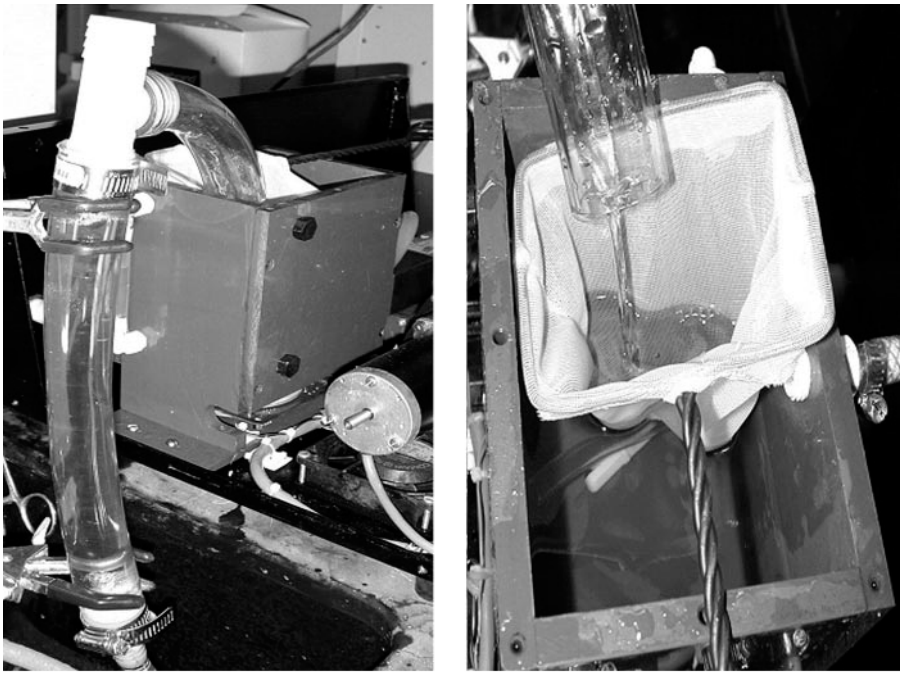

a. b.

Figure 1. Images demonstrating the 25-mm ID tubing functioning as the IVC model, the fluid pump, T-connection device allowing simulated internal jugular access **(a)** and the inline seine filtration net **(b)**. The seine filtration net prevents fragments of thrombi that escaped the filter during device retrieval from entering the fluid pump.

Clot Burden Findings

Filter	Starting Mass (g) ± SD	Retrieved Mass (g) ± SD	Retrieved, % (range)
Recovery			
Group A	0.6 ± 0.1	0.2 ± 0.1	25 (0–53)
Group B	1.4 ± 0.2	0.06 ± 0.03	4 (0–7)
Günther-Tulip			
Group A	0.6 ± 0.2	0.11 ± 0.02	22 (12–26)
Group B	1.3 ± 0.2	0.15 ± 0.09	13 (3–23)
OptEase			
Group A	0.6 ± 0.05	0.23 ± 0.08	43 (29–72)
Group B	1.3 ± 0.2	0*	0*

Five iterations were performed for each experiment. The small (group A) and large (group B) starting masses were statistically significantly different ($P < .0001$) within the three filter types. No other statistically significant differences were found.
* All the thrombi of group B lodged caudal to the OptEase filter, and no thrombus was retrieved with the filter. This data set was excluded from the comparison statistics.

ommendations as summarized by Kerlan et al (17) regarding retrieval of IVC filters with retained thrombus shows a lack of consensus. The Bard package insert states, "Do not attempt to remove the Recovery filter if significant amounts of thrombus are trapped within the filter." The Cook package insert states, "Retrieval of the filter with significant amounts of trapped thrombus (greater than 25% of the volume of the cone) is not recommended." The Cordis package insert states, "Do not retrieve if thrombus is present within the filter and/or caudal to the filter." We developed an in vitro model to determine the fate of retained thrombus during the retrieval process.

MATERIALS AND METHODS

Study Design

We designed an in vitro model that allows for a known quantity of thrombus to be trapped within an IVC filter, retrieval of the filter according to each manufacturer's protocol, and subsequent measurement of the amount of thrombus retrieved with the filter. The starting quantity of thrombus was divided into two groups: group A (<1 g) and group B (>1 g). The mass of the retrieved thrombus as well as the percentage of the original mass was obtained and calculated. Five iterations of each size of thrombus were performed with each of the three different retrievable filters clinically available in the United States at the time of the study.

Development of the in Vitro IVC Model

The in vitro model (**Fig 1a**) required two major factors: simulation of the fluid dynamics within the IVC and simulation of the filter retrieval process. A computer-controlled pump (UHDC, SIDAC Engineering, Toronto, Canada) was used to establish a continuous flow of 50% v/v glycerol/water at 20 mL/sec within a 25-mm inner diameter (ID) tubing simulating flow within the inferior vena cava for the experiments. Flow was directed from the pump toward the IVC model, through a T-connector device allowing access for placement of both the thrombus and filters, to an inline seine filtration net (**Fig 1b**) preventing fragments of free thrombus in the fluid circuit from entering the mechanical pump, before returning to the pump reservoir. A second T-connector device with an aerostatic rubber septum (No. 57, SubaSeal, Fisher Scientific, Pittsburgh, PA) was added to the circuit between the pump and the location of filter placement specifically for the OptEase filter. The initial T-connector allowed access from above the filter, simulating access from the internal jugular vein, and the second T-connector allowed access from below the filter, simulating femoral venous access.