Greenfield filter versus Mobin-Uddin umbrella

The continuing quest for the ideal method of vena caval interruption

During the past 10 years, the Mobin-Uddin umbrella and the Greenfield filter have been developed as transvenous methods of interrupting the vena cava with minimal morbidity and operative mortality. We have used the transvenous method of caval interruption in 97 patients: the Mobin-Uddin umbrella in 65 and the Greenfield filter in 32. There was an overall operative mortality rate of 4%; related more to the underlying disease than to the technique of filter or umbrella placement. On the basis of clinical follow-up, the recurrence rate for nonfatal pulmonary emboli was 3% with the Mobin-Uddin umbrella and 3.3% with the Greenfield filter. No subsequent lethal embolus was observed with either device. Mispacement occurred with three of the Mobin-Uddin umbrellas and four of the Greenfield filters, all during the early part of our experience. Lethal migration of the transvenous device occurred in one patient with a Mobin-Uddin umbrella. Detailed long-term follow-up with vena cavograms or postmortem examination in 40 patients (18 umbrellas and 22 filters) revealed occlusion of the vena cava in 5% with Greenfield filters and in 7.5% with Mobin-Uddin umbrellas; clot was observed proximal to the umbrella in one patient. Consequently, we recommend the Greenfield filter as the ideal method for protection against thromboembolism because of its ease of insertion under local anesthesia, its high patency rate thereby eliminating stasis sequelae, and its protection from lethal thromboembolism.

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Since Ochsner and associates1, 2 popularized control of thromboembolic episodes by the surgical ligation of the inferior vena cava more than three decades ago, the quest has continued for an improved method of protection from emboli without adding to the sequelae of thromboembolic disease. Acutely, ligation of the inferior vena cava can cause up to a 47% decrease in cardiac output with profound cardiovascular instability secondary to a reduction in venous return.3 Formation of collateral venous channels around the ligated segment improves venous return with time, but also provides pathways for recurrent emboli.4-6 Clinically, ligation can either cause or augment prior existing venous stasis in a significant portion of patients.7 Because of these problems, alternative methods of caval interruption have been developed.8-9 An attempt to maintain patency while providing protection from emboli led to the development of vena caval plication by Spencer and colleagues10 and, subsequently, vena caval filtration by DeWeese and Hunter.11 These procedures avoided the acute cardiovascular effects of ligation by maintaining caval patency in a reasonable percentage of patients, but they still required general anesthesia with its associated high mortality rate in severely ill patients.12 With the advent of the Mobin-Uddin umbrella approximately 10 years ago, a transvenous method of caval interruption was introduced that precluded general anesthesia and its associated mortality rate.13-15 The use of the device, however, has been associated with a high incidence of caval thrombosis, resulting in the continued problem of venous stasis, collateralization, and subsequent recurrent emboli.16 Recently, the Greenfield filter, designed specifically to maintain caval patency while providing protection from pulmo-
nary emboli, was introduced.\textsuperscript{17, 18} Like the Mobin-Uddin umbrella, it is inserted via the jugular vein with the use of local anesthesia. This report compares our clinical experience with these two transvenous devices over the past 5 years (Fig. 1).

**Methods**

The study population included 97 patients from The University of Chicago Hospitals and Clinics and Michael Reese Hospital. Thirty-two patients had the Kim-Ray Greenfield filter and 65 had the Mobin-Uddin umbrella inserted. Indications for insertion were recurrent emboli in patients receiving adequate doses of heparin or warfarin sodium (Coumadin); proved pulmonary embolus and in patients with contraindications to, or complication of, heparin therapy; and prophylactic insertion in patients who could not tolerate further loss of pulmonary function from a second embolus. The two devices were evaluated as to ease of insertion, long-term patency, ability to protect from pulmonary emboli, and clinical sequelae of venous stasis.

**Surgical technique**

The techniques of insertion of both the Greenfield filter and the Mobin-Uddin umbrella are similar. With the use of local anesthesia, the jugular vein is isolated in the neck through a small supraclavicular incision and cannulated with the appropriate insertion catheter. All Mobin-Uddin devices must be inserted via the jugular vein, whereas the Greenfield device offers the option of using the femoral vein. This latter approach was used in one of the 32 patients receiving this device. Vena cavograms were utilized to localize the renal veins and determine the desired level of placement in all patients receiving a Greenfield filter (Fig. 2). The lower pole of the right kidney shadow on the intravenous pyelogram was used to localize the level of placement for the Mobin-Uddin umbrella. In each situation, the chosen site was marked by placement of radiopaque skin markers over the appropriate lumbar vertebra (Fig. 2). Fluoroscopy was used to locate the metallic markers and monitor the placement of the filter. Air embolism was avoided during the initial insertion of the capsule by having the patient perform a Valsalva maneuver. Ideally, the inserted filter or umbrella should lie below the renal veins and above the bifurcation of the vena cava into the iliac veins (Fig. 3). The Mobin-Uddin device was deliberately seated with firm traction in order to secure the metal spike in the wall of the vena cava. The Greenfield filter was partially extruded from its insertion capsule to seat the struts of the filter at the desired point in the vena cava prior to ejecting the whole filter. An x-ray film of the abdomen was obtained after insertion to document the placement of the filter at the desired position. The 23 mm Mobin-Uddin umbrella was used in the initial 15 patients, and the 28 mm umbrella was used in the last 50 patients. All patients were maintained on warfarin therapy for 6 months after insertion. Anticoagulation was continued longer only if there was persistent venous stasis or thrombophlebitis.

**Results**

There were four deaths in the 97 patients studied. Two occurred in those receiving the Greenfield filter and two in those receiving the Mobin-Uddin umbrella. This resulted in a mortality rate of 3% for the Mobin-Uddin umbrella and 6% for the Greenfield filter. In only one patient, in whom a Mobin-Uddin umbrella migrated into the lung immediately following insertion, did the procedure cause the death. The other three deaths were secondary to the thromboembolic episode.

Table I shows the complications of insertion. In eight patients the insertion capsule could not be passed via
the jugular vein under the clavicular head and into the inferior vena cava. Misplacement was the most common complication of insertion and necessitated the insertion of a second device. No complications developed as a result of a misplaced device. With experience, misplacement has become less of a problem. Migration occurred only with the use of the 23 mm Mobin-Uddin umbrella and has not occurred since we switched to the 28 mm umbrella. The two umbrellas that migrated settled in the right lung. In one patient the umbrella precipitated hypotension, myocardial infarction, and death; the other caused no symptoms. All the Greenfield filter devices show extrusion of the struts of the filter beyond the wall of the vena cava on follow-up vena cavograms (Fig. 4). This was confirmed at autopsy in six patients. The struts could be seen extruding through the vena cava wall but had not penetrated any adjacent vital structure (Fig. 5).

Clot was noted in the vena cava in three patients prior to insertion of the device. Clot was noted below
**Fig. 4.** Arrows point to hook well outside the 0.5 mm vena caval wall.

**Fig. 5.** Perforation of wall confirmed at autopsy. Note patency of filter.

**Fig. 6.** Clot noted in inferior vena cavogram prior to insertion of filter.

the renal veins in two patients and above the one remaining renal vein in a patient who had recently undergone a nephrectomy for renal cell carcinoma (Fig. 6). The device was placed just proximal to the clot and below the renal veins in two patients and deliberately above the renal veins in the other. The Greenfield filter was used in all three patients.

Long-term patency of the vena cava was evaluated by autopsy or vena cavogram in 40 patients—22 with Greenfield filters and 18 with Mobin-Uddin umbrellas (Table II). Vena cavograms were obtained between 1 and 34 months, with a median of 17 months after insertion. Thirteen patients (73%) with Mobin-Uddin umbrellas had caval occlusion at the time of examination, whereas only one patient (5%) with a Greenfield filter
had caval occlusion. This was the only patient with a Greenfield filter who was suspected to have a recurrent embolus. The exact time sequence was difficult to define, but one would have to assume that an embolus had recurred because the autopsy showed the filter totally occluded by a fresh thromboembolus. Two patients with Mobin-Uddin umbrellas had recurrent emboli, in neither case lethal. One embolus came from the cephalad clot of a completely occluded Mobin-Uddin filter or a large ovarian collateral (Fig. 7).

The clinical development or augmentation of venous stasis sequelae was not seen in patients with a Greenfield filter but was observed in patients with the Mobin-Uddin umbrella (Table III).

**Table II. Patency of inferior vena cava**

<table>
<thead>
<tr>
<th>No.</th>
<th>Greenfield filter</th>
<th>Mobin-Uddin umbrella</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patent</td>
<td>Occluded</td>
</tr>
<tr>
<td>Cavogram</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Autopsy</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Totals</td>
<td>22</td>
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</table>

**Table III. Clinical sequelae of venous stasis**

<table>
<thead>
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<th>Developed with insertion</th>
<th>Made worse with insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenfield filter</td>
<td>0/13</td>
</tr>
<tr>
<td>Mobin-Uddin umbrella</td>
<td>5/53</td>
</tr>
</tbody>
</table>

**Discussion**

The development of transvenous devices for caval interruption was a significant step forward in eliminating the need for general anesthesia. Since many patients requiring caval interruptions are extremely ill and have decreased pulmonary reserve, general anesthesia is a major risk. Use of these devices has lowered the mortality rate of caval interruption from the 10% to 15% associated with transabdominal ligation or plication to the 4% rate observed in our population. However, the insertion of a filter or umbrella is beset with problems, the most common being failure to pass the insertion capsule and misplacement of the devices. Failure to pass the jugular insertion capsule has been alleviated with the availability of a femoral insertion capsule for the Greenfield filter. The femoral and iliac veins and inferior vena cava must be free of clots for this route to be used. No femoral insertion capsule is available for the Mobin-Uddin umbrella.

Misplacement has occurred with both devices.
However, over the past 2 years, with increased experience and the routine use of venography and metallic markers, misplacement has rarely occurred. When it does occur, a second device is inserted and no attempt is made to remove the misplaced device, particularly if it is a Greenfield filter, since thrombosis is rare.

Intravascular migration occurred in two of our patients with Mobin-Uddin umbrellas and in none of our patients, or those reported by others, with a Greenfield filter. Unfortunately, this complication portends a disastrous outcome, as shown by the death of one of our two patients and the 63% mortality rate associated with migration of Mobin-Uddin umbrellas in the series reported by Mobin-Uddin’s group. The 28 mm umbrella has lessened the risk of migration, although an incidence of 2.5% has been reported.

All the struts of the Greenfield filter pierce the vena caval wall by design to prevent migration. Our cavigrams and autopsy findings confirm this penetration, also noted by others. We have not encountered vital organ penetration, and we accept the minor extrusion of the struts in lieu of possible migration to the lungs.

The incidence of recurrent emboli was similar with both the Greenfield filter and the Mobin-Uddin umbrella. The single recurrent embolus in a patient with a Greenfield filter occurred acutely, whereas both emboli with the Mobin-Uddin umbrella recurred late, in patients with a thrombosed cava. The recurrent embolus may have come from cephalad clot above an occluded umbrella or via collateral venous channels that develop secondary to the thrombosis.

Patency greatly favors the Greenfield filter. This is not surprising, since Mobin-Uddin developed a slowly occluding device while Greenfield sought to maintain patency. Mobin-Uddin recently has modified his umbrella by applying a heparin-bonded coating to increase patency. We can only assume that he believes greater patency could improve the device.

The high patency rate of the Greenfield filter most likely accounts for the absence of venous sequelae in our experience. The maintenance of physiological flow through the cava negates venous stasis and has shown to accelerate resolution of a clot caught in the central cone of the filter. The dependable patency of the Greenfield filter has allowed us to safely insert the filter deliberately above the one remaining kidney in a patient with renal cell carcinoma and vena caval clot below and above the renal vein. Long-term caval patency in this patient has been confirmed by venography.

REFERENCES
Discussions

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The authors are to be complimented, as they are not trying to claim superiority of a design of their own making over another design. When examining all the measures to prevent recurrence of pulmonary embolus, we must remember that the large number of different devices offered indicates that none of them is altogether perfect. We must ask ourselves: What are the inherent hazards of the device? How effective is the device in preventing further emboli?

The three intracaval methods of inserting these devices all utilize local anesthesia, which is extremely important in the very ill patient. Ligation and other methods of vena caval interruption do require a general anesthetic and share with the Mobin-Uddin umbrella a high likelihood of totally occluding the vena cava.

The intracaval techniques are extremely tempting in the very ill patient, who may have an infected abdominal incision or burn from which sepsis may spread to the retroperitoneum. Misplacement of the intracaval device is discussed in the author’s paper. In addition, migration can be fatal.

We have been guided in judging our results by the early writings of Rudolph Matas, who commented that no judgment should be made of an effective method for preventing pulmonary embolism until one has examined it through a period of time and made sure that the effectiveness attributed to the device is not caused by the periodic fluctuation of the incidence of pulmonary thromboembolism.

This point was made by Bill Coon, when he reviewed the Michigan experience over three decades. He showed an annual twofold variation, and yet the mortality rate for the condition stayed the same despite a number of different methods that have been championed for prevention. Any technique we suggest must be evaluated with these observations in mind.

Our experience involving 29 cases with the umbrella extending over 8 years has been reviewed. The cases are about equally divided between (1) those in which there was a contraindication to anticoagulation or (2) anticoagulant failures. Eighteen of this group were catastrophically ill. A number of them had contraindications to an abdominal incision for ligation or plication of the vena cava.

Morbidity in terms of edema was directly related to the severity of the phlebitis antecedent to the insertion. There was no instance of air embolism or of dislodgement of the 28 mm umbrella, which we now routinely use. To the best of our knowledge, there were no perforations of the vena cava wall of clinical significance.

I would ask the authors if, in the patient with a propagating embolus above the umbrella, they may not have developed the propagation in the space between the umbrella and the distal renal vein seen in the slide.

We perform vena cavograms through the modified umbrella introducer prior to actually locating the umbrella. There is a nice inwash from the lowermost renal vein. We feel that the umbrella should be placed just below this point.

The Greenfield filter with its larger tines may project out through the vena caval wall. This must be considered a potential danger.

The authors’ figures and others show a very low incidence of recurrent embolus and a high patency rate of the vena cava.

A newcomer on the scene is the Hunter balloon, which occludes the vena cava entirely at the moment of its inflation and does not appear to produce shock. Over the ensuing year air is resorbed and the balloon slowly deflates.

In the authors’ report there were no subsequent emboli, no deaths except those caused by the concurrent disease, and a very low rate of edema in the utilization of the Hunter balloon.

It is somewhat amazing to me that an intracaval device like the Greenfield filter remains patent and associated with a low incidence of peripheral edema on the one hand and yet is so highly effective in preventing pulmonary emboli. Perhaps the authors have an explanation for this.

It has been interesting to review this comparison of two devices. This report is doubtless the first comparison of intracaval devices in the literature.

DR. CIMOCHOWSKI (Closing)

Thank you very much, Dr. Lawrence.

For data to be really meaningful, a prospective study comparing ligation, plication, and the Mobin-Uddin and Greenfield devices will have to be conducted. Our study has all the hazards of a data base from two university hospitals, from four different surgeons, and was looked at retrospectively. However, there are positive aspects to our study.

The perforation problem may be more emotional than real. We, obviously, did not hesitate to show you the pathology that we discovered and the perforations that exist almost universally with the Greenfield device. However, to date, we have not seen one single problem with it and neither has anyone else, despite literally hundreds of the Greenfield devices having been inserted by now.

Also, we saw quite distinctly at the autopsy table that the device tends to hug the vena cava rather than to protrude at a right angle. By contrast, the Mobin-Uddin umbrella is at an angle more perpendicular to the vena caval wall, which probably accounts for its significant clinical perforation and migration.

I would like to emphasize that only on occasion have we used the Greenfield filter prophylactically. We do feel, however, that there is a role for it. We have used it prophylactically mainly in patients who have large clots lying directly below the renal veins in the vena cava or large, free-floating clots in the iliofemoral system. In both cases, we would be...
concerned with embolization causing immediate death or very serious morbidity.

Recently, we have had an interesting patient, in whom a vena cava clot was noted to be protruding into the right atrium. The patient was given streptokinase and then the next echocardiogram, 24 hours later, demonstrated continued extension into the right atrium. We placed the patient on bypass the following morning and, much to our chagrin and amazement, the clot had completely dissolved in the previous 24 hours. This might portend, in the future, the use of streptokinase for these large clots in patients in whom protection would require bypass or suprarenal positioning of the device.

As to our slide showing the clot above the Mobin-Uddin device, it is possible that the Mobin-Uddin device was placed too low. More probably, because of the inherent design of the device to clot, the natural progression was for a new clot to form above it. This has not been seen with the Greenfield filter.

We have not used the Hunter balloon device. However, I believe it is just a new alternative to an old solution, that is ligation, and will subsequently be shown to have all the problems associated with ligation except for the fact that it is placed under local anesthesia.

The reason that the Greenfield filter can give protection against pulmonary emboli and still remain patent is related to design. The device is designed to catch clot in the center of its cone. Due to its cone shape, a considerable amount of clot can be trapped by the device without reducing the cross-sectional area of the cava. This midstream exposure of the clot accelerates its lysis, as opposed to clots that lie in the wall of the vena cava. Simultaneously, while there is significant protection from embolization, blood flow continues around the outside of the clot so that the physiology of venous return to the heart is maintained in a normal manner, thereby precluding the sequelae of venous stasis.

Clot in the ovarian veins could be handled either by ligation of the ovarian veins with placement of a filter into the inferior vena cava or else by ligation of the ovarian veins and simultaneous plication or ligation of the inferior vena cava. Obviously, we would favor placing a filter in the vena cava and ligating the ovarian vein.