Surgical Prophylaxis of Pulmonary Embolism*

Richard F. Kempczinski, M.D.†

John Hunter is credited with the first reported venous ligations for the treatment of suppurative thromboembolitis in 1784. However, ligation of the inferior vena cava (IVC) to prevent the progression and embolization of infected thrombi in patients with puerperal sepsis was first recommended by Trendelenburg in 1910. Little attention was paid to the potential need for venous interruption until 1934, when Homans suggested that ligation of the femoral vein be performed to prevent pulmonary embolism. However, since such a limited procedure could not provide protection against pulmonary emboli in all cases, Homans revised his recommendation to include ligation of the IVC when there was reason to suspect that the source of the emboli was above the inguinal ligament. Although this operation successfully prevented pulmonary emboli, it was associated with an appreciable incidence of both early and late morbidity. To achieve a similar degree of protection without the adverse lower extremity sequelae that follow IVC ligation, a variety of procedures was introduced to partition the IVC into multiple small channels, preventing the passage of large, potentially fatal, pulmonary emboli without producing total caval obstruction (Fig 1). In the 10-year period between 1958 and 1967, no fewer than 7 such procedures were introduced to accomplish this purpose (Table 1).

Although successful, these procedures all required a general anesthetic and a direct surgical approach to the IVC, usually through a retroperitoneal, flank incision. Since the majority of patients requiring such procedures generally had their thromboembolic complications superimposed on a preexisting major medical or surgical problem, the need for an additional general anesthetic added significantly to their morbidity. Consequently, when a transvenous approach to the IVC via the internal jugular vein was introduced in 1967, it was hailed as a major advance in the management of these critically ill patients. Although still requiring a surgi-

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Suture
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Serrated
Balloon
1967
Staples

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Adams-DeWeese
Miles
Spencer
DeWeese

Designer/Author
Mozes-Antebi
Creenfield
Hunter
Mobin-Uddin

Table 1—Procedures for Direct Partition of the
Inferior Vena Cava (IVC)

<table>
<thead>
<tr>
<th>Designer/Author</th>
<th>Procedure/Device</th>
<th>Year Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>DeWeese</td>
<td>Suture filtration</td>
<td>1958</td>
</tr>
<tr>
<td>Spencer</td>
<td>IVC partition</td>
<td>1959</td>
</tr>
<tr>
<td>Moretz</td>
<td>Smooth IVC clip</td>
<td>1959</td>
</tr>
<tr>
<td>Miles</td>
<td>Serrated clip</td>
<td>1964</td>
</tr>
<tr>
<td>Adams-DeWeese</td>
<td>IVC clip</td>
<td>1965</td>
</tr>
<tr>
<td>Ravitch</td>
<td>Staples</td>
<td>1966</td>
</tr>
<tr>
<td>Mozes-Antebi</td>
<td>Beads</td>
<td>1967</td>
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Table 2—Procedures for Transvenous Partition of the
Inferior Vena Cava

<table>
<thead>
<tr>
<th>Designer/Author</th>
<th>Procedure</th>
<th>Year Introduced</th>
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</thead>
<tbody>
<tr>
<td>Mobin-Uddin</td>
<td>IVC umbrella</td>
<td>1967</td>
</tr>
<tr>
<td>Hunter</td>
<td>Balloon catheter</td>
<td>1970</td>
</tr>
<tr>
<td>Greenfield</td>
<td>Filter</td>
<td>1973</td>
</tr>
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</table>

Scope of the Problem

Because of more liberal use of pharmacologic and mechanical prophylaxis for deep venous thrombosis and more effective anticoagulant treatment once thrombosis occurs, the need for venous interruption is uncommon. In early studies anticoagulants were reported to be complicated by pulmonary embolism in 5-25% of all patients being treated for venous thrombosis and in 2-20% of patients with previous history of pulmonary emboli. These early reports are likely to be an overestimate of the true risk of recurrence, since more recent studies (see "Treatment of Venous Thromboembolism") that used objective methods to document recurrence and carefully controlled heparin therapy have reported much lower rates of treatment failure. In addition, therapeutic levels of anticoagulation are contraindicated in several patients (Table 3), or the therapy may have to be discontinued because of complicating hemorrhage or thrombocytopenia. Since approximately 30% of patients who experience a pulmonary embolism will have a recurrent embolism if appropriate treatment is not promptly instituted, the availability of safe venous interruption procedures with minimal morbidity is important in the overall management of patients with venous thromboembolism.

Indications

Although IVC ligation is now rarely performed for the management of routine pulmonary emboli, several specific situations might warrant its continued use. Patients with multiple small pulmonary emboli that have resulted in the development of pulmonary hypertension or cor pulmonale may be unable to tolerate further emboli, regardless of their size. In such patients IVC ligation may be necessary. Similarly, the unusual occurrence of paradoxic embolization via an intracardiac, septal defect to the arterial circulation represents another appropriate application for IVC ligation. Patients with demonstrable recurrent emboli following previous IVC plication or the insertion of intracaval devices may also require ligation to prevent further emboli. Although the occurrence of septic emboli unresponsive to antibiotics has been considered a standard indication for IVC ligation, recent experimental work with the Greenfield filter suggests that this device may be equally effective in the management of this problem without the superimposed morbidity of IVC ligation.

The accepted indications for IVC plication or insertion of 1 of the intracaval devices include: (1) recurrent pulmonary emboli, despite adequate anticoagulation; (2) pulmonary embolism or active iliofemoral, venous thrombosis in patients in whom anticoagulation is contraindicated; (3) the development of bleeding or thromboembolic complications secondary to anticoagulation; and (4) following pulmonary embolotomy.

More controversial indications for IVC interruption include: (1) progression or extension of an iliofemoral thrombus despite adequate anticoagulant therapy; (2) demonstration of a large, free-floating thrombus within the iliac vein or IVC at the time of initial venography; (3) as a prophylactic procedure in patients at high risk of recurrent pulmonary embolism; and (4) following a
already exist. In 5-10% of patients in whom transvenous placement of an intracaval device is attempted, technical problems will force the procedure to be abandoned and necessitate a direct surgical approach to the IVC. However, as the insertion devices are being continuously miniaturized and improved, this indication may be eliminated.

In most hospitals today, IVC interruption is performed using 1 of the transvenous intracaval devices. Although no clear-cut consensus has emerged favoring 1 device over the other, certain generalizations seem possible. Although the development of late lower extremity sequelae appears to be more a function of the extent and activity of thrombophlebitis within the legs themselves than the specific technique used to interrupt the IVC, preservation of IVC patency prevents the development of unfiltered venous collaterals that might become the pathway for recurrent emboli. Although the Hunter-Sessions balloon ignores this ideal of preserving IVC patency, it offers the theoretic advantage of a smooth intracaval surface that will not penetrate the wall and permits the continuation of full-dose anticoagulation. Fortunately, this latter complication appears to be more theoretic than real and may be entirely eliminated if angulation of the Kim-Ray Greenfield filter is prevented by extrusion over a guide wire. Furthermore, since the Greenfield filter maintains patency of the IVC, it can be placed in the suprarenal vena cava, if required by the proximal extension of thrombus or the caval anatomy. This represents a real advantage over the Hunter balloon. Filter migration was more prominent with earlier devices and has not been seen in recent clinical series. Filter misplacement and premature ejection are best avoided by appropriate preoperative definition of IVC anatomy using venography and strict adherence to the manufacturer’s recommendations.

The continuation of anticoagulants following IVC partition will be associated with an increased risk of bleeding complications. However, since IVC partition does not speed resolution or limit extension of active thrombophlebitis in the lower extremities, continued use of therapeutic levels of anticoagulants should be considered in all patients in whom it is not otherwise contraindicated to minimize late lower extremity sequelae and recurrent embolism.

Although the “birds’ nest filter has not yet been released for general clinical use, it promises safe, effective protection against pulmonary emboli without the need for a surgical procedure (Fig 2). If long-term studies confirm continued IVC patency without filter migration, this procedure may well emerge as the preferred form of surgical therapy for prevention of pulmonary emboli and may expand the prophylactic use of venous interruption.

### Surgical Alternatives

Femoral vein ligation is rarely used today because of recurrent embolism rates as high as 26% after this procedure. However, it might occasionally be considered in very poor risk patients in whom venography had confirmed the presence of thrombi limited to the infrarenal veins and in whom an intracaval device might be contraindicated.

Direct IVC ligation or partition, using sutures or clips, is generally contemplated only in those patients already requiring an abdominal exploration and in whom appropriate indications for IVC interruption

### Table 4—Indications for Insertion of an IVC Filter

<table>
<thead>
<tr>
<th>Condition</th>
<th>Incidence, %</th>
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</thead>
<tbody>
<tr>
<td>Anticoagulants contraindicated</td>
<td>35</td>
</tr>
<tr>
<td>Recurrent pulmonary embolism</td>
<td>31</td>
</tr>
<tr>
<td>Prophylaxis</td>
<td>18</td>
</tr>
<tr>
<td>Anticoagulant complication</td>
<td>17</td>
</tr>
<tr>
<td>Following embolectomy</td>
<td>9</td>
</tr>
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</table>

single massive pulmonary embolism, where a recurrent embolus might prove fatal.

Although the latter indications are not uniformly accepted for partition of the IVC, as the morbidity of the transvenous approach continues to decrease, widespread prophylactic use of these devices becomes increasingly attractive. The reported clinical indications for IVC filter insertion in a recent large series are illustrated in Table 4.

### Diagnostic Studies

Before considering a patient for IVC interruption, the diagnosis of pulmonary embolism must be securely established. Although a high-probability ventilation-perfusion scan is reasonably accurate in patients without significant, intrinsic pulmonary disease, a pulmonary angiogram remains the most accurate means for confirming the diagnosis (see "Diagnosis of Pulmonary Embolism"). Furthermore, once the diagnosis is established, a venacavogram should be performed for the following reasons:

1. to exclude venous anomalies, such as a bifid IVC, which could result in misplacement of the filter at a level that would not effectively prevent recurrent emboli;
2. to document the level of any thrombus within the IVC, allowing the introducer to be manipulated with minimal risk of dislodging potential emboli; and
3. to localize the renal veins and thus permit placement of the filtration device immediately caudal to them.

If the pulmonary angiogram had been performed through a femoral venous puncture, the catheter can be simply withdrawn and the venacavogram performed via the same access site.
The reported complications associated with the various forms of caval interruption procedures are summarized in Table 5. Although perioperative morbidity remains high, even with the transvenous intracaval devices, it is rarely attributable to the procedure itself and more often reflects the severity of the underlying medical condition predisposing to the thromboembolic complication. As noted previously, lower extremity sequelae of venous edema and insufficiency are more often a reflection of the extent and severity of the underlying thrombophlebitis rather than the means used to achieve IVC partition. Although recurrent emboli cannot be completely eliminated by any of the devices currently in use, fatal emboli are extremely uncommon in the absence of filter misplacement, provided the source of the emboli had been properly identified preoperatively and the filter had been properly placed proximal to it. Maintenance of patency of the IVC will prevent the development of large, unprotected collaterals that may achieve a caliber sufficient to permit recurrent fatal embolization. Accordingly, a high incidence of IVC patency on late angiographic follow-up is a desirable feature of any partition technique and should be 1 of the criteria used to compare various devices. The occasional disastrous hemodynamic sequelae of IVC ligation are due to sequestration of blood in the lower extremities and inadequate volume expansion. They should be virtually eliminated by proper use of monitoring devices, such as the Swan-Ganz catheter, and aggressive fluid replacement.

**Conclusion**

The need for inferior vena caval (IVC) interruption to prevent pulmonary emboli will be infrequent, since the majority of patients with venous thromboembolic disease can be satisfactorily managed by adequate anticoagulant therapy. However, once the presence of pulmonary embolism has been objectively confirmed in a patient in whom anticoagulants are either contra-indicated or ineffective, the need for urgent IVC partition is established, since the risk of potentially fatal, recurrent emboli remains high. In such patients, direct IVC interruption will be rarely indicated, and

### Table 5—Results of IVC Interruption

<table>
<thead>
<tr>
<th>Procedure/Device</th>
<th>No. of Patients</th>
<th>Mortality</th>
<th>Recurrent Pulmonary Embolism</th>
<th>Leg Sequelae</th>
<th>Patency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ligation</td>
<td>1,179</td>
<td>14.3</td>
<td>7.3</td>
<td>22.8</td>
<td>0</td>
</tr>
<tr>
<td>Suture plication</td>
<td>141</td>
<td>10.6</td>
<td>4.2</td>
<td>14.8</td>
<td>69</td>
</tr>
<tr>
<td>IVC clip</td>
<td>554</td>
<td>10.8</td>
<td>5.4</td>
<td>14.3</td>
<td>74</td>
</tr>
<tr>
<td>M-U umbrella</td>
<td>2,562</td>
<td>16.0</td>
<td>0.5</td>
<td>—</td>
<td>40</td>
</tr>
<tr>
<td>KRG filter*</td>
<td>260</td>
<td>14.0</td>
<td>5.0</td>
<td>—</td>
<td>97</td>
</tr>
<tr>
<td>Hunter balloon*</td>
<td>135</td>
<td>15.0</td>
<td>1.5</td>
<td>—</td>
<td>0</td>
</tr>
</tbody>
</table>

*Modified after Bernstein.*

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**FIGURE 2.** Comparison of the appearance of the Mobin-Uddin umbrella (left), the bird's nest filter (center), and the Greenfield filter (right) in a simulated inferior vena cava. (From Roehm JOF. The bird's nest filter: a new percutaneous transcatheter inferior vena cava filter. J Vasc Surg 1984; 1:498-501. Reproduced with permission.)
the majority of these patients can be managed by the insertion of transvenous intracaval devices. These techniques are all highly effective in preventing recurrent fatal emboli and the choice among the specific procedures should be made on the basis of ease of insertion in a given patient and the device's record in maintaining patency of the IVC. As these devices continue to be improved and the morbidity associated with their use decreases, more aggressive prophylactic insertions may become more common.

REFERENCES
1 Hunter J. Observations on inflammation of internal coat of veins. Trans Soc Improv Med Chir 1793; 1:18
11 Silver D, Sabiston DC Jr. The role of vena cava interruption in the management of pulmonary embolism. Surgery 1975; 77:1-10